EngOpt2010

2nd International Conference On Engineering Optimization

6 - 9 September 2010

Instituto Superior Técnico • Lisboa • Portugal

Book of Abstracts

and

CD-ROM Proceedings

Edited by

Hélder Rodrigues • José Herskovits • Cristóvão Mota Soares • José Miranda Guedes • João Folgado • Aurélio Araújo • Filipa Moleiro • Jayachandran P. Kuzhichalil • José Aguilar Madeira • Zuzana Dimitrovová

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Design Optimization

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01005
Shape Optimization in Wear Contact Problems

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The problem of optimization of contact interaction of a moving rigid punch and elastic half-space is investigated taking into account friction and wear. The punch shape is accepted as a desirable design variable and the wear volume rate under constraints on the friction dissipation power and the total load applied to the punch is taken as an optimized quality criterion. The ratio of the wear volume rate and the friction dissipation power under constraint on the total load is also considered as an effectiveness criterion. A necessary condition of the optimality of quasi-steady state of wear process is derived and discussed. The optimization problem is investigated analytically and exact solutions are obtained for the axisymmetric punch which has a circular contact region and moves translationally with a constant velocity or performs rotations with constant angular velocity.

01007
Optimal Punch Shape Under Probabilistic Data Concerning External Loading

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Shape optimization problem for rigid punch interacted with elastic medium is investigated. Additional forces applied to the elastic medium are supposed to be random in considered problem formulation. Probabilistic approach is applied as for formulation as for solution of the optimization problem. As a result the optimal designs of the punch with circular base are obtained and presented.

01013
Buckling optimization and prebuckling enhancement of imperfect composite plates using piezoelectric actuators

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An imperfect composite plate equipped with piezoelectric actuators is investigated. Geometric nonlinear effects are considered only in the prebuckling regime such that higher order strain energy terms can be disregarded. The actuators are used to achieve two goals: to optimize buckling loads under uncertain loadings via stress stiffening effects and to ameliorate the plate prebuckling response through application of piezoelectric bending moments. A strategy is proposed where the piezoelectric membrane forces and bending moments are separated by proper selection of voltages imposed on symmetrically bonded piezoelectric patches. Piezoelectric forces and moments are then used separately to optimize buckling loads and to improve prebuckling response.

01023
Experimental optimization of control techniques to design a flexible satellite attitude controler

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Placing a rigid-flexible satellite or any other spacecraft in orbit is a risky and expensive process; years of research and a lot of money are transformed into equipments that will be beyond any possibility of maintenance in case something goes wrong. Besides, Attitude Control System (ACS) for flexible space satellites demands great reliability, autonomy and robustness. These flexible structures face low stiffness due to minimal mass weight requirements. Satellite ACS design usually are based on computer simulations without experimental verification which due to model uncertainties, can take to instability and/or inefficient controller performance. In that context, experimental validation of new equipment and/or control techniques through prototypes is the way to increase system confidence. Experimental set up also allows verifying a variety of control techniques dealing with stabilization, identification, attitude control and robustness that need to be validated and implemented in order to improve ACS performance. In this paper one investigates the robustness and performance of two different multivariable methodologies in designing the ACS for a rigid-flexible satellite. The first one is the traditional time domain approach called LQG (Lineal Quadratic Gaussian) and the second one is the frequency domain H–Infinity approach. Although these control techniques have their particular characteristics, this investigation tray to highlighted the advantages and benefits of each technique as for the control algorithm implementation. The satellite ACS design is performed initially in a computer simulation environment, following experimentally verification of the same control algorithm using Quanser rotary flexible link module. The controller performance was investigated considering its capacity of maneuvering the rigid- flexible link to a desired angle position at the same time that the link's vibrations are eliminate while maintaining the maneuver as fast as possible. This preliminary investigation has shown that the controller performance based on the simulation model can be degraded when applied in an experimental mode. Besides, the control algorithm complexity is function of the control methodology that fact has to take into account for implementing in the satellite onboard computer.

01026
Post-optimization of a wing section for a pro-green aircraft configuration using a genetic algorithm

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In pro-green aircraft configurations drag reduction may be attained through the use of wings with significantly higher aspect ratios and lower sweep angles than those usually employed in conventional aircrafts. The reduction in sweep angle opens an opportunity for these wings to be designed for large extensions of laminar flow due to the lower occurrence of cross-flow. Hence, even operating at high Reynolds numbers in the transonic regime, Natural Laminar Flow (NLF) may be achieved, leading to lower fuel consumption and allowing significant reductions in pollutant emissions. The aerodynamic optimization procedure of a NLF wing section for a design condition corresponding to a Mach number of 0.74, a Reynolds number of 20 million and a lift coefficient of 0.72 is presented. Among the panoply of non-derivative optimization methods available, a genetic algorithm has been selected for its suitability to the current purpose. The baseline geometry has been previously optimized for the intended design condition using other methods, yielding a relative thickness of 11.7% and a relative camber of 1.78% for a sweep angle of 19 degrees. Based on the foregoing parameters and the corresponding locations of their maxima along the wing section chord, a solution space of 432 individuals has been constructed allowing for small to moderate variations around the (reference) geometric characteristics of the baseline.

Individuals described by a combination of parameter values (allele) were evaluated by a suitable fitness function with the aim of maximizing their lift-to-drag (L/D) ratio. Following the recommended “good practices” of evolutionary optimization, an initial population was formed with 23 individuals, whereas subsequent generations contained 10 individuals. Parent selection was essentially based on the “roulette wheel” method, but 20% were directly chosen among those exhibiting the highest values of the fitness function. Random mating was also applied to avoid the sectionalizing bias occurring in point crossover of the parents. A small rate of mutation was allowed, although it has been set to zero in late generations for the sake of convergence. The aerodynamic characteristics of each individual determining their L/D value were obtained from Reynolds-Averaged-Navier-Stokes (RANS) simulations, employing the infinite swept wing approach. The Spalart-Allmaras turbulence model was used in the numerical calculation of regions of turbulent flow. Due to the high computational cost of the RANS simulations coupled with the genetic algorithm, only a simplified transition prediction method was employed. Hence, the specification of the extensions of laminar flow over the upper and lower surfaces of the wing section was specified in the RANS simulations by the so-called C1 criterion. Special attention was given to the survivability of the allele along the various generations of the evolutionary optimization procedure, thus providing a better understanding of the selection process of best values. A number of optimized geometries have been obtained, but significant improvements were only achieved with a reduction of relative thickness with respect to the reference value, thus raising concerns about the wing susceptibility to aeroelastic phenomena.

01027
Uniform energy density as a design objective for forced support displacements

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When forced support displacements are involved in addition to design independent loads for a continuum/structure, then the objectives of minimum compliance and of maximum strength do no longer give the same optimal design, characterized by uniformly distributed energy density. For compliance minimization it is in relation to design independent loads favorable to add material and a total volume constraint will be active, but in relation to forced support displacements it is favorable to remove material. A detailed sensitivity analysis proves this and show how compliance sensitivities are determined locally without coupling of two separated load cases. A choice between compliance minimization and strength maximization must be taken or, as suggested in the present paper, uniform energy density can be chosen as the design objective. Different definitions of compliance are possible, such as the compliance due to forced support displacements only, compliance due to forced support displacements combined with further external loads, or the change in compliance when external loads are added. In general it is found that compliance is a questionable design objective, that should not be used when forced non zero support displacements are involved. The direct objective of maximum strength in terms of minimum of maximum effective stress or strain energy density is a local quantity and is mostly suited for mathematical programming. However, in the present study focus is on a recursive design procedure as applied for only design independent loads. Having rejected the objectives of compliance minimization as well as that of strength maximization, we choose the objective of obtaining uniform energy density and show by examples that the obtained solutions are close to fulfilling also strength maximization, with the price of increased compliance. Optimal design examples are presented and discussed in detail for several different combinations of forced support displacements and design independent loads.

01028
Optimization of Keyway Design

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Keys and keyways commonly perform connection of shaft and hubs. The designs of these are controlled by different standards, e.g. DIN 6885. Different design principles are possible, these include parallel keys, tapered keys or Woodruff keys. Among these, the most common is the parallel key that is the subject of the present paper. The key and keyway design is controlled by the standards based on only one parameter, the shaft diameter. It is remarkable that very little effort have been done to improve the design with respect to fatigue, i.e. by minimizing the stress concentrations, although other principal different designs are possible and have been proposed in the literature. The present paper propose to make small modifications to the standard design that nevertheless have a large positive effect on the stress level. The purpose of the present paper is therefore twofold; firstly find stress concentration by using FE analysis of existing standard designs, and secondly improve/optimize the keyway design by lowering the stress concentration. The keyway related stress is indeed fully 3 dimensional, a number of different factors will have an influence on the needed FE analysis complexity and on the resulting maximum stresses found by the analyses. Firstly the keyway may be loaded by: tension, bending or torsion, secondly the load may be transferred with or without a key inserted in the keyway and finally the position of the maximum stress is found at the keyway end or in the prismatic part. Restricting the numerical analysis the present paper deals only with torsion. To make easy comparison with literature possible the keyway is loaded in torsion without the key. This means that there is no need for contact analysis, which would complicate the numerical analysis considerably. From the literature we know that there is a difference in the maximum stress for pure torsional loading without the key relative to torsion applied through the key. The reported experimental result is that in the prismatic keyway part the maximum stress is 4-7% greater with a key relative to no key while the difference is 12-14% at the key end. These values were rather unaffected by different ratios of fillet radius to shaft diameter. This leads to the conclusion that the optimization can be performed without the key. With the simplification made the analyzed stress concentration factor is in the present paper fully controlled by the keyway fillet in the bottom of the prismatic part. Obeying the standards the only possibility to improve the stress concentrations is to select the maximum fillet radius. Previous work on shape optimization in relation to machine elements has shown that changing from the circular shape to an elliptical shape has a large influence on the stress concentrations. This is also pursued in the present paper.

01029
Design LQG/LTR controller for decreasing vibrations in thin and thick plates by the finite elemet model using heterosis element and comparison of lagrange and heterosis elements

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At this paper, method of decreasing vibrations in thin and thick plates caused by forces and environmental unwished factors is described. At first, the method of making the finite element model of plate by using Heterosis element and then designing of optimized regulator, attention to noise caused by environmental instigations and sensors is done. The Heterosis element provides the first order modeling ability in the finite element method and negatives shear locking phenomenon in thin plates. For deriving dynamic equations related to the finite element model, the Hamilton principle with tensorial notation has been

applied and by comparison natural frequencies to known cases, correctness and accuracy of model has been shown. By expressing dynamic equations in state space, necessary preparations for designing optimized regulator are provided. According to type of plate application, special nodes for applying control signals or getting feedbacks are under consideration and this affects the controllability and observablity of system (the rank of controllability and observability must be equal. And at this research by dimensional correction this work is done). Detailed computer program for these systems that are MIMO and have fairly dimensions, has been completed in MATLAB environment that does the finite element modeling, designing estimator (Kalman filter) and optimized controller with system recovery. The dynamic behavior of a sample vibrational system, before and after adding optimized regulator has been studied and the results show the very good decreasing of vibrations.

01032
Performance analysis of an ant-based clustering algorithm

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The collective behaviors and self-organization of social insects have inspired researchers to reproduce this behavior. Methods inspired in ants are a great promise for clustering problems. The main objective of the present paper was to evaluate the performance of the Clustering Modified Algorithm based in Ant Colony in relation to other modification of the algorithm denominated ACAM. The main changes were: substitution of the picked pattern by the ant in case it has not been dropped in 100 consecutives iterations; comparison of the probability of dropping a pattern in a certain position with the probability of dropping this pattern in the current position; evaluation of the probability of dropping a pattern in a new position in case the pattern has not been dropped in the position of raffle draw, but in a neighboring position. For the evaluation of the algorithm performance, two real databases were used. The results showed that the algorithm proposed in this work was better than the ACAM for the two databases.

01033
Optimization of natural gas transmission pipelines

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Natural gas transmission pipelines transport large quantities of natural gas across long distances. They operate at high pressures and utilize a series of compressor stations at frequent intervals along the pipeline. A mathematical formula has been deduced to be used as an objective function to optimize the design variables of natural gas transmission pipelines including compressor stations in order to minimize the total capital cost. The design variables for steel transmission pipelines with different diameters and compression ratio between 1and 1.5 carrying 150 – 550 MMSCFD of natural gas have been optimized to select the optimum diameter, number of compressor stations, length between each two compressors, suction and discharge pressures at compressor stations. The software computer program Lingo has been used in this work.

01034
Optimal design of a multimodal dynamic vibrations absorber

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The effective control of the vibration and noise levels in vehicles, machines and structures has been continually studied in engineering. Approaches that have been used with optimal results are the dynamic vibration absorbers (DVAs). These devices appear as an interesting alternative since they possess important characteristics of reliability and efficiency. However, in its simply form, these devices can attenuate vibration only in a narrow single frequency band making its application limited when different forcing frequencies are presents in the primary system. In order to avoid this problem, will be developed in this paper an optimal multimodal vibrations neutralizer which will be able to attenuate vibration in different wide frequency bands. The optimal DVA parameters are obtained using the association heuristics + finite elements method. In this sense, the genetic algorithms are associated to a commercial finite elements software and the structural optimization is performed in order to find de optimal DVA parameters (mass, stiffness and damping). The compound structure (primary + DVA) used to define performance indexes related to the vibration level of the system over the previously chosen frequency bands. These indexes are then optimized with respect to the design parameters, which are chosen as the vibration levels and physical parameters of the DVA. Numerical example will be fully described to illustrate the main features of the proposed methodology.

01035
Design of Modular Extrusion Dies Using Numerical Shape Optimization

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Plastics extrusion is a manufacturing process suited for continuous profiles with a fixed cross-section. The function of the extrusion die is to reshape the melt, which originally has a circular cross-section, to the desired profile shape. When constructing new extrusion dies, the key challenge is to design the transition region between outflow and inflow of the die in such a way, that the material distribution at the outflow is homogeneous. In industrial applications, extrusion is a large-scale process, financially attractive only for mass products. This is not so much due to the manufacturing costs of the die, but the construction and time-consuming running-in experiments that must precede each production cycle. As part of the Cluster of Excellence ”Integrative Production Technologies for High-Wage Countries” at the RWTH Aachen University, there is a joint effort by the Chair for Computational Analysis of Technical Systems (CATS) and the Institute of Plastics Processing (IKV) to modularize extrusion dies by building them up from a standardized inflow component and an individual second component. The standardized part is intended to be reused for all dies covering a specific subsection of the range of products. Whilst the shape of the inflow part needs to be determined beforehand through analytical considerations and experiments, a numerical shape optimization tool has been developed as a means for the design of the individual component. The core of the optimization tool is the

in-house flow solver XNS, which uses the finite element method with Galerkin/Least-Squares stabilization, can utilize various parallel machines (Xeon clusters, IBM Blue Gene, etc.), and is able to exploit the common communication interfaces for distributed-memory systems (SHMEM and MPI). These features make it ideal for the rather costly computations arising from simulating extrusion. The extrusion process can in general be described by steady Stokes equations without major loss of accuracy. However, the accurate modeling of the plastics behaviour generally calls for shear-thinning or even viscoelastic models. Since most industrially relevant extrusion dies are not symmetric, there is usually the need for 3D computations, leading to large computational grids. XNS has been extended by an optimization framework, creating the basis for the integration with a variety of optimization algorithms. Furthermore, a geometry kernel has been developed, which internally describes the geometry of the die with T-splines. Topics discussed will be our approach to shape optimization and how it fits into the modularization concept. Concerning the latter, we will focus on the geometry representation and the objective functions. Recent examples in 2D and 3D will be shown. They will compare different objectives and different material models, giving insight into the influence of these factors on the optimization result.

01039
Topology Optimization of Two Linear Elastic Bodies in Unilateral Contact

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The optimal solutions are most sensitive to the boundary conditions when performing topology optimization of components. In many applications the design domain of the components are subjected to unilateral contact conditions. In order to obtain relevant conceptual designs by topology optimization of such systems, the contact conditions should be included explicitly in the optimization. Recently, in a number of works by Strömberg and Klarbring, such a method has been developed for one elastic body unilateral constrained to rigid supports. Here, this approach is extended such that a system of two elastic bodies in unilateral contact is considered. For this systems the compliance is minimized by adopting the SIMP-model. A nested formulation of the problem is solved by SLP, where the sensitivities are obtained by solving an adjoint equation. In this latter equation, the Jacobian from the Newton method used to solve the state problem appears. The state problem is treated by an augmented Lagrangian formulation of the two bodies in contact. Thus, the Jacobian is simply the gradient of the corresponding system of equations to this formulation. The method is implemented in the toolbox Topo4abq by using Matlab and Intel Fortran. The method is both efficient and robust. This is demonstrated by solving several 2D-problems. The results are also compared to the solutions obtained when the contact conditions are treated by joining the two bodies to one body. In a near future 3D-problems will also be solved by using the presented approach.

01042
Reliability based design for a raked wing tip of an airframe

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A reliability-based optimization methodology has been developed to design components of an airframe structure. Design is formulated for an accepted level of risk or reliability. Design variables, weight and the constraints became functions of reliability. Uncertainties in load, strength and material properties as well as the design variables were modeled as random parameters with specified distributions, like normal, Weibull or Gumbel functions. Objective function and constraint or a failure mode became derived functions of the risk-level. Solution to the problem produced the optimum design with weight, variables and constraints as a function of the risk-level. Optimum weight versus reliability traced out an inverted-S shaped graph. The center of the graph corresponded to a fifty percent probability of success, or one failure in two samples. Under some assumptions, this design can be quite close to the deterministic optimum solution. Weight increased when reliability exceeded fifty percent. Weight decreased when the reliability was compromised. A design can be selected depending on the level of risk acceptable to a situation. The reliability-based optimization software was obtained by combining three codes. MSC/Nastran code was the deterministic analyzer. Fast probability integration of the NESSUS software was the probabilistic calculator. NASA Glenn Research Center's optimization testbed CometBoards became the optimizer. The optimization capability required a deterministic finite element structural model, and probabilistic models for material properties, thermo-mechanical load and design variables. Reliability-based optimization method was applied to design the raked wing tip of the Boeing 767–400 extended range airliner made of composite and metallic materials. The members of the wing tip were grouped to obtain a set of 13 active design variables. For constraint formulation, the structure was separated into a number of subcomponents. Strain constraints were imposed on members in the subcomponents. There were 203 strain constraints for the panels and the spars and 16 additional constraints for the rod members. Three translations and one rotation at the tip of the structure were also constrained. The design model had a total of 227 behavior constraints for two critical load cases. Constraint can be imposed on principal strain or on a failure theory for laminates. Deterministic optimum solution was generated first, followed by stochastic design. The stochastic optimization calculation required continuous running of the code for more than 5 days, but the execution was smooth and eventless. The optimum design exhibited nine active constraints consisting of eight strain and one displacement limitations. The optimization process redistributed the strain field in the structure and achieved up to a 20-percent reduction in weight over traditional design.

01043
An Industry-Strength Novel Optimization Tool for Constrained Multi-Objective Design

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In the last ten years, the software available for performance analysis of different processes and systems in a wide range of applications, has achieved the high level of maturity. The corresponding software market is estimated by billions of USD per year. Usually the results of this analysis are practically employed in order to improve the design of these systems and processes. This is performed in a manual way (by the "trial and error" method), mostly based on the experience of designers and their intuition. In many important cases, the need to satisfy contradictory requirements (due to the multidisciplinary character of the problem), makes the design extremely complicated and time and money consuming. Usually a significant number of design cycles is needed, where each cycle may take months and even work years of a group of designers. That is why, the request for reduction of design costs by using automatic tools ("optimization tools") capable of both reducing design costs and improving the quality of design, became extremely high. Unfortunately, until now, the conventional approach to this challenge proved unsatisfactory due to the following reasons: 1) non-global character of the existing search techniques; 2) inaccuracy and inefficiency of the existing methods for incorporation of real life multi-constraints into design process and 3) huge computational volume required. In this connection, the main objective of the paper is to present a new general-purpose robust and efficient optimization software which is aimed at real-life automatic constrained designs in a wide range of applications. The paper describes the algorithm and technological approach and exemplifies its applicability to high-scale engineering and software designs. The optimization algorithm is based on a hybrid genetic approach. Genetic Algorithms are employed as a search driver in combination with a specially developed variant of Reduced Order Models method Local Approximation Approach (LAM) which makes use of multi-domain linked local data bases. The method features an efficient strategy for handling multiple nonlinear constraints. Within this approach, the genetic algorithm is enhanced by including infeasible (that is constraint violating) solutions into the search through the use of specially tailored discontinuous objective functions. This allows for finding difficult-to-discover optimal solutions residing on the boundary between the feasible and infeasible regions (as it happens in many challenging problems). Another important feature of the method is the use of relatively inexpensive but sufficiently accurate computations as a driver of the design stream. This is achieved by combining LAM approximations with accurate problem-dependent analysis in a predictor-corrector manner. From the software viewpoint, we use multilevel parallelization of the whole computational framework and thus the overall high level of computational efficiency is achieved which allows for obtaining the needed solutions on a daily basis even for computationally consuming problems. The above mentioned features makes this software package the unique tool which is considerably superior to existing design tools in terms of accuracy, efficiency and robustness. The design tool is applicable to both continuous and discrete real-life problems. To illustrate this, two markedly different applications are given. The first one exemplifies a variety of configuration designs by the multi-point optimization of transonic aerodynamic wing in the presence of multiple engineering constraints. We show the ability of the method of finding aerodynamically feasible multi-pointedly optimal shapes which satisfy a large number of geometrical and aerodynamic constraints. The second example deals with software test data generation - the problem of creating a software test set which optimally satisfies adequacy criteria (that is criteria which distinguish good test sets from bad ones). It is shown that the optimal solutions possess good test coverage capability.

01046
Robust Structural Optimization of Stochastic Dynamical Systems

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An efficient first-order scheme to carry out reliability-based optimization of uncertain structural systems under stochastic excitation is presented. The problem is formulated as the minimization of an objective function subject to deterministic and/or reliability constraints. The main feature of the approach is the generation of a sequence of steadily improved feasible designs. This property is important from a practical point of view since the optimization process can be discontinued at any stage and still leading to better designs than the initial feasible estimate. This is particularly attractive for dealing with involved problems such as reliability-based optimization of structural systems under stochastic excitation. One of the difficulties in this type of problems is the high computational cost involved in the reliability analyses required during the optimization process. This is due to the fact that reliability estimation of stochastic dynamical systems for a given design involves the estimation of failure probabilities in high-dimensional parameter spaces. A key feature of the proposed approach is the identification of descent feasible directions and the implementation of a line search strategy. The computation of descent feasible directions implies the determination of the gradient of the failure probability functions. An efficient approach based on the behavior of the performance functions that define the corresponding failure domains is considered in this work. With only a few extra evaluations of the performance functions, and no extra reliability analyses, it is possible to generate sufficiently accurate estimates of the sough gradients. On the other hand, an efficient line search strategy combined with approximate failure probability functions is

implemented in the approach. Directional derivatives are used for constructing explicit approximation of the failure probability functions along search directions. The estimation of the directional derivatives requires only few extra evaluations of the performance functions. Numerical examples involving realistic finite element models have shown that the algorithm requires only a few iteration cycles for converging to the final design. It is also shown that uncertain system parameters may cause significant changes in the reliability of final designs. Therefore all uncertainties involved in the design problem should be accounted for during the optimization process in order to obtain robust designs. The proposed methodology has the potential to be used in realistic structural optimization problems under uncertain conditions.

01050
The Adaptational Maximum Phenomenon in Complex Systems

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Any complex system interacts with its changing environment and its viability depends on its adaptability. The number of arbitrary coefficients in the structure of equivalent equations of complex system changes in the process of learning. In systems with more than six variables, the number of arbitrary coefficients increases first, and then, passing through the maximum, begins to decrease. This phenomenon makes it possible to explain the processes of system growth, complication and death in biological, economical and physical-engineering systems. We use the linguo-combinatorial method of investigation of complex systems, in taking key words for building equivalent equations. This phenomenon is able to increase the adaptability of different systems.

01051
Multi-Objective Optimization using Genetic Algorithm or Nonlinear Goal Programming

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Many engineering problems in its formulation has the need to address the mathematical model as a problem with multiple objectives, also called multiple criteria decision making (MCDM - Multiple Criteria Decision Making). In practice, this type of problem occurs due to lack of resources to meet all the project needs. One simple and illustrative example relates the objectives, cost and safety. In engineering projects we are always looking to maximize safety and minimize the project cost. These goals are often antagonistic and deserve to be treated with the application of MCDM mathematical models. To solve MCDM problems, various techniques may be used and this article discusses the application of two different solution methods: the use of non linear goal programming technique (NLGP) and the application of genetic algorithms (GA) to solve problems multiple criteria. NLGP were developed during the Second World War and require some expertise to determine the Pareto frontier. Genetic Algorithm, presented in the mid-1970 by J.Holland, was popularized by one of his students D. Goldberg in 1989. The technique presents many advantages but also some problems to be overtake. This article presents the aim of the two techniques, discusses their advantages and disadvantages and illustrates the application with two case studies where we compare the results obtained and the time needed to reach a solution to the problems presented. A discussion is made regarding the establishment of weights for the objectives and the process to decide the best design in the Pareto frontier. The two case studies were selected to illustrate the NLGP and the GA techniques application. The first one is a mathematical non linear problem and the second is selected from the naval architecture and ocean engineering field. Finally, recommendations are given for an efficient implementation of the methods in some engineering design problems.

01061
Shape Optimization in Support of the Design of Heart Assist Devices

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The World Health Organization (WHO) reports cardiovascular diseases as number one cause of deaths worldwide. In 2004, 12.9 million people died from heart disease or strokes which accounts for an estimated 22% of all deaths. Occlusion and stenosis of arterial blood vessels inhibits regular blood flow and causes elevated shear stress and recirculation favoring further deposition, and thus, has major effects on many of the diseases categorized as heart disease. Later stages of heart disease often leave heart transplantation as the only cure. As a response to the dramatic shortage of donor organs, a temporary cure is the implantation of ventricular assist devices (VADs) that support the ailing heart in maintaining sufficient blood flow. In the development of VADs, designers are faced with two possibly competing objectives: first, the pump needs to provide a desired flow rate; and second, the flow patterns should not induce blood clotting (thrombosis) or red blood cell damage (hemolysis). Over the last decade, computer simulations of fluid flow have steadily gained acceptance as an effective tool for evaluation of design modifications. The flow features in complex geometries such as blood pumps, as well as the evolution of those features resulting from design changes, are hard to predict even by experienced design engineers. By employing shape optimization techniques to directly compute an optimal design, this drawback can be avoided. To this end, we have extended the in-house flow solver XNS by an optimization driver and a geometry kernel. XNS is a finite element solver that uses a stabilized space-time Galerkin/least-squares discretization. The code meets several requirements for the accurate numerical simulation of VADs: it includes constitutive models for viscoelastic fluids such as blood and incorporates special mesh update techniques to accommodate deforming and rotating parts of the computational domain. Furthermore, an MPI-based implementation allows XNS to exploit the potential of parallel processing on high-performance distributed-memory computer architectures. The optimization driver runs in its own process and computes the update of the design parameters. Both gradient-based and gradient-free optimization methods are available. The computational domain is updated by the geometry kernel that contains different methods for shape modification. These include the geometry modeling toolkit OpenFlipper and an in-house T-spline library. In the first part of the presentation, we provide a detailed description of the proposed shape optimization framework and demonstrate how it is employed to optimize the design of a single component of the MicroMed DeBakey VAD. The second part is concerned with the robustness of the optimal shape with respect to simulation parameters. We apply a subtle combination of automatic differentiation techniques to transform the entire framework. The resulting code is used to compute the sensitivity of the optimal shape with respect to viscosity. Results from the optimization of an arterial bypass graft confirm the validity of this approach. We discuss how it offers a new way of investigating the influence of the constitutive model on the optimization outcome.

01072
Development of Camber Morphing Capability in a Telescopic Morphing Wing

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A wing camber morphing concept applied to a telescopic wing is described. The concept is based on a nonuniform thickness distribution shell that under actuation deforms the airfoil from one symmetrical airfoil shape into a different cambered airfoil shape. Optimization is used to obtain the shell thickness distribution

for minimum shell section weight and best airfoil shape adjustment. Complete finite element modelling of the wing structure is performed including actuation and unidirectional coupled structural-fluid analysis is used to estimate the morphing benefits. Optimization is also used to calculate the best wing configurations for the best performance in different performance measurement parameters. Comparison between the morphing wing performance and an optimum fixed wing (for cruise at 30m/s and weight of 100N) performance is made. The morphing wing generally outperforms the fixed wing with exception in a 9.5% reduction in rate of climb and insignificant drag penalties at the optimum cruise speed. In a limit case of comparison between the morphing wing and a weightless fixed wing the benefits form morphing generally decrease, although there are still very significant benefits in stall speed and endurance, and penalties in rate of climb become more intense. Morphing benefits assessment challenges are discussed.

01075
Pareto-based multi-objective hot forging optimization using a genetic algorithm

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In order to succeed the ever-increasing demand of industry, innovative intelligent solutions to optimize its processes through new strategies for process design and control are searched. The application of optimization principles and intelligent control approaches to dynamic processes, such as forging, will save money due to reductions in the total number of process operations, wear and tear on equipment systems, scrap material, and the overall energy requirement. Efficient control techniques must be preceded by well-designed processes. A generally accepted definition of a well-designed process is one that is Pareto optimal, i.e., no design objective can be improved without degrading at least one other design objective. Indeed, optimal design enables effective trade-off of competing design objectives, including controllability and robustness goals. Forging process optimization requires the design of several parameters, including initial work-piece temperature and dimensions, number of dies, die temperatures, and deformation rate profile. Other design parameters include the initial billet's heat-up profile, possible thermo-mechanical billet conditioning steps and subsequent heat treatment profiles quenching steps, and machining steps. Utilizing appropriate models together with optimization algorithms, an optimal forging process can be designed to meet cost and quality specifications while also ensuring that the design is robust. Previous studies on metal forging optimization consider the weight coefficients approach to solve multi-objective problem by using a single-objective functional which combines multiple objective functions into one. Nevertheless, it is difficult to make sure whether the solution achieved is an optimal one since each set of coefficient combination will induce one optimal solution. The main goal of the present work is the design of a Pareto-based multi-objective optimization model for multi-stage hot forging processes. The optimization methodology considers a genetic algorithm supported by an elitist strategy. Fitness of each individual will be evaluated by objective functions, and a Pareto ranking procedure is used to determine the corresponding fitness value. An iterative procedure will be considered by evaluating all the individuals by one of the objective functions and finding individuals whose objective function value is minimized, then repeating for the other objective functions until all of the individuals have their own Pareto ranking. Pareto optimal solutions will be found managing the drawing of the Pareto front and then extracting the optimal solutions according to selected preferences. The design example consists of a two-stage forging process applied to a pre-heated billet made of AISI 1018 steel. Two sets of variables will be considered: shape design variables and process variables. In the numerical example the shape variables are

the variations of the active control points of a cubic B-spline defining the preform die geometry. The process variables considered are the warm-up temperature of the work-piece and stroke length for each stage. The objective functions are the minimization of the forging load, the control of the forged shape and the material microstructure.

01079
Some aspects and applications of state observers methodology for crack detection, localization and evaluation in continuous systems

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Lately, new techniques of fault detection and localization at mechanical systems that are dynamically loaded have been developed to attend the industry demand caused by the technology progress. Even the tools for theoretical analysis of dynamic systems being sophisticated, there are great difficulties at the prediction of the dynamic behavior of some structural components or machine elements at the fault diagnosis, caused by the inaccuracy of the theoretical model, or caused by the difficulty on measuring some state variables. The methodology of state observers is perfectly inserted on this reality, because its capability of estimate the state variables of a system based on the measurement of the output and control variables. The methodology becomes more attractive because it makes possible the reconstruction of the states where the measurement is hard or just impossible, detecting failures at points that are not available to be measured and monitored trough the reconstruction of its states. Because of the magnitude of its effects, the crack nucleation or propagation demands essential care at mechanical systems. Knowing that this kind of fault can appear with the deterioration caused by vibrations and dynamical conditions, it becomes an excellent object for studying the use of the State Observers methodology to detect, locate and evaluate cracks conditions. For the suggested system, a coupled cantilever beam, were used a Finite Element Method, which showed itself the best one to do this kind of analysis, with beam elements at an elastic foundation, obeying a crack model. It was simulated with conditions of impulsive impact and harmonic excitation, and analyzed the results supplied by the State Observers through RMS differences between the two function curves. A complete observation system with a Global Observer of the process and Robust Observers, dedicated to accompany the stiffness variation of each element, was used, locating the fault and evaluating the percentage of penetration of the crack in the beam. An experiment was constructed using a real system that was assembled with the same characteristics of the simulated one, with the same size and proportions. An observation system build at SIMULINK (MATLAB®) environment was added to this system, providing the difference between the response curves graphically and through RMS differences.

01084
Designing the optimum regulator for the bounding flight

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Recent research interests are directed towards unmanned vehicles as small as insects and birds. These obey mechanisms different from those of much larger manned vehicles. We need to establish a new design paradigm for that purpose. Biomimicry is one of the tools applicable to this new goal. This research is the

outcomes of analysis of an intermittent-flight technique called 'bounding flight.' Many birds fly with a technique by mixing the wing-flapping and wing-folding phases. Such a flight trajectory undulates up and down. This is the bounding flight. Some small passerines like wagtails and even large woodpeckers make most of this flight technique. The wing-folding phase does not generate lift and hence reduce the total drag. In the wing-flapping phase, however, the load factor has to be larger than unity to be aloft in a total cycle. Therefore we need to examine the trade-off between the drag reduction and the lift enlargement in the bounding flight. Our proposal is the one based on mechanics of a mass particle and conventional aerodynamics. In this abstract we confine our description upon the horizontal motion only. Muscular power is used to generate thrust. Since power is equal to thrust-times velocity, inversely thrust is equal to power/velocity. Form drag of the body and wings is in proportion to velocity squared, whilst lift-induced drag is inversely proportional to velocity squared. After all the wing-flapping phase is described by m du/dt = P/u – (A_b + A_w)u^2 – n^2g^2/B_w u^2, where m, u, P, A_b, A_w, n, g and B_w designate mass of a bird, the horizontal velocity, the power, drag coefficient of the body, drag coefficient of the wings, the load factor, the acceleration due to the gravity and induced-drag coefficient, respectively. Suppose t_f and t_p denote the total cycle-time of the bounding flight and the duration of the wing-flapping phase, then the load factor n is equal to t_f/t_p. The wing-folding phase is simply described by m du/dt = –A_b u^2. We shall show the bounding flight is the solution to the following optimum regulator: J(u,t) = Min_P \int_t^{t_f} (u_max – u)^2(u – u_min)^2 dt, subject to the equation of motion above and the inequality constraints: u_min ≤ u ≤ u_max and 0 ≤ P ≤ P_max. The Hamilton-Jacobi-Bellman equation assumes the following form: – \partial J/\partial t = Min_P [(u_max – u)^2(u – u_min)^2 + \partial J/\partial t du/dt]. The solution is given as follows. (A) P = 0 if \partial J/ \partial t > 0: the wing-folding phase; (B) P is indefinite if \partial J/ \partial t = 0: switching; (C) P = Pmax if \partial J/ \partial t < 0: the wing-flapping phase.

01086
Automated procedures for the design of MEMS plate-shaped accelerometers

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Nowadays, micro-accelerometers are among the most common MEMS (Micro-electromecanical systems)-based devices. In fact, they find application in a variety of fields, ranging from the automotive industry, like air-bag systems and suspensions, to consumer electronics, like mobiles, GPS systems and computers. They usually take one of two main configurations: comb-drive or plate-shaped. In both cases, an important issue, which is to be taken into account for a proper design, is the squeeze-film damping effect. This phenomenon, which affects the frequency response of the device, is due to the presence of a thin film of fluid (also air), constrained between two walls, which are endowed with a reciprocal normal motion. To control such an effect, and more generally to control the global performances of the sensor, like its sensibility, parameters as the shape and the dimension of the seismic mass, the number and the size of holes on the seismic mass and the working pressure have to be correctly chosen. In this paper, a procedure for optimizing the design of a plate-shaped capacitive accelerometer is proposed. In particular, the size and the shape (rectangular or square) of the seismic mass is determined in order to get the desired electrical sensibility and the widest bandwidth. This aim is achieved by varying iteratively a set of design parameters, as the ambient pressure and the stiffness of the supporting elements. Since, the found working pressure can be very low, a second stage of the design methodology allows to find the number and the size of holes to be present on the seismic mass, in order to have the widest bandwidth at the atmospheric pressure and the best sensibility. In both cases, the optimization process is

carried out by MATLAB® software, which is completely compatible with the multi-physics finite elements solver Comsol®, used to perform numerical analysis of the squeeze-film damping effect. The proposed design methodology is completely automatic and flexible, since it can be easily modified in order to include other types of analysis, like structural analysis for the optimization of the geometry of the supporting elements.

01094
Structural Topology Optimization of Assemblies

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Most structures in aerospace, automotive and naval industry are composed of discrete elements assembled in different ways. Classical structural optimization methods are able to obtain ideal non-compliant structures but they do not consider manufacturability and assemblability issues. New approaches to structural optimization include design for manufacturing and assembly (DFMA) criteria. This investigation proposes a structural optimization method that identifies directly the elements in the structure and the way they have to be attached through to connectivity restrictions. In the field of assemblies design is necessary the optimization of joints between components, because these affect the compliance of the structure and the ease of manufacture. Torsion springs are used to model the different joints. Additionally, the number and types of employed unions affect the assemblability of components and therefore the production costs. The objective function involves the minimization of the area required for manufacturing. The design of the assemblies involves joint optimization between elemental components and the minimization of their compliance. The spring constants operate as design variables and the finite-element method is used in the structural analysis. The optimization stage makes use of stochastic and evolutionary techniques. The results are applied to the design of basic structures and different automotive vehicles.

01095
Stochastic Manpower Planning by Dynamic Programming

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We study a manpower planning problem, which is to determine the optimal numbers of employees in different categories to meet uncertain demands for manpower of certain skills. More specifically, we consider two types of jobs with random demands for manpower over a finite planning horizon. Two types of manpower are available, who possess different skills and incur different costs. Type-1 employee can only be assigned to type-1 job, while type-2 employee is more skillful and can be assigned to both type-1 and type-2 jobs. Including the fixed cost of recruitment, we develop a dynamic programming model which decomposes the original problem into four subproblems. We apply the supermodularity and multimodularity analysis to find the optimal policy of the model. The optimal policy is characterized, and the monotonic properties of the optimal policy are studied in this paper too.

01100
Mathematical models of absolutely streamlining and retroreflecting bodies

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We provide several mathematical billiard constructions that reveal certain extremal properties. Namely, bodies of zero resistance and bodies invisible in one direction will be constructed and their properties will be discussed. These results are related to a far-going generalization of Newton's minimal resistance problem. Retroreflectors are optical devices that reverse the direction of incident flows of light. Eaton lens is a well-known perfect retroreflector based on light refraction. We propose and discuss various models of asymptotically perfect retroreflectors based solely of light reflection (that is, billiard models of retroreflectors). We believe that these mathematical models have potential applications in space aerodynamics (optimizing the shape of artificial satellites on low Earth orbits) and in optics (perfect retroreflector design, solar sails).

01101
Flash Zone Optimization of Benzene-Toluene-Xylene Fractionation Unit

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Optimization of a typical fractionation unit and reduction of energy consumption has been carried out only by modifying the implementation and change in the flash zone of a tower. Previous studies have economized such issue by other methods which require additional equipments, hence reducing the cost effectiveness. It is theoretically illustrated and represented by simulation means that an insertion of the vapour product of the flash drum into upper stages of the distillation column separately instead of common procedure of combination with the liquid exiting the bottom of the flash drum can lead to energy conservation in reboiler duty, increased L/G of the top section of the column and to a reduction in the upper section diameter. A typical example of a BTX plant is used by provision of HysysTM as a simulation.

01102
Four Different MILP Models to Generate Optimal Error Correcting Codes, Or How a Much Greater MILP Model is Much More Efficient

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In this paper we present four MILP models to generate optimal error correcting codes over a given alphabet A with a given length (the number of characters of each word) L and minimum Hamming distance d, and in some cases imposing words with a constant weight (the number of characters different than zero), w, and one initial MINLP model. By optimal code we mean the code with the maximum number of words with the given constraints. From the experience with the initial nonlinear model we rapidly reach the conclusion that even for small codes the solver got trapped in a suboptimal solution which is associated to a local optimum of the objective variable, the number of words of the error correcting code. So we linearized the model to guarantee that

the solver will converge always to the global optimum. The second approach, a MILP model, is the more straightforward but it implies the use of a number of indexes equal to the double of the length of the code. In the second MILP model, with a more complex model, we reach a solution where the number of indexes is equal to the length of the code and in a third approach we developed an alternative very artificious approach where we keep constant the number of words and maximize the minimum Hamming distance. We compare the three MILP solutions with some code generation problems and we reach the conclusion that the second approach is the best MILP model. Nevertheless even with this solution when the length of the words increases, and so the search space explodes, the runtimes got prohibitive even when we impose the constraint of constant weight words or constant composition words, in the case of ternary codes.

01119
Durability-based Structural Optimization with Reduced Elastic Multibody Systems

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Structural optimization is a capable tool in the design process of mechanical systems. If a structural optimization task is expanded to a dynamic problem, the use of a multibody systems (MBS) is often suitable. Dynamic quantities in the structure that is to be optimized, such as time series of stresses, can be derived by the superposition of time dependent MBS-results and position dependent FEM-results. A meaningful method of dealing with these dynamic stresses is the derivation of damage values by a durability analysis. These damage values can be used as scalar performance criteria for the structural optimization problem. The minimization of damage at the most critical positions by changes in the geometry is thus the final goal for the optimization. Since damage values are extremely sensitive with respect to dynamic stresses, the accurate determination of dynamic stresses is of particular importance regarding an expedient optimization result. One possibility of meeting this requirement is the consideration of the optimized structure's flexibility in the MBS-simulation. Therefore, the use of an elastic MBS (EMBS) is essential. Due to computational performance, the entire elastic body, that is usually the FE-model, cannot be included in the EMBS-simulation. Hence, a reduced FE-model is necessary leading to a reduced EMBS. The process of model reduction is also a source of errors affecting the structural optimization. This contribution presents a structural optimization loop comprising reduced EMBS-simulation, FE- and durability analysis. Whereas conventional approaches in this field require a postprocessing of EMBS- and FE-results, the presented work allows the calculation of damage values during runtime of the EMBS-simulation. Here, those quantities are direct output from the EMBS-simulation, in order to speed up computation times. An error free recovery of dynamic stresses in a predefined frequency range is assured by a FE-model reduction based on so-called Krylov-subspaces. This feature represents an innovation compared to conventional structural optimization loops including reduced EMBS-simulation. Those modal approaches, which are state of the art, have to struggle with uncertainties of the EMBS-results. This disadvantage can be omitted in the approach proposed in this contribution. The developed optimization loop and its advantages are illustrated with the help of a nontrivial example.

01121

Structural Optimization of a Composite Plate subjected to a Small Mass Impact

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This paper presents the optimization of a composite plate subjected to a small mass impact under a mode II delamination constraint, considering impact response and delamination threshold load predicted by closed form solutions. These solutions are inexpensive from a computational point of view and have good agreement with experimental data. Therefore, this approach can be very interesting when working with optimization methods that require a large number of iterations to converge. In other hand, the closed form solutions have implicit limitations. An example is the plate and impactor masses ratio that must be within a defined range, otherwise the impact model do not apply. Consequently, the plate optimization problem must be well stated and constrained in order to provide results comprised in the closed form solutions validity. In this work, the optimization problem and strategy are stated and discussed, aiming to evaluate its application. The optimization method employed is the simulated annealing, together with appropriate optimization heuristics. Final optimization results are validated by finite element analysis with the capability of predicting damage in composites under impact.

01127

Optimum positioning of dynamics vibration absorbers applied to pipes using finite elements numerical analysis

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The problem of vibrations at pipes is relevant at industrial applications, considering that it is very hard to design efficient coupling and supports due to complex geometries and great length of tubings. This problem is even worst when measurement and control equipment (outflow measurers, pressure measurers, and outflow valves, among any others) are applied at the system. This interference generates the emission of alternate vortices and fluid recirculation zones, which causes periodic excitation at the pipes. Then, happens what is called flowing inducted vibrations. The theory of Dynamics Vibration Absorbers (DVAs) is very good known and developed, but only recently, with the advance and globalization of informatics, that the application of control techniques becomes possible with practical results. This research has as purpose find optimal points for the installation of dynamics vibrations absorbers at straight tracks of pipes, what means that what will be found are positions where the DVAs show more efficiency as a function of the forces that generates more vibrations. For this, there is used a modeling through Finite Elements, to obtain the time response from the tubing and evaluate the

vibrations levels with and without absorber. The modeling was done with bi coupled beams with two degrees of freedom per node (rotation and displacement). One element of measurement responsible by the vortices emission was modeled as a concentrated mass at a node referent as its position at the pipe and a harmonic force as result of the emission of vortices. In the other hand the absorber was modeled as a spring – mass system in a way that the quotient between the stiffness and the mass result in the square value of the natural frequency of the DVA and also equal the frequency of the excitation force. For each acceptable position of the measurer, a variation of the DVA position was done passing by the two nodes of the discretization, creating then efficiency surfaces, what means that were created tridimensional surfaces which a plane is constructed as a combination of the DVA position and the orthogonal direction to them which contains the percentage of obtained absorption. These percentages were calculated with the quotient between the RMS values of the structure with and without DVA. In contrast with what was initially thought, the best position for the observer does not match the measurer position. The optimal position for the absorber is always distant from the measurer. Probably this occurs as an effect of propagation of waves and depends directly of the vibration modes of the pipe that is more excited by the frequency of vortices emission.

01129

Design Optimization of a Variable-Span Morphing Wing

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The present work focuses on the study, design and validation of a variable-span morphing wing to be fitted to a mini UAV. An aerodynamic shape optimization code, which uses a viscous two-dimensional panel method formulation coupled with a non-linear liftingline algorithm and a sequential quadratic programming optimization routine, is used to solve a drag minimization problem to determine the optimal values of wing span for the whole vehicle's flight speed envelope while subject to geometric constraints. A simple weight representation model based on empirical data obtained from a wing prototype was used to estimate the variable-span wing weight. The UAV flies in a relatively narrow speed range - from about 12 m/s to 30 m/s. Near its maximum speed it is possible to obtain a 20% wing drag reduction with the variable-span wing in comparison with the original fixed wing. An analysis is also performed to estimate the roll rate available with asymmetric span control showing that the variable-span wing matches the aileron in terms of roll power. An electro-mechanical actuation mechanism is developed using a simple and cheap rack and pinion system. The wing model is designed with the help of graphical CAD/CAM tools and then a full scale model is built for bench testing the wing/actuator system. The concepts used on the morphing wing for both fixed and moving wing parts are considered simple and effective. The actuation concept is feasible but still needs improvements for flawless continuous operation. Future work is planned on the design optimization code: implementation of a coupled aero-structural analysis model for simultaneous aerodynamic and structural design optimization problems.

01130
Effect of frictional sliding on the unilateral damaged behaviour for Laminate Composite

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This paper presents a unilateral damage model coupled with an orthotropic elastic behaviour, to analyse the micro-cracking of the matrix in a representative elementary cell of a plate made of long glass fibre reinforced polymer matrix. The cracks are supposed to grow along the fibres direction with different opening ways. According to the sign of the stress normal to the fibres direction (in the plate plane), the cracks are supposed to be open or closed and lead to a different behaviour in each case. When the cracks are closed, the lips of the cracks can slide (with friction) or stick according to the respective value of the shear and normal stresses. At that moment, the virgin behaviour is recovered in compression. The shear behaviour is either damaged or virgin according to the state of the cracks (sliding or sticking). Damage can increase even with closed cracks. Some numerical results are presented to show the model ability to report the different situations.

01132
An optimal barrel vault design in the conceptual design stage

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In modern architecture, there is a tendency towards wide-span roofs, often conceived as shell structures or space trusses. Since the geometry plays a key role in the structural behaviour of such structures, this entails an increasing attention for the optimal design of shell structures. Due to its very general and flexible formulation, structural optimization is a very promising design tool to reach this optimal design. In this paper, structural optimization is considered in the conceptual design stage. The aim is to optimize the overall shape of the structure based on an initial design concept for the shape. The initial concept has been proposed by an architect, possibly based on morphological indicators or on a preceding topology optimization. Since the detailed design of the structure is not available yet, it is proposed to perform the structural optimization with a simplified analysis model, considering a limited number of relevant load cases. In general, the aim is to locate the global optimum that corresponds to the least material use. Alternatively, however, the design space can be explored to see the variety of good or near-optimal solutions in the design space. The most interesting result from an aesthetical point of view will not necessarily be the global optimal design. In this paper, structural optimization is applied for the design of a barrel vault. The initial design concept is a cylindrical shell with edge beams. The volume is minimized to determine the optimal dimensions of the shell. As the design is in the conceptual design stage, the analysis model only considers four load cases, i.e. self weight, use load, snow and wind load. According to Eurocode 1, the load cases are combined in 13 load combinations using safety factors and combination factors. For the load combinations considered in the ultimate limit state (ULS), the maximal and minimal principal stresses are constrained. For the load combinations in the serviceability

limit state (SLS), a limit is imposed on the maximal displacement. To illustrate the importance of decisions in the conceptual design stage, the results for three different parameterizations are compared. In the first two parametrizations, the shape of the structure is considered to be fixed. First, only the shell thickness and the width and height of the edge beam are considered as design variables. Second, the uniform thickness of the shell in the first parametrization is replaced by a quadratic variation of the shell thickness in the circumferential direction. In the third parametrization, the radius of the cylindrical shell is optimized. Although the same constraints are considered in the three cases, the optimization with the second and third parametrization results in a substantial decrease of the value of the objective function. These results clearly illustrate how the choice of the parametrization affects the optimal design. The use of structural optimization in the conceptual design stage is therefore a valuable tool to assist the designer in the trade-off between aesthetical arguments and an optimal geometry from a structural point of view.

01138
Topology optimization of uniformly heated actuators by ESO method

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This work describes an ESO based topology optimization strategy for uniformly heated compliant mechanisms. The evolutionary structural optimization method has been successfully applied for compliant mechanism optimization under directly applied input loads. The present paper aims to progress on this work line and an extension of this procedure is developed to approach the case of thermal actuators. Compliant mechanisms are especially suitable for MEMS design, where use of hinges and any assembly processes are prohibited and must be made in one piece. Compliant mechanisms that function under the application of a force at an input port generate the desired force or deflection at the output port, transferring the work through material deformations. Thermal actuators, which can be described as thermally actuated compliant mechanisms, are those mechanisms where the input load is a thermal load instead of a force. As an initial approach, this research considers only uniformly heated systems. Recently, topology optimization has become an efficient tool for automatically conceiving these kinds of devices and enabling systematic design procedures, which can result in a save of conception time and manufacturing cost. The evolutionary structural optimization method (ESO) has been successfully applied to several optimum material distribution problems, but not for thermal compliant mechanisms. More advanced problems like actuators automatic design where mobility is obtained by means of temperature variations in the system, have not been analyzed using this methodology and most applications of this method have been oriented for maximum stiffness structure design. This paper shows that this computation method may be useful also in the design of thermal compliant mechanisms, and provides engineers with a very simple and practical alternative design tool. Here an additive version of the ESO method is adopted, where the sensitivity numbers are formulated based on optimality criteria methods and used to optimize the topology with a heuristic update scheme. The optimal design of the mechanism is obtained by repeating the cycle of finite elements analysis and element additions until the volume reaches the prescribed value, producing the largest increase of the output displacement for the prescribed volume. An enhanced version of the smoothing technique is used to prevent checkerboard patterns. Since final solution depends on the pre-assigned volume, a tolerance can be defined for the convergence check, and stop the process when the maximum output port is reached if it is clear that further addition of material will not improve the solution. The proposed strategy has been tested in several numerical applications and benchmark examples to illustrate and validate the approach, and designs obtained with this method compare favourably with the analytical solutions and the results derived by other authors using different optimization

methods, showing the viability of this technique for uniformly heated actuators optimization. Despite the well known shortcomings of the method, results obtained in this paper prove that the proposed additive strategy is capable of producing correct optimal topologies and may be of considerable interest.

01140
Decreasing Computational effort using a new multi-fidelity metamodeling optimization algorithm

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High fidelity simulation models are used extensively in engineering optimization. However, most of them require a large number of analyses and high computational effort. Consequently, a new multilevel optimization approach is developed for multidisciplinary structural design optimization based on multi fidelity modeling to decrease computational effort. Such method is a composition of a statistical estimating method reducing the required number of experiments and a continuous variable Metaheuristic algorithm. It starts with an integrated grid of sample points, and then updates them based on the accurate analysis response and replaces low fidelity to high fidelity where needed as well as the high fidelity analyses, which are far enough from the optimum results, would be omitted according to the corresponding low fidelity responses. Some examples have been presented to show the influence of the algorithm on the computational effort and the results represent higher performance and lesser number of analyses as compared to different optimization techniques like Ant Colony and Genetic Algorithm. It is shown that the algorithm decreases the high fidelity computational cost, demonstrates the noticeable effectiveness of the presented method.

01142
Turbine blade profile optimization using soft-computing techniques

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An in-house code, previously developed by the authors, based on NURBS curves, has been used to parameterize the T106 low pressure turbine profile and a design optimization strategy for the aerodynamic design of turbine profiles based on a Response Surface method has been developed. A CFD numerical approach has been introduced to validate both the obtained profiles and the flow solver (the MISES code) used into the optimization strategy for the metamodel set up. Special attention has been focused on the metamodel configuration and validation. The DoE used for the metamodel set up is an important issue for the present approach and it has been described in some detail. The aerodynamic performance improvement of the optimized profile, compared to those of the original T106, has been confirmed by detailed CFD investigations. The design strategy tested in this work has shown its high potential for the automatic design of aerodynamic profiles with interesting timescales for and industrial use.

01143
Application of the particle swarm optimization method on the optimization of mooring systems for offshore oil exploitation

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There are several methods inspired on nature for solving optimization problems. One of these methods is the Particle Swarm Optimization. This paper presents an application of this optimization tool in mooring systems for floating platforms used for offshore oil explotation, following security criteria established by design rules. The objective is to find the minimum offsets for these platforms, taking the radius of the mooring system and the azimuth of the lines as project variables. Results of typical systems are presented, indicating that the method is effective. In order to facilitate the installation of mooring systems in a real case, the optimized radius of lines located at the same corner should be equal. For this purpose, the grouping of the mooring lines per corner is taken into account in the optimization process. This work also discusses the maximum velocity influence of the particles at the evolution and efficiency of the optimization algorithm.

01146
Design optimization of a multistage axial turbine using a response surface based strategy

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An optimization design approach applied to a 4 stage axial flow turbine (AGARD E/TU-4 testcase) is presented. For this purpose the commercial software ModeFRONTIER has been adopted. A workflow based on geometrical parameterization of the system, a two dimensional throughflow flow solver and a multiobjective genetic algorithm has been built. Only blade sections restaggering has been considered leaving the meridional channel and the number of blades for each single row unchanged. This in order to re-design an existing turbine with the possibility for a direct substitution of the original bladings with the new ones. The optimization goal is the maximization of the total-to-static turbine efficiency (at design operating conditions) keeping the massflow rate unchanged. Two optimization approaches have been considered: with the direct use of the flow solver or with metamodels based on a RSM. The multilayer perceptrons - Artificial Neural Networks - have been used as RSM. Since the number of input variables is high and the design space not easy to fill, a Design of Experiment sensitivity analysis has been carried out, in order to select the best combination of algorithms for an efficient design space exploration. A quasi random algorithm (Sobol) coupled with a statistical distribution algorithm (Normal distributed Latin Hypercube sampling) have been used as space fillers. The DoE has been validated with the flow solver in order to obtain the training dataset for the supervised learning perceptrons. Using the ANNs, the flow solver has been by-passed and a quick and accurate optimization has been carried out, based on metamodels for massflow, total-to-static efficiency and power output. The obtained optimum turbine has been compared to the original and validated using the throughflow solver. The proposed approach has demonstrated its potential for the optimization of multistage axial turbines and it is considered a very useful candidate for design optimization of multistage axial turbomachinery with a high number of stages.

01148
Optimization of loads and geometry of thick-walled pipeline elements operating in creep conditions

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The paper presents methods for geometry and dimensions optimization for thick-walled pressure elements operating in creep conditions in power plants. In some coal-fired power stations, pipeline elements have worked for over 200 000 hours and increased number of failures is observed. The paper discuses thermal wear processes that take place in those elements and lead to rupture. Mathematical model based on creep test data, and describing creep processes for analyzed material, has been developed. Model has been verified for pipeline operating temperature, lower than tests temperature, basing on Larson-Miller relation. Prepared model has been used for thermal-strength calculations based on a finite element method. Processes taking place inside of element and leading to its failure has been described. Than, basing on prepared mathematical creep model and FE model introduced to Ansys program farther researches are made. Analysis of dimensions and shape of pipe junction and its influence on operational element lifetime is presented. In the end multi variable dependence of temperature, steep pressure and element geometry is presented, allowing optimization of process parameters in function of required operational time or maximization of steam parameters. The article presents wide range of methods. The creep test data were recalculated for operational temperature using Larson-Miller parameter. The creep strain were modelled, used equations and their parameters are presented. Analysis of errors were conducted. Geometry of failing pipe junction was introduced to the Ansys program and the finite element analysis of creep process were conducted.

01152
Aerodynamical, Global Optimal Design of the Shape of Aerospace Model Fadet II

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The aerodynamical, global optimal design (GOD) of the shape of a flying configuration (FC), namely, the simultaneous determination of the distributions of its camber, twist and thickness and also of the similarity parameters of its planform, leads to an enlarged variational problem with free boundaries. The author has developed an optimum-optimorum (OO) theory, which is able to solve this enlarged variational problem inside of a class of FCs, which is defined by some chosen common properties. This theory was also used by the author for the inviscid GOD of the shapes of three models with high aerodynamical performances. These models are: Adela (a delta wing alone) and, more recently, the integrated wing-fuselage FCs, Fadet I and Fadet II, global optimized at cruising Mach numbers, respectively, 2.0, 2.2, 3.0. The inviscid GOD of the FC's shape represents now the first step of an iterative optimum-optimorum theory, which uses a Navier-Stokes solver, up the second step of iteration, is able to introduce the influence of friction in the drag functional and in the optimization process and allows a weak interaction with structure requests. The iterative optimum-optimorum theory, proposed here, is a deterministic method, which presents almost all the attributes of genetic algorithms like migration, mutation, evolution and crossover. The aerodynamical performances of these three models were checked in the trisonic wind tunnel of DLR-Koeln in the frame of her research contracts, sponsored by the DFG. The comparison between the theory and experiment is presented here for the GOD aerospace model Fadet II.

01154
Reliability optimization of a series parallel system with multiple choice and budget constraints: a simulated annealing approach

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System reliability has been considered as an important measure in designing and monitoring the performance of many engineering systems. Reliability optimization problems have gained the attraction of many researchers since 1960s [Kuo et al, 2000]. To maximize system-wide reliability two general approaches are considered: Enhancement of component reliability, and Allocation of redundant components. This paper considers the problem of maximizing reliability in a series parallel system with multiple choice constraints and system budget. It is categorized in the class of Enhancement of component reliability problems. A series- parallel system (SP) is a system arranged so that there are m subsystems operating in series, each subsystem consisting of n identical components in parallel. Applications of such systems can be found in the areas of communication, networks and nuclear power systems. This maximization problem is formulated as a 0-1 integer programming mathematical model, where each binary decision variable represents a reliability level for one of the components in the system. The multiple choice constraint represents the idea that only one reliability level could be chosen for a component at one time. The objective function, which is the reliability of the whole system, is a nonlinear function of all the components individual reliabilities. This makes the problem a Nonlinear Integer Programming problem, which is characterized as NP-Hard. In the case the number of components in each subsystem is one, the problem reduces to a simple series system. The objective function of the latter problem can be transformed in to a linear function by taking the logarithm. The resulting problem will be a multiple choice knapsack, which is addressed in a paper by Sung et al (2000). The authors proposed a branch and bound solution approach to the problem. In the general form of the problem where subsystems have more than one component, the objective cannot be transformed into a linear function; therefore the approach mentioned above is not applicable. For this case we propose a simulated annealing approach. Simulated annealing is a computational stochastic technique for obtaining near global optimum solutions. In the proposed simulated annealing approach a method for generating an initial feasible solution, acceptance criterion of the new candidates and the definition of neighboring solution are discussed. A numerical example is also provided to illustrate the solution procedure.

01158
Study of economic aspects of cold-formed steel over hot rolled steel for purlins

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One of the great advantages of cold-formed steel (CFS) is the immense flexibility that the material affords in forming cross-sections. This flexibility would seem to readily lend itself to optimization of member cross-section shapes. Cold formed sections also having the great flexibility of cross-sectional profiles and sizes available to structural steel designers. Whereas, the low strength-to-weight ratio of hot rolled steel members leads to increase in overall load on structure as compared with cold-formed steel sections which is having high strength-to-weight ratio. In this paper focus is given on study of economic aspects of cold formed sections as purlins in comparison with traditionally used hot rolled sections for Industrial structures by using IS 800-1984 & IS 800-2007 with IS 801-1975. The most economical sections and cost comparison is presented in the paper for 5m, 6m and 8m spans with roof slopes of 100, 150 and 200. Similarly focus is given on the effect of sag rods in the design of purlin members.

01160
Finding Continuous Pareto Set in Multi-Objective Optimization

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Multi-objective optimization is nowadays a word of order in all engineering projects. Although the idea involved is simple and were established around ends of XIX century, the implementation of any procedure to solve a general problem is not an easy task. Evolutionary algorithms are widespread the unique technique available to find a candidate set for the solution. Usually they supply a discrete picture of what is called Pareto frontier even if this frontier is continuous. In this paper we solve the multi-objective problem directly and intuitive hints are indicated in how to guess the Pareto set in the decision space having only the objective functions definition. This is done for two dimensional functions but it opens a new path for future research works in multi-objective optimization.

01164
A Multidisciplinary Simulation Framework for Optimization of Rotorcraft Operations and Environmental Impact

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Rotorcraft mission performance analysis has always been an important topic for the rotorcraft industry. This topic is now raising even more interest as aspects related to gas emissions and noise gain more importance for environmental and social impact assessments. The present work illustrates a multidisciplinary analysis case where a selected helicopter manoeuvre is optimized in order to minimize the noise and emissions footprints under specific operational or environmental constraints. For this purpose, an integrated tool is being developed within the JTI Green Rotorcraft initiative that is capable of computing and optimizing flight paths against noise and gas emissions as well as assessing its environmental impact. This simulation framework tool is the result of a collaborative effort between LMS International (BE), National Aerospace Laboratory NLR (NL) and Cranfield University (UK). In order to simulate the characteristics of a specific trajectory, as well as to evaluate the gas emissions and noise that are produced during the rotorcraft's operation, three computational models have been integrated into the simulation tool. These models consist of a rotorcraft flight mechanics simulator (jointly developed in a European project), a rotorcraft environmental noise analysis model (jointly developed in a European project), and an engine performance and emissions evaluator developed at NLR. The integrated process has been created in order for the three simulation

tools to communicate with each other, and iteration loops have been added to account for fuel burn during the course of the mission. The multidisciplinary integrated process has been performed with the deployment of the OPTIMUS process and simulation integration framework developed by Noesis Solutions. The optimization processes carried out for the purpose of this work are based on OPTIMUS' built-in optimization algorithms as well as on algorithms developed at NLR. A comparative evaluation between a baseline and the optimized trajectory's results has been waged for the purpose of quantifying the operational profit (in terms of fuel required) gained by the helicopter's operation within the path of an optimized trajectory under specific constraints. The application of the aforementioned methodology to a case study and the actual gain in terms of environmental impact, demonstrates the validity of this integration and optimization process for a class of rotorcraft missions, based on the simulation performed.

01165
Shape Optimization of Internal Passages for a Steam Cooled Airfoil

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This paper deals with a shape optimization problem of turbine airfoil's cooling system. Originally the airfoil in question is equipped with ten circular internal cooling passages. In this work there assumed that cooling would be provided with non-circular channels whose shape is optimized with respect to thermal and economical objectives. Shape of the specific passages is modelled with use of four Bezier's splines to compose a smooth and closed profile. The optimization is done with the evolutionary approach where for the specific solution assessment the Conjugate Heat Transfer (CHT) analysis is used. The computations are performed for a well documented C3X airfoil. Originally, it is cooled with air flowing through internal passages of circular cross-section. However in modern gas turbine airfoils shaped cooling passages are dominant because they can be better fitted to the blade profile. This made the authors to introduce such passages and optimize their shape. Since the presence of cooling introduces, apart from the positive effects, some drawbacks which are i.e. the increased thermal stress level. To avoid stress concentrations a cooling passage should be smooth. A very convenient way of smooth shape modelling is utilization of the Bezier's splines. A single Bezier's curve is based on, so-called, control points. Depending on the number of control points, a curve with different properties is obtained. Most frequently the Bezier's curve is built on four control points. In such a case the spline is a cubic one and in consequence a smooth curve. To provide adequate flexibility of the curve there decided to model a passage shape with use of four such splines. In order to match a passage with the blade profile a shape copy technique was proposed. The top and bottom curve of the passage was a scaled copy of a selected segment of the blade profile. The two other curves were built to close the contour. Taking into account some restraints applied to the splines which provide smooth connections of the curves, 12 control points are required to define a passage. The evolutionary approach used for the optimization procedure utilises a floating point design variable coding. Each individual consists of a set of design parameters, which define a cooling system structure. The computations were performed for 4 cooling channels with 48 design variables. Each cooling structure is evaluated on the basis of a weighted single-objective function, which incorporates the thermal and economical criteria. The components of the objective function result from a CHT analysis carried out with ANSYS CFX software. Since the full CHT predictions which involve external gas, solid and coolant are computationally expensive, only the interior of the blade was taken into account with fixed boundary conditions at the profile. Such a technique is a significant step towards a more reliable thermal field determination comparing to the empirical formulae approach.

01166
Supply Chain Network Optimization with environmental Impacts

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Sustainable Supply Chains can be seen as logistic structures that guarantee the production and distribution of products globally in an environmentally friendly manner. To achieve such goal companies must invest on the design and planning optimization of their logistic structures while accounting for the trade-off between profits and environment impacts. In spite of a considerable amount of research having already been carried out on process supply chain management, a new area exploring environmental aspects is now emerging. In recent years there has been a growing awareness for the importance of incorporating environments aspects along with the traditional economic indicators. This trend has been motivated by several issues, a major one being tighter governments regulations and customers' perception towards more environmentally conscious systems, which may eventually lead to higher product sales (Guillen-Gosalbez et al. 2009). Hugo et al. (2005) presented a combination of life cycle criteria for the design and planning of multi-enterprise supply chain networks. By the same authors, a multi-objective optimisation approach for hydrogen networks is described, where the trade-offs between investment and greenhouse gas emissions was investigated (2005). More recently, work has been published on Closed -Loop Supply Chains, where forward and reverse flows are taken into account simultaneously (Salema et al. 2006). Recently, Melo et al. (2009) presented a survey, where the majority of cited papers feature a cost minimization objective, followed by a few where network configurations with minimum total cost are sought. The author noticed that very few articles refer to models subject to multiple and conflicting objectives. In this work and using a generic and uniform mathematical framework, i.e. the Resource-Task-Network (RTN), the optimal design and planning of a supply chain is investigated by means of a bi-objective formulation, where profit maximization is addressed together with minimization of environmental impacts. Multi-objective optimization may become very lengthy with an increase of the problem dimension and complexity. For this reason we adopt an alternative optimization approach, based on symmetric fuzzy linear programming (SFLP), which is based on one single new objective criterion, which embodies a compromise between the initial conflicting objectives.

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01167
Global Optimization of Design Parameters of Network Arch Bridges

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The paper presents an approach for optimization of network arch bridges. Optimization of the virtual prototype of the network arch bridge has been performed through execution of a simulator,

evaluation of the performance objective, and adjustment of the system parameters in an iterative and directed way, such that an optimal solution is obtained for the simulation as measured by the performance objective. The structural analysis of the virtual prototype of the model is performed by finite element simulation. Evaluation of the performance and response of the bridge with respect to constraints to adjust of the system parameters is performed through a global optimization algorithm, an evolutionary algorithm named EVOP. To interface the simulation with EVOP, a platform is established by Visual C++ in order to transfer the parameters from EVOP to the simulator input file and to extract the response values of interest from the simulator's output file for return to EVOP. The problem is formulated as a mixed integer-discrete nonlinear programming problem. Material cost of superstructure of bridge is the optimum design criteria. The design variables are geometric shape of the arch, rise of the arch cross sectional dimensions of the arch, number of hangers, cross sectional area of prestressed cables of the hangers and hanger arrangement. Constraints derived from the AASHTO and AISC design equations for stress and displacement are considered in the optimum design. The results are compared with the ones optimized by traditional method of design. The new approach using global optimization technique shows significant improvement over the traditional one.

01171
Co2 Optimization Of Reinforced Concrete Cantilever Retaining Walls

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This paper describes a methodology to design reinforced concrete (RC) cantilever retaining walls typically used in road construction based on minimum embedded CO2 emissions. The traditional approach to design does not fully optimize the use of materials. Most designs are based on the prior experience of the engineer, who selects cross-section dimensions and material grades by comparing past designs. However, structural optimization methods are a clear alternative to designs based only on experience. Here, the design involves optimization by a simulated annealing algorithm applied to the embedded CO2 emissions of the RC walls. This approach is possible since data on the environmental impact of most construction materials have been compiled by distinct organizations and, hence, the CO2 impact of a given structure can now be computed. The formulation of the problem includes 17 discrete design variables. All the structural conditions had been imposed using Spanish codes, as well as some habitual recommendations in this type of projects. This algorithm had been applied to different walls heights and landfill conditions, allowing the comparison with those obtained with economical optimization criteria. The method followed in the present study consisted in the development of an evaluation computer module that checks all the relevant limit states. Dimensions, materials and steel reinforcement were taken as variables. Then the embedded CO2 and cost objective functions were calculated. Simulated annealing was then used to search the solution space so as to identify sets of solutions of optimized values for the designer. The methodology described will enable structural engineers to mitigate CO2 emissions in their RC structural designs.

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01175
An improved heuristic for the single machine weighted tardiness scheduling problem with sequence-dependent setups

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In this paper, we consider the single machine scheduling problem with sequence-dependent setup times. The ATCS procedure, proposed by Lee, Bhaskaran and Pinedo, is the best existing dispatching rule for this problem. Dispatching rules and similar efficient heuristics are quite relevant for scheduling problems. Indeed, not only are they often the only approach that can solve large instances within reasonable computation times, but they are also used to provide initial solutions to local search and metaheuristic procedures. We develop a modified version of the ATCS procedure. This version includes modifications to the three stages of the ATCS heuristic: preprocessing, job selection and improvement step. These modifications improve the solution quality of the heuristic, with only minor increments to its computation time.

01179
P-Delta effect in structural optimization

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As known, many scientists faced the problem of the optimal design of elastic plastic structures. Today, many of the fundamental features of the behaviour of an optimal structure under different loadings and limit conditions are sufficiently known. These results together with the technological progress led to the gradual introduction of some aspects of optimal design in international codes. The main goal of such codes is to allow the structural engineers for designing structures more adequate for the loading conditions that they will suffer during their lifetime and, as a consequence, more safe than those given by traditional approaches. The formulation of an optimal design problem, besides the choice of an objective function, substantially requires the definition of appropriate load conditions and the choice of special limiting criteria to impose on the structural behaviour. As known, the intensity of the loads which the structure must suffer is often a difficult task due to their randomness characteristic. Furthermore, the definition of a special load model, together to the assignment of reasonable limit values that the load must not overpass, strongly influence the choice of the limit behaviors that the structure must satisfy which, from the other hand, is related to economic and safety features. So, the optimal design problem might be formulated taking into account static and dynamic loads, imposing constrains identifying with different limit conditions related to as many different load conditions. The formulations proposed in the present paper will make reference to the Italian code, that prescribes that the structural design be effected taking into account different combinations of static and dynamic loadings, suitably amplified by prefixed load multipliers, in correspondence of which the structure must respect the serviceability conditions and not reach the instantaneous collapse. Unfortunately, imposing the ultimate limit load condition it is not possible to have information on the structural behaviour below the instantaneous collapse: actually, before the collapse the structure could be subjected to ratcheting or it can be in the field of the oligocyclic fatigue. Obviously, it could be preferable to dimension a more safe structure that under the action of high intensity loads doesn't exceed the limit of the alternating plasticity. Furthermore, usually the design is performed in the field of small displacements and, as a consequence, the design problem is iteratively solved making reference to the initial structure configuration. On the contrary, in particular in the case of the use of optimization procedure, the structural response can be strongly influenced by some secondary effect as the P-Delta one. In this paper the optimal design problem of

elastic perfectly plastic structures subjected to fixed and dynamic loadings is performed at first imposing an elastic shakedown limit, related to appropriate serviceability conditions, as well as an impending instantaneous collapse limit, related to high intensity loads. Subsequently, the same problem is performed but imposing an elastic shakedown limit and an alternating plasticity limit. Both the cases are also studied taking into account the P-Delta effect.

01180
Design of Radial Turbine Meridional Contours using Particle Swarm Optimization

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In order to achieve high performance, the geometry of radial turbines in turbochargers by ABB Turbo Systems Ltd is being optimized in an iterative way through the use of both in-house and commercial CFD codes. To accommodate the lower turbine mass flow rate requirements of new applications, an existing high-performing turbine stage is modified by trimming the blade geometry to smaller outlet diameters. The new meridional contour of the blade tip must lead to the highest possible turbine stage efficiency. In this paper, an optimization system for the design of such meridional curves is presented, which applies the Particle Swarm algorithm on a radial turbine design parameterized by Bezier curve control points. The objective function is a linear combination of bounded sigmoid functions and favors designs for which the mass flow rate is achieved within a certain tolerance, the maximum Mach number of the relative velocity along the blade tip and an estimate for the energy dissipation are minimized, and various empirical geometrical constraints are fulfilled. Multiple runs, each differently initialized, show that within the time limit of the practically allowed number of design evaluations (15000), the chosen optimization scheme delivers similar variants with a maximum percent error of 0.45% for the parameter positions and a percent error of 0.05% for the mass flow rate. The optimization system is implemented in Python and calls shell scripts to handle pre- and post-processing. In-house FORTRAN software is used for the turbine geometry generation and the flow calculation. On contemporary hardware the quasi-3D flow calculation is fast enough to facilitate serial evaluation of designs at a rate of approximately 900 variants per hour and optimized design can be obtained in a daily workflow. The resulting high performance is verified computationally by fully-3D calculations using the commercial CFD code Numeca FINE/Turbo.

01181
Pareto optimization of a washing machine suspension system

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The washing machine is a well known home appliance which is used at least weekly, in some cases daily, by almost every family. The importance of the task the machine performs combined with the variety of available machines has made competition between manufacturers harder and harder. Among the strongest drive forces in the field of washing machine development are the capacity increase together with reduction of energy consumption. Since the first machines with spin-drying ability the washing machine has had a reputation of being noisy and causing vibrations. A soft suspension improves the vibration isolation and reduces the vibration output, but the severity of the vibration problem can be increased with the bigger tub volume that a machine with higher capacity demands. As the same outer standard dimensions of the machine housing must be preserved, a stiffer

suspension might be needed to keep the tub from hitting the housing at when passing the critical spin speed. Hence there are conflicting criterias to be dealt with. This paper focuses on several aspects of vibration dynamics in washing machines: the capacity maximization through the study of tub movement, the vibration output from the machine to the surroundings, and the "walking" tendency of the system. A computational model of a washing machine with bottom mount suspension has been built in Adams/View from MSC. Software, based on production drawings. Experimental data was used for validation of mathematical and computational models of functional components of the system as well as for the model of the complete washing machine. The models of the functional components have been parameterized and are used for suspension optimization in a computer cluster. Three objective functions related to kinematics and dynamics of washing machines have been defined and a numerical algorithm has been created to solve Pareto optimization problems. The algorithm is a genetic algorithm built around Matlab's subroutine "gamultiobj.m" and executed on an in-house developed computer cluster with possibility of parallel computing of Adams/View models. The results are presented as optimized parameter values of suspension functional components, in this case bushings with respective Pareto fronts. The focus has been set on delivering couplings between parameter values and performance trade-offs in terms of objective functions to facilitate parameter tuning. The obtained optimization results have successively been used in the development of a novel washing machine which will go into production after the summer 2010.

01201
Wing Weight Optimization Model Restrictions Based on Aeroelastic Sensibility Studies

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The wing´s structural design of an aircraft involves the interaction of various technologies. Nowadays an integrated project must result in a compromise solution based on the final objective of the aircraft, i.e. it should optimize performance, aerodynamic characteristics, weight, flexibility, flight qualities or dynamic behavior, among others. Usually the objective of an aircraft in its preliminary design phase is to reduce the weight to the maximum, knowing that it will always increase during the project´s development and will influence many technologies. Therefore a mass optimization model is necessary during the wing´s structural design. In parallel it should be considered that preliminary aeroelastic sensibility studies are important, due to the fact that these have an impact to the wing´s optimal stiffness. The objective of the work presented here is to demonstrate the importance of an integrated study of a mass optimization model including restrictions originated from aeroelastic studies. A method for applying the stiffness restrictions will be presented resulting in a practical example.

01205
A methodology for microchannel heat sink design based on topology optimization

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Microchannel heat sink design consists in an innovative technology which has been studied as alternative to increase cooling efficiency of small electronic devices, such as high-power LEDs

(Light Emitting Diodes), and high-end microprocessors of CPUs. As time passes, these electronic devices become smaller and more powerful, and as consequently, they dissipate a large amount of heat which requires very efficient cooling systems. In order to achieve an optimized heat sink design, its cooling systems must have high efficient fluid flow channels, by minimizing pressure drops along its extension, and providing the largest amount of heat dissipation possible. Microchannels constructed on a conductive body allow us to obtain an efficient heat sink design having better thermal dissipation with small mass and volume, and large convective heat transfer coefficient, and, thus, suitable for cooling compact areas of small electronic devices. Thus, the main objective of this work is the study of a methodology for microchannel heat sink design through the application of the Topology Optimization Method, which allows the distribution of a limited amount of material, inside a given design domain, in order to obtain an optimized system design. This method combines the Finite Element Method (FEM) and Sequential Linear Programming (SLP) to find, systematically, an optimized layout design for microchannels in heat sinks. Essentially, the topology optimization problem applied to channel fluid flow consists of determining which points of a given design domain (small heat sink) should be fluid, and which points should be solid to satisfy a multi-objective function that maximizes the heat dissipation, with minimum pressure drop. In this multi-physics analysis, channel fluid flow operates at low Reynolds number, thus, the Stokes flow equations are considered. Some results are shown to illustrate the methodology, and computational simulations of some optimized channel layouts are employed to validate the implemented topology optimization algorithm.

01207
Topology optimization using a discontinuous Galerkin method

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The use of the so-called material distribution approach to topology optimization gives rise to an optimal control problem in the coefficients of the governing partial differential equation. Bendsoe and Kikuchi provided in 1988 the first numerical results of the method applied to the equations of linear elasticity. Since then, the method has been continuously developed and extended in various ways, and has presently achieved wide adoption in both academia and industry. Traditionally, topology optimization is thought of as a preliminary calculation followed up with some CAD post-processing, possibly further shape optimization, and verification steps before the optimal design is manufactured. Historically, the main reason for employing post-processing is the need of CAD-type design representations for many state-of-the-art manufacturing processes. In MEMS or microfluidic applications, however, manufacturing processes such as micro-etching and micro- and nanolithography may directly handle black-and-white rasterized mask representations of optimal designs, which constitute typical output of the topology optimization method. Thus, to further speed up the product development cycle, one may easily envision omitting the intermediate steps between topology optimization and micro-manufacturing. Before this transition is possible, it is imperative to ensure that numerical solutions of the partial differential equations with discontinuous coefficients with large jumps, typically resulting from the control in the coefficients structure of the topology optimization problems, are accurate enough to directly predict the performance of the manufactured designs. The quest for accuracy implies dealing with high-fidelity FEM simulations and overcoming the loss of solution regularity due to the discontinuous behavior of the PDE coefficients. As a consequence of the latter issue, finite elements based on the lowest

order polynomials are most often utilized for topology optimization, in turn contributing to the low accuracy of the solutions and demanding even higher resolution grids to compensate for that. On the other hand, discontinuous Galerkin methods have been previously successfully utilized for solving PDEs with piece-wise discontinuous coefficients with large jumps, with accuracy independent from the size of the jumps in the coefficients. It has also been demonstrated that linear algebraic systems resulting from DG discretizations of such PDEs may be efficiently solved using iterative solvers with a number of iterations also independent from the size of the jumps. Therefore, in this paper we investigate the use of discontinuous Galerkin methods within the topology optimization framework. Our initial study is focused on the qualitative differences between the conforming (continuous Galerkin) and non-conforming (DG) methods applied to well understood problems in the structural optimization literature. We also study the convergence of DG-based topology optimization methods on refining meshes, which is challenging because most non-conforming error estimates are formulated with respect to mesh-dependent norms.

01208
Topology optimization of devices for wireless energy transfer

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The research presented here consists of a novel extension to the topology optimization method, that allows for systematic design of metalic/dielectric devices for microwave applications. This is accomplished by interpolating Maxwell's equations and an impedance boundary condition between two material phases, i.e. a dielectric and a conductor. The motivation for the work originates from the ever increasing usage of small hand-held, or autonomous, electrical devices such as hearing aids, medical implants and communication devices. These devices all require antennas for communication as well as a power supply, usually a battery. Since more and more functionality is incorporated into these devices, standard antenna designs are becoming less and less usable and the requirements to the batteries are increasing. The power supply issue took a new turn in 2007, where a MIT group lead by Prof. M.Soljacic demonstrated that one could obtain efficient mid-range wireless energy transfer (WiTricity) using magnetically resonant coupled copper coils. Common for the design of antennas and devices for WiTricity are that they consist of an elaborate spatial distribution of a conductor, e.g. copper, in a dielectric background, e.g air. This makes the design of such devices an obvious candidate for the topology optimization method. The design scheme is implemented in a fully parallel C++ FE/topology optimization coed, and is demonstrated through the design of 3D resonators for energy harvesting from radio frequency signals as well as the design of electrically small antenna systems.

01210
Waste Load Allocation Using Non-dominated Archiving Multi-colony Ant Algorithm

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The optimal waste load allocation (WLA) problem, in general, is a mathematical model incorporating a water quality simulator within the framework of multi objective optimization. The goals are defined as to improve the water quality and minimize the total treatment cost of

dischargers. The fraction removal levels of the dischargers are the decision variables. This paper explores the capabilities of Ant Colony algorithms to solve the optimal Waste Load Allocation as a multi-objective optimization problem. We use QUAL2K as a water quality simulator and a powerful ant colony algorithm known as Non-dominated Archiving Multi-colony Ant Algorithm (NA-ACO). The applicability of the model is demonstrated through a hypothetical case example. Results' location near global optima demonstrates the suitable performance of applied algorithm.

01213
Probabilistic Optimization of the Redesign Procedure of an Integrated Thermal Protection System Following Future Tests

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In reliability based design optimization, uncertainties are considered when calculating the reliability of the structure. Uncertainty is often compensated for with safety factors and knockdown factors in the design process. However, after design, it is customary for the component to undergo various uncertainty reduction measures (URMs), such as thermal and structural testing, that leave a design with a higher level of safety than it was designed to have. It would be useful to quantify the effect of these future tests during the design process. It may also be beneficial to design the URMs along with the structure by trading off the cost of more weight against the cost of additional tests, redesign, or improved analytical simulations. In a previous study, we examined the effects of a single future thermal test on an integrated thermal protection system (ITPS). An ITPS protects space vehicles from the severe aerodynamic heating experienced upon atmospheric reentry while also providing some structural load bearing capability, so thermal tests are of great importance. In that study, we developed a methodology to predict the probability of failure based on the possible outcomes of future test through Monte Carlo sampling, while using Bayesian updating to quantify the uncertainty reduction and improved uncertainty estimates after the test. We also examined the effect of the redesign that may follow a test if it showed that the original design is unsafe or overly conservative. We observed that performing a single test can reduce the probability of failure by two orders of magnitude when the test is followed by redesign to restore the original design temperature. We compared this deterministic approach with probabilistic redesign that can trade weight against reliability in the redesign. While that study focused on demonstrating the effect of a future test for given redesign rules, the proposed paper will extend the methodology to including parameters of the future test and redesign process following the test in the original optimization process. There are many tunable parameters in a test and redesign based on the test, such as the post-test target probability of failure, the criteria for undertaking redesign, and the bounds on the change in designed variables. Incorporating these parameters into the optimization carries the obvious benefit of allowing trading off the costs of tests and redesign against the cost of additional weight. However, it will also allow us to consciously design for the probability of failure at the end of the test and redesign process rather than accepting whatever probability comes out of the traditional design process. In this way, we will optimize the design to meet traditional physical constraints, such as maximum temperature, stress, and deflection, while also optimizing its future performance after tests.

01221
Design and optimization of diabatic distillation columns with sequential heat exchangers for single and double feed columns

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A methodology for design and optimization of diabatic distillation columns with sequential heat exchangers (SHC) is presented. The methodology allows determining the optimal heat load distribution, the inlet flows and temperatures, for both, the hot and cold utilities. The distillation process of the ternary system water/ethanol/ethyleneglycol is used as example to ilustrate the methodology and to compare the optimized diabatic and adiabatic processes in terms of second law efficiency. Results show that SHC can reduce the entropy production in 19% and 14% compared to the single and double feed adiabatic distillation columns respectively.

01224
Integrated Design Approach for the Deployment Control of Hoop Truss Deployable Space Antennas

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In this paper, an integrated design approach of kinematic synthesis and servo control in one design stage is presented for the deployment control of hoop truss deployable space antennas. The hoop truss deployable space antenna is a kind of satellite antenna which is widely investigated and applied in most countries because of advantages such as simple configuration, easy folding, good thermal stability and the ease to achieve large calibers. After antennas are transmitted to space and orbited, they are driven to deploy to the preplanned reflector configuration. Servo motor provided the driven force (or input motion) by ropes in trusses to obtain motion characteristics of deployment angular (angular displacement, angular speed, angular acceleration and jerk). In the whole deployment process, the deploying angular speed and acceleration should be smooth and the deploying angular acceleration should not be large for fear of intense impact to antennas, which may lead to vibration or even a damage of antennas. Therefore, the input motion of ropes should be planned to fulfill the requirements above. Traditionally, researchers always simply design the motion as a linear acceleration-uniform speed- deceleration process. They do not consider the non-linear relationship between deploying angular speed and the input motion of ropes which may lead to discontinuity of motion characteristics of antennas and do not discuss how to reduce the peak value of angular acceleration. The first purpose of this paper is to present an approach to reduce the peak angular acceleration with variable input motion of ropes based on B-spline function synthesis, and describe the design variables and constraints for selecting proper motion function. Then, considering the practical implement, the deployment of antennas is achieved by servo motor with control systems, so the design of controller parameters is another important factor which may influence the deployment effect. In the past, the desired input motion and controller are designed respectively. But complicate input motion may increase the difficulty of control and may augment the motor power dissipation. Sometimes the design result for the whole system may be beyond expectations, because the input motion design is not necessarily optimal from the control standpoint. So it is better to consider the two design process together. The second contribution in this paper is to present a design approach to integrate the input

motion and control design simultaneously. The integrated design approach is formed as the non-linear optimization problems. The peak value of angular acceleration and the motor power dissipation are taken as the objective function. The design variables for B-spline function presented above and the controller parameters are united to be the design variables. Finally, SQP optimization approach is applied to obtain the optimal design of controller parameters and the state of input motion. Compared with traditional methods, examples are given to demonstrate the feasibility and validity of this approach.

01229
Accessibility in Layout Optimization

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Component and facility layout plays an important role in the design and usability of many engineering products and systems as mechanical design, facility layout, process plan, management and architecture including ship compartment layout. In real-world applications, all designer's requirements can not be formulated as simple mathematical expressions. The accessibility to components is one of these requirements which can not easily be taken into account in the layout optimization process. Firstly, this accessibility deals with the required vacant space located around the component and used to guarantee the correct mechanism of the component. This space is described, in this paper, as a virtual component with particular attributes. Moreover, the accessibility requirement means that each component has to be attainable from the container's entry. In order to consider it in the layout optimization process, designers usually use their expertise to modify the layout problem description and satisfy a priori all the accessibility specifications. This paper proposes an alternative approach based on the integration of the accessibility to components in the layout problem formulation. The accessibility is considered as a design constraint or an objective of the optimization problem. This method is applied on a two dimensional real-world problem which deals with the layout optimization of components inside a shelter. Some research leads are also described in order to use this approach for the three dimensional layout problems.

01230
Parallel Population Evolutionary Algorithms for the Time-Cost Trade-Off Relation Project Scheduling Problem

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This research presents three approaches to solve multi-mode project scheduling problems with the objective of minimizing both project makespan and total cost. Total cost includes (1) total renewable resource investment for project executions; (2) activity mode execution cost including non-renewable resource consumption. The first approach applies a dual-population memetic algorithm (DPMA) within a double-loop, which consists of project deadline and renewable resource availability level. The second approach employs a double branch and bound method to find Pareto optimal solutions for cost and makespan. The third approach is a horizon varying

two-phase method, which employs the minimization of total cost on a one-by-one basis for the deadlines within a pre-specified interval. Phase 1 of this approach uses a truncated branch and bound algorithm or shortest path method to construct an initial dual-population. Phase 2 applies a modified DPMA for evolution and further refinement. A comparative study is conducted via four benchmark instances drawn from PSPLIB. The experimental results indicate that the exact solution method is useful for small size problems with small resource factor values of both renewable and non-renewable types. The third approach is capable of producing near Pareto optimal solutions in a short time, and is not much affected by the resource factors.

01232
Topology optimization involving incompressible materials using P1-nonconforming elements

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A kind of nonconforming finite element with the potential to reduce computational cost of the whole topology optimization process is introduced. The reduction is obtained due to its linear shape functions which can be defined based on its vertices. This element is called the P1-nonconforming finite element (P1NC). Topology optimization problems involving incompressible materials are solved to demonstrate the unique characteristics and applicability of P1NC. Locking-free property inherent to nonconforming finite elements enables the use of P1NC with pure displacement formulation free from the numerical instability associated with material incompressibility. Mean compliance minimization problems for structures with incompressible materials and channel design problems for Stokes flow are solved based on finite element analysis by using the proposed P1NC. Implementation of the finite element analysis using this element is straightforward since it is not much different from that for bilinear conforming elements. Results show that P1NC can efficiently reduce numerical cost for topology optimization method involving incompressible materials especially in large-sized problems such as three-dimensional problems.

01238
An efficient iterative scheme for the resolution of RBDO problems

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Design Optimization is a frequent approach in engineering. However, various random factors, such as lack of precision of an industrial process or human errors may introduce perturbations in models provided by designers. When a purely deterministic optimization procedure has been

used, the consequences of variability and uncertainty can turn out to be considerable. A simple way to get more robust design consists in applying safety factors, provided by experiments, to correct the values of design parameters. Nevertheless, this approach leads rarely to the required reliability level. In best cases, reliability is higher than the desired one and structure is not optimal. In worst situations, probability failure is underestimated. In order to get optimal designs verifying a predetermined reliability level, Reliability-Based Design Optimization (RBDO) has been introduced. This approach considers dimensions, material properties, ... as random variables and takes into account optimization inequality constraints into a probabilistic way. The mean values of random parameters can be treated as conception parameters modified all along optimization procedure in order to suit both efficiency and reliability requirements. In RBDO, the state of a system if often modelled by one or several limit state equations depending of deterministic and random parameters. The system is said to be safe for a given set of parameters if the whole corresponding equations are non-negative and to be defective otherwise. As parameters may be random, optimization process is led under the restrictions that the probability of failure related to each equation is lower than a required level. As evaluation of probability of failure is often time-consuming, several equivalent alternatives, such as Reliability Index Approach (RIA) or Performance Measure Approach (PMA), have been set up in order to approximate this probability by using approximations such as FORM and SORM. These ideas have led to several efficient methods which can be found in litterature. However, computational stress remains important and additional efforts have to be made to improve their performance. We propose a new approached method based on the RIA. It consists in optimizing a structure into a deterministic way and modifying the deterministic design in order to ensure a predetermined reliability level. This second step is achieved by using an original iterative scheme : at each step, limit state equations are approximated around the Most Probable Failure Point and a new set of parameters is chosen to meet reliability requirements for approximated functions. The method may be considered from the point of view of safety factors as an iterative calculation of exact safety factors. Several kinds of approximation have been tried and compared in order to identify the most effective strategy. The complete decoupling structural and reliability turns out to be really effective in order to improve computational performance. On top of that, although this method doesn't ensure that computed point is optimal from economical point of view, numerical experiments has shown that results are rather good. In order to illustrate the efficiency of the algorithm, several original numerical examples applied to mechanics will be exhibited.

01240
Aerodynamic shape optimization using adaptive remeshing

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Adaptive mesh refinement is one of the most important tools in Computational Fluid Dynamics (CFD) for solving complex engineering design problems. The paper investigates two practical transonic aerofoil design optimization problems using a genetic algorithm coupled with an Euler aerodynamic analysis tool. The first problem consists in the minimization of transonic drag whereas the second is a reconstruction transonic problem solved by minimizing the pressure error.

In both cases, the solutions obtained with and without adaptive mesh refinement are compared. Numerical results obtained by both drag minimization and reconstruction design clearly show that the use of adaptive mesh refinement reduces the computational cost and also produces a better solution.

01244
Optimum synthesis of mechanisms with apparent stiffness restrictions

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This paper deals with the optimum synthesis of mechanisms including apparent stiffness restrictions. These kind of restrictions are of interest in some problems such as that of the suspension of vehicles where a progressive or regressive effect is to be achieved. Provided that a mechanism is composed of non-deformable links and a spring, it can be demonstrated (see, for example, [1]) that the relationship among the apparent stiffness of a mechanism in a point and in a direction ant the stiffness of the spring is equal to the proportion of the velocity in the mentioned point and direction and the velocity of extension/compression of the spring to the power of two. In order to solve this problem, one can use the formulation developed in [2], and afterwards expanded in [3], among others. The aforementioned formulation was developed to perform synthesis of mechanisms with position restrictions, while the present problem includes velocity restrictions. In order to solve this problem, it is necessary to include them in the evaluation function. The former function computes the minimum distance achievable for a point to reach a position, so now it is necessary to include the computation of the velocity field of the mechanism. This is performed with the following approach: for each of the precision points, the position problem is solved with the former formulation. This problem itself is a nonlinear optimization solved via Newton-Raphson second order optimization. Afterwards, the velocity field of the mechanism is obtained, and scaled to the desired input value. This is performed via a triangular decomposition suitable for underdetermined problems. The full error function is composed as the sum of the quadratic differences among the velocity relations desired and obtained. The optimization of this error function is performed via a combined Genetic Algorithm - Newton Raphson approach. The Genetic Algorithm provides good initial guesses that are afterwards improved with an approximated Newton-Raphson method. The introduction of velocity conditions as objectives for the analysis is not only useful for optimizing apparent stiffness, but is also applicable for kinematic synthesis, where the tangent to the path described by the mechanism is also to be achieved. The obtained results show the procedure to be quite general and stable.

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01251
Comparison of volume constraint and mass constraint in structural topology optimization with multiphase materials

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Instead of adopting the common idea of using volume constraint in topology optimization, this work is focused on the structural topology optimization of multiphase materials with mass constraint. Related optimization models involving mass constraint and interpolation model are proposed. GSIMP (generalized Solid Isotropic Material with Penalization) and UIM (Uniform Interpolation Model) interpolation schemes are discussed and compared. The former is found to introduce the nonlinearity into the mass constraint and brings numerical difficulty to search the global optimum of the optimization problem. The adopted UIM scheme makes it possible to have a linear expression of mass constraint with separable design variables. This favors very much the mathematical programming approaches, especially the convex programming methods. Numerical examples show that the presented scheme is reliable and efficient to deal with the topology design problems of multiple materials with mass constraint. The latter is proved to be more significant and practically meaningful than the volume constraint in structural topology optimization of multiphase materials.

01252
Multidisciplinary Design Optimisation of a Morphing Wingtip

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Over the last few years, better knowledge of aerodynamics and structures and the permanent need to improve the performance and efficiency of aircraft has led to the generalised adoption of wingtip devices. The requirements faced by wingtip devices throughout the various flight conditions are, however, different. A static wingtip device (as is the case with existing designs) must be a compromise of these various conflicting requirements, resulting in less than optimal effectiveness in each flight condition. A morphing device, on the other hand, can adapt to the optimum configuration for each flight condition, leading to improved effectiveness. The concept now being studied consists in a moving wingtip device, able to rotate about two different axes: vertical axis (toe angle) and aircraft's longitudinal axes (cant angle). These can be controlled independently by servo-actuators. The wingtip behaviour is inherently multidisciplinary (with coupled structural and aerodynamic effects), requiring multidisciplinary design optimisation (MDO) in order to determine the ideal wingtip configuration for each case: for each flight condition, an MDO procedure is carried out in order to determine the optimum wingtip geometry (design variables) such that a performance metric (such as the lift, drag or lift-to-drag ratio, depending on the flight condition) is maximised or minimised (objective), subject to certain constraints, such as the mechanical stress or displacement (state variables). The

multidisciplinary analysis procedure uses a multifield solver based on ANSYS (for the structural field) and CFX (for the computational fluid dynamics). A purpose-built fully parametric routine generates the geometry and mesh and applies the boundary conditions and loads, launches the solvers and performs all the required post-processing (retrieving the quantities of interest and computing the desired variables). This allows an entirely automated multidisciplinary analysis where the optimiser controls all the parameters. It also allows for greater flexibility in the choice of the optimiser logic (since the optimisation algorithm is separated from the analysis procedure and can either be one of ANSYS' built-in methods or another method implemented in any programming language). Preliminary results are presented along with the resulting geometries. The feasibility of such a morphing wingtip is discussed. The performance metrics of the morphing wingtip are compared to those of a fixed wingtip to quantify the gain associated with the use of the morphing concept. The next step will be a cost-benefit analysis of the morphing wingtip device taking into account this gain and the incurred penalties (e.g. weight; complexity; actuation energy) in order to assess the interest of the proposed concept.

01257
Numerical and shape optimization of stress relief groove in flat ends of pressure vessels

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Flat ends of pressure chambers are well known alternative for dished ends, particularly for pipes with smaller diameters. The main disadvantage of such solution is the presence of stress concentration observed in the junction area of the pipe and the end plate. In order to reduce the stress level in this region, the stress relief groove was introduced. The European codes for calculations of pressure vessels suggest the use of the circular shape of the groove. Calculations of its parameters like radii – rik - and the minimum thickness of the end plate – eh1 - gives certain limits for both parameters. These limits are mainly influenced by the internal pressure, the admissible stress for material chosen for the pipe and the flat end and by the inner diameter of the pipe. The numerical test performed for several admissible combinations of design variables – groove radii and minimum plate thickness - have shown the existence of zones of plastic strains, which appears in the stress relief groove in the area close to the connection with cylindrical pipe. For the established material combination introduced for the pipe and the flat end the observed maximum value of the equivalent strains strongly depended on the choice of groove parameters. Numerically obtained values for the maximum equivalent plastic strain vary in a meaning way. This observation encouraged the Authors to establish the optimal set of radii of the groove and the minimum end plate thickness. In the performed investigation the minimization of the maximum equivalent plastic strain was chosen as the objective function. This parametric optimization was made with the help of the ANSYS finite element code and the Authors optimization subroutine prepared in APDL language for optimization part. The described above procedure was the first step of the analysis, which helped to find the solution with the minimum value for the maximum equivalent plastic strain within the range suggested by the code rules given in EN-12952. In the next, final step the Authors focused on the modification of the shape of the groove. The proposed shape variation based on the use of splines functions modifying groove shape defined by the optimal parameters obtained in the first study. Again the reduction of maximum equivalent plastic strain was observed for the new optimal shape. This means that the circular shape of the groove, easy for manufacturing, is not optimal in the strength sense. The above study was both performed for the constant internal pressure and for the cyclic change of the loading internal pressure.

01264
Analysis of Reinforced concrete structures by using the Capacity Spectrum Method

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The importance given to predict the structural behaviour of different constructions in a seismic scenario is a theme of clear interest at the moment. In this sense it is clear that the study of how the reinforced concrete's (RC) structures resist earthquakes is a predominant task if we take into account that these are the type of structures that predominate in all new constructions. In this work we study the structural behaviour of different RC structures by using a nonlinear analysis based on the Capacity Spectrum Method (CSM) which is a performance-based seismic analysis technique. Basically the method consists in comparing the capacity of the structure with the demands on the structure. The capacity of the different structures analyzed will be calculated by using the SAP 2000 software, allowing us to obtain the so called pushover curve. In the case of the demand of the structure, this will be calculated in the form of a curve called response spectra, from experimental data obtained in Alicante (Spain). This process will permit to have a better comprehension of the structural behavior of RC buildings in different seismic scenarios.

01266
Interfacing ANSYS with Global Optimization Technique

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The paper describes interfacing of a global optimization technique, evolutionary algorithm named EVOP with finite element software, ANSYS. A program written in Visual C++ has been developed which works as a platform for data structure definition and to transfer the parameters from EVOP to the simulator ANSYS input file and to extract the response values of interest from the simulator's output file for return to EVOP. The program uses batch mode execution of ANSYS in a parametric fashion. ANSYS writes its response in a separate file for further use of EVOP and it sends updated design variable to ANSYS and new simulation goes on progressively to obtain the optimized solution. Some design examples have been optimized using the program which shows the efficiency of the algorithm.

01267
A language to specify the partitioning structure of decomposed design optimization problems

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Decomposition-based design optimization implies the partitioning of the system into a number of subproblems, and subsequently the coordination of the optimization for the decomposed system. Several methods for coordination, as well as generic frameworks for coordination method implementation have been proposed. However, intuitive approaches to specify the structure of the decomposed problem are rare. Specification of the problem structure is typically based on matrix or graph representations of the entire system. For larger systems, these representations become intractable due to the large number of design variables and functions. A different method is presented by Alexandrov and Lewis (2004a,2004b) who developed reconfigurable multidisciplinary analysis (REMS) which is a linguistic approach to the problem description and formulation. REMS starts from the definition of individual subproblems that are subsequently automatically assembled into the complete system description. We present an alternative language for the specification of problem partitioning structures in decomposition-based system optimization. The language we propose follows a similar process as REMS, but does not automate the assembly process. Instead, the language provides for a pure local definition of variables and functions in the various disciplines. The language contains additional elements to specify the assembly of the subproblem definitions into subsystems and systems. The assembly may be divided into multiple levels, where each level is associated to a level of abstraction in the system. Hence, for the specification of the problem structure one does not have to oversee the entire system. The local definitions and assembly process provides the designer control over the complexity and tractabiltity of the various interactions between disciplines. We present two examples from MDO to show that the flexibility provided by the proposed language allows designers to reconfigure problem decompositions with great ease. A compiler has been developed that generates an interchange file of the partitioning structure in INI format. From the interchange file for instance the matrix representation or input files for a coordination framework may be automatically generated.

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01269
Optimization of structural elements with cracks

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Problems of optimization of elastic beams, plates and circular cylindrical shells of piece wise constant thickness are studied. Various types of loading will be considered but the main attention will be paid to the loss of stability of beams , plates and shells under compressive loads. The beams under consideration have stepped rectangular

cross-sections whereas columns of circular cross-section are studied as well. It is assumed that stable cracks are located at the re-entrant corners of steps.In the case of cylindrical shells the attention will be focused on the investigation of the influence of the frequency of free vibrations on the crack parameters. It is assumed that the beams and plate trips under consideration can be treated as non-homogeneous plates consisting of a number of layers made of fiber reinforced composite materials. In a lamina fibers are embedded in the matrix material unidirectionally. The matrix material and fibers are assumed to be linear elastic. Higher order classical laminated plate theories are used in order to prescribe the loss of stability of the structure. The influence of a crack on the loss of stability of the column is prescribed by means of local flexibility and the function of compliance which is coupled with the stress intensity factor K known from the linear elastic fracture mechanics. The local flexibility is defined by means of a six times six matrix. However, it is shown that in the case of buckling of a beam or a column there exists an element of the matrix whose influence on the buckling behavior is dominating in comparison to that of other elements. Similar situation occurs in the case of free vibrations of elastic cylindrical shells made of laminated composite materials. An optimization procedure is developed for optimization of beams, columns and plates of piece wise constant thickness for various combinations of matrixes and fibers. Beams with different end conditions are considered. The influence of crack dimensions and crack locations on the critical values of compressive loads is evaluated numerically. Numerical calculations have been carried out for columns with different numbers of steps and different crack lengths.

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01273
A Distributed Agent-based Approach for Robust Optimization

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Structural design and optimization in engineering more and more address so-called non-standard optimization problems (NSP). The category of problems associated with NSP is characterized by complex topology conditions of the optimization space (nonlinearity, multimodality, discontinuity etc.). By that, NSP can only be solved by means of computer simulations. Hereby, the corresponding numerical approaches applied often tend to be noisy. Examples for NSP are problems used in robust optimization, where the design and solution have to be robust with respect to e.g. implementation errors, production tolerances, uncertain environment conditions etc. However, a generally applicable strategy for solving given problem types equally efficiently is not available. In this context, the paradigm of multi-agent systems (MAS) provides the required computational and theoretical basis and workbench to solve NSPs appropriately. MAS contains considerable portions of autonomous behaviour that can be best formalized and automatized. What is lacking, despite the many suggestions for methods in distributed and adaptive optimization, is a holistic approach for simulation-based optimization by using AI-technologies -- in particular MAS and expert or knowledge-based systems -- along with a computer-aided simulation and experimentation environment for optimization. In this paper, therefore, a distributed agent-based optimization approach for solving NSPs is introduced. The approach elaborated consists of a network of cooperating but also competing strategy agents that wrap various optimization methods (e.g. SQP, DE, ES, PSO etc.) of different search characteristics. Amongst others, the strategy agents contain an expert system modeling their specific behaviour in an optimization environment by means of rules

and facts on a highly abstract level. In order to manage the complexity of solving NSPs using MAS efficiently, a simulation and experimentation platform has been developed. Serving as a computational steering tool, it applies MAS technology as well as a network of various optimization methods. As a consequence, an elegant interactive steering, tailor-made modeling and powerful visualizing of structural optimization processes can be carried out. To demonstrate the far reaching applicability of the proposal approach, numerical examples are discussed, involving function and robust optimization problems.

01274
Comparative Analysis of Commercial Aircraft Trajectory Performance

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A hybrid optimal control approach to commercial aircraft trajectory optimization is proposed and tested comparing its results with short and medium-range typical flights. Given the sequence of phases and flight modes conforming the vertical flight profile of a commercial aircraft, the initial and final states and a set of path constraints, we solve the problem of finding control inputs, switching times between flight modes and the corresponding trajectory of the aircraft that minimizes fuel consumption. Three different profiles are defined for both ranges: typical nowadays flown profiles; free-flight profiles, used as optimal benchmark performance; and optimized procedure profiles. Performances, procedures and consumptions are analyzed. Results show that current flight profiles efficiency could be substantially improved seeking a new Air Trafic Management paradigm.

01275
Structure-preserving differentiation of functional networks in design optimization and optimal control

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Model-based design of complete technical processes or systems is increasingly more often realized by modular development approaches like MATLAB and Simulink. They enable engineering teams from various disciplines easily to cooperate. Subsystems are encapsulated into blocks of information, total models are formed by nesting and linking single modules or blocks. A profound knowledge of the details of the respective subsystem is no longer necessary for system design and integration, a new level of abstraction is introduced. For multidisciplinary design optimization and optimal system control - both in a mathematically strict sense - the knowledge of the model system alone is not sufficient. The need of sensitivity information makes it necessary to compute first and second order derivatives of the model equations with respect to design functions and parameters, the optimal control of those systems subject to multiple constraints requires the calculation of even higher order derivatives. The analytical differentiation of complex models is extremely time consuming and error-prone. Numerical differentiation suffers from inaccuracy and high computational costs. Algorithmic or automatic differentiation techniques reduce the non-computational effort. Basically, these techniques break down every function to elementary mathematical operations and

apply the chain rule for the derivative of the composite of two functions to the sequence of those operations. Unfortunately, by this approach the original structure of the model is destroyed. This significantly reduces the efficiency of these approaches in case of higher derivatives. In this paper, a modified approach is presented combining analytical and algorithmic differentiation while preserving the modular structure of the model. The analytical derivatives of a single (sub-)module are typically available with a tolerable effort and can be reused for different applications. The information of a single module is forwarded via so-called local transfer matrices, which encode the linking structure between two modules. It is proven that the model's global topology can be computed from this local information: One can determine those components of the model input, which affect a particular output component, if only the local dependencies are known. The proposed algorithm works especially well for hierarchical models with a nested module structure, i.e. a module may contain submodules, which again contain submodules, and so on. Only the derivatives of the lowest level have to be available. The sensitivity information is automatically propagated through the different levels. Two algorithmic implementations of this approach have been realized and are presented: An elegant recursion for each (sub)module and a more efficient forward propagation of efficiently calculated intermediate values. As an industrial example for such a modular modelling and control approach, contributions to aerobatic airplanes in the context of the Red Bull AirRaces are presented. The full 6 DoF airplane model is split into dynamic layers (position, translation, attitude and rotation). These are hierarchically formulated as sequences of blocks, each representing a distinct effect (e.g. deflection of a rudder) or quantity (e.g. aerodynamic force). Derivatives of orders up to three are calculated for optimization and optimal control purposes.

01277
Piezoelectric Energy Harvesting System Optimization

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The searching for alternative energy sources has been increasing in order to avoid environmental damages. It has been happening for different reasons, where the most important one is the necessity of developing new clean and renewable energy sources as the classical ones have exhaustive been using nowadays. This work is part of an area denominated Power or Energy Harvesting and it is based on transducers that are used to provide electrical energy as output when different energy input is applied on. In this paper, mechanical vibrations have been converted in electrical energy. In this case, the three most used transducers are: magnetic, electrostatic and piezoelectric. However, the mechanical system is strongly influenced when an electrical circuit is coupled to it. This paper works with a model on Piezoelectric energy harvesting which describes all interaction between the mechanical and electrical system. This model is based on Impedance Methodology and it was also used for finding out the system optimal behavior. The structure modeled was a piezobeam with free-sliding boundary conditions.

01279
Reliability Based Design Optimization Methodology for the Conceptual Design of Roof Trusses

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Due to the reliance on code-based design practices, Reliability Based Design Optimization (RBDO) methods have only recently gained popularity among design engineers. Although the potential benefits include improved performance and lighter weight, RBDO methods are typically applied to optimize

predefined geometries and topologies in later design stages, which results in sub-optimal solutions. This paper discusses a hybrid methodology for incorporating reliability analysis earlier in the design process during conceptual design. Supporting RBDO during conceptual design, however, requires a hybrid methodology to probabilistically assess the performance of truss designs having varying topology, geometry, and member sizes within a single trial. This research effort focuses on integrating RBDO capabilities into an implicit redundant representation multi-objective genetic algorithm (IRR MOGA) design program. The hybrid method calculates a reliability index based on the controlling limit state for the truss designs evolved by the IRR MOGA search process. The unstructured IRR MOGA problem domain allows for topological forms to change dynamically during the search process without using heuristics or pre-defined topologies. The proposed hybrid method integrates OpenSees First Order Reliability Analysis (FORM) modules into the IRR MOGA design program. Since the conceptual truss designs were statically determinate, exceeding a single limit state indicated failure. Limit states were defined based on the maximum stress limits of each member (buckling was considered for compression members) and based on maximum deflection limits for the top truss nodes. The limit state corresponding to the smallest reliability index was the controlling limit state. The modulus of elasticity, all member areas, all top node locations, and all top node loadings were specified using a mean and standard deviation distribution as uncertain. FORM analysis determined the reliability index through iteration after the original space was converted into a reduced space. Therefore, analysis provided a conservative value of the failure probability which was used during the IRR MOGA fitness evaluation along with truss weight. Violations of maximum and minimum member length constraints were imposed as penalties on overall fitness. The quality of designs obtained using the proposed hybrid RBDO method were evaluated by comparing the truss designs evolved with truss designs that were optimized using local perturbation RBDO methods. The hybrid RBDO method results provided a Pareto optimal set of non-dominated truss designs that had different topologies, geometries, and member sizes, which reflected the tradeoffs occurring in trying to optimize the weight and reliability design objectives. The solution provided was not a single truss design. Instead a Pareto-optimal set of truss designs was provided to design engineers. Integrating RBDO methods into the conceptual design process resulted in the design of high-performing, low-weight trusses.

01283
Optimized Systems Engineering Approach for the Design of Large Array Infrared Photodetectors

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Quantum Well Infrared Photodectors (QWIPs) are no longer only subjects of academic research but are valid candidates for practical InfraRed (IR) imaging applications satisfying the needs of agencies such as the US DoD, NASA, NRO etc. For large scale IR imaging systems, QWIPs are integrated into large format focal plane arrays. For the design of large scale QWIP FPAs, many system parameters must be considered in addition to the bandgap engineering aspects of the quantum heterostructure comprising the fundamental QWIP unit. In this work, we present an engineering optimization technique for robust and optimized design of QWIP-based large format FPA for IR detector platforms. We integrate systems engineering approach into the design optimization and identify the main subsystems in the design flow of a QWIP based IR detector system. We further illustrate how the performance parameters associated with these subsystems can be incorporated into the heterostructure design via appropriate cost functions that are optimized in an iterative fashion. Quantum heterostructures are tailor-made semiconductors that are grown by Molecular Beam Epitaxy (MBE) or Metal Organic Chemical Vapor Deposition (MOCVD) and consist of alternating layers of semiconductor materials of similar

lattice constants. The band structure and material parameters (potential barrier, layer thickness, etc.) of the heterostructure can be controlled over a relatively wide range. This flexibility has advanced the idea of "custom-designed" heterostructures for IR detection. QWIPs are based on optical transitions within a single energy band (intersubband transitions) and are therefore independent of the bandgap of the detecting material. The design of QWIP devices is a complex and involved process requiring knowledge of the fundamental device physics based on quantum confinement of charge carriers, carrier transport/scattering mechanisms within the device, and optical coupling mechanisms to the monolithically integrated QWs. Not surprisingly, most research efforts in QWIPs have been focused on the fundamentals of device physics with insufficient attention to the overall system performance optimization aspect. As the QWIP technology becomes more mature, it becomes crucial to redirect attention to the design optimization of QWIP-based IR imaging systems. In this paper, we will present an example for QWIP-based IR FPA performance optimization where we integrate optimization techniques such as simulated annealing or genetic algorithm with quantum heterostructure design methodology based on the solution of time-independent Schrödinger's equation using the single band effective mass approximation. We further integrate FPA system parameters (such as FPA pixel size, operating temperature, choice of material system, etc.) into our design optimization methodology. We will present the performance of a non-optimized example design of QWIP-based large format FPA in comparison with an optimized design. We will compare the overall system cost, performance (photo-responsivity, dark current, thermal response, etc.) and lifespan for the optimized and non-optimized FPA designs.

01286
Combining Shape and Structural Optimization for the Design of Morphing Airfoils

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The great interest in developing morphing airfoils is mainly based on their capability to adapt their shape to optimize some specific aircraft performance indices during the mission. Nevertheless, the design of these kind of devices requires the availability of ad-hoc developed procedures able to tackle the conflicting requirements such as the high deformability requested to change the airfoil shape coupled to the load carrying capability. Hence, the design of the external aerodynamic shape and the whole airfoil structure should be simultaneously led. This work proposes a compact approach to combine an aero-structural shape optimization, able to determine the most efficient aerodynamic shape which at the same time minimize the requested energy to deform the airfoil skins, with a topology and sizing structural optimization. The link is a compact parametric technique, based on a Class/Shape function transformation method, here extended to represent the geometry changes of both morphing airfoil leading and trailing edge. The definition of the basic and deformed airfoil shapes is strongly influenced by the presence of the airfoil skin, which plays a determinant role in the design of any morphing technique. The compact method presented in this work allows to compute both axial and bending stresses in the skin and to generate the airfoil shape changes for the aerodynamic analysis. The best internal structural configuration is obtained by synthesizing a single-piece flexible structure able to adapt itself for matching the optimal shape derived from the aero-structural shape optimization, with the most efficient use of embedded actuators. In many cases this requires to invent new structural concepts which are strictly related to the currently available technologies. Recent developments in actuation and sensing technology have restored energy in the research of adaptive structures. Smart material based technology may be applicable to the design of morphing structures, thus reducing the complexity due

to mechanical hinges and numerous moving parts by means of embedded and distributed actuation devices. Many studies reported in literature are also based on skin made of special active materials whose mechanical characteristics can be tuned, for example, by means of electrical inputs. In this work an alternative approach to obtain the required shape change by efficiently distributing the elastic energy into the optimized structure by means of few actuators is proposed. This approach is based on the distributed compliance concept instead of the distributed actuation one and leads to the compliant structures, that is both flexible and bearing bio-inspired structures. By spreading elastic strain over the structure, all its elements share the input load and produce large displacements. In this way, the design of this kind of structures depends on the choice of the actuation device and produces a structural configuration suitable to host it. The optimal compliant structure is synthesized using an ad hoc developed topology and sizing optimization procedure, including an in-house non-linear FEA solver using Finite Volume Beam elements. This is a specific design tool that can assist engineers in the design of the optimal internal structure.

01287
Optimization of cooling appliance control parameters

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This paper presents the optimization process and its simulation tool, for the optimization of the control parameters in the cooling appliance. The simulation tool simulates temperatures inside the cooling appliance at different modes of regulation. In our appliance some of the cabinets have a common cooling system, which means that the regulation of the cabinets is interdependent. The result of simulation consists of data, which is used during the optimization process to evaluate each found parameter setting. The optimizer uses an evolutionary heuristic search approach to find the optimal set of control parameters iteratively over evolving generations. The approach is based on probabilistic methods to decide on changes and the direction of search. The aim was to use a parameter-less algorithm that is able to find optimal, or at least very good solutions, relatively quick, and without the need for an algorithm parameter setting specialist. The implemented evolutionary algorithm, with the origins in genetic algorithm, does not need any predefined control parameters values. We were able to find a set of control parameters of a cooling appliance, that give an optimal performance with the lowest possible energy consumption. Additionally, we found out that the results of the optimization, resulting in one prototype, do not apply to another. Namely, change of the characteristics of the appliance and its thermal responses, also change the optimal settings. Nevertheless, if we find out that some components bring improvement to the appliance, they are further optimized; but those without influence to the appliance performance are omitted, which leads to cost reduction. This is some kind of the evolutionary selection of the reliable and robust components.

01288
Discretization by finite elements for the control of a beam rotating

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It has been previously established a model for a vibration system of rotating flexible beam and two masses suspended as control elements. The effect of the proposed vibration control is the modification of the inertia of the system by moving the sliding masses, making it possible to obtain the optimal

control rule. Some results have been presented for the optimal control of vibration of the tip of the beam during that rotation with this proposal. The dynamic model is derived from the modes of vibration of the beam itself holding the two sliding masses. A sub structuring technique for establishing the model for each part, and then close the system. In the simulation of the optimal control problem, the dynamic model, the main difficulty is the inclusion of more modes of vibration. This paper proposes a new way of discretization based on finite elements for the rotation of the flexible beam holding the two sliding masses. The idea is to get a more elaborate model for comparison with the initial results already described, since the finite element model should contain the result of the overlap of the masses. So during the rotation of the beam the masses will be positioned in different elements as the movement. The position of the sliding masses can best be described as moving cargo on specific elements of the discretization. From the dynamic model obtained by finite element discretization is intended to simulate the optimal control problem for the analysis of initial results and comparison with the results of the previous proposal

01294
Surrogate based bilevl optimization for laminated composite stiffened panels

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We present here an original optimization method for laminated composite material design and its application to the case of an aeronautical stiffened panel. Part of the difficulty with such optimization problems is that design variables are both continuous (geometric dimensions of skins and stringers) and discrete (prescribed fiber orientation angles) and composite specific manufacturing and design constraints (symmetric, balanced lay up and continuity between adjacent stacking sequences for the blending problem) are hard to handle within an optimization process. Such problems are part of Mixed Integer Non Linear Programming. The method we present here tries to apply classical gradient-based optimization techniques to this MINLP problem by using a classical representation of the stacking sequence known as the lamination parameters. We are interested here in aeronautic applications and more specifically in laminated composite fuselage optimization. We are therefore concerned with large part of the fuselage made of several repetitive super-stringers (conceptual element made of a stringer and the two adjacent half-panels). In this work, we carry out a bilevel optimization strategy based on the classical lamination parameters and surrogate models of critical buckling loads built over the lamination parameters. Benefits of using lamination parameters is that it does not change the number of design variables no matter how many plies there are. At the top level, the design variables are the geometric dimensions and the lamination parameters. The overall objective is to minimize the weight under buckling constraints, strain constraints and blending constraints. At this stage of our optimization method, the buckling constraints are approximated through a surrogate model over the thickness and the lamination parameters built over a learning basis of feasible stacking sequences. To build such a surrogate we had to handle the discreteness of some of the variables. We therefore carried out a method to build a reasonably accurate surrogate model using a mixture of experts centered at

the different authorized values for the thickness by slightly perturbating the set of discrete values. The blending constraints are seen as the distance between adjacent lamination parameters. These specific blending constraints are designed in such a way that the overall problem has an additively separable formulation, making the problem perfectly suited for decomposition-aggregation algorithms (prices decomposition, interaction prediction principle). At the local level, we find the closest stacking sequences to the optimal lamination parameters found at the previous stage with respect to blending constraints and buckling : only buckling is considered at the lower level because it is the criterion sensitive to stacking sequence.

01296
Sizing optimization of collapse-resistant frames

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Structural design optimization has progressed over the last decades to a valuable computational tool, which assists the engineer in making best use of structural material according to pre-specified criteria and constraints. Typically, the aim is to minimize the cost (or weight/material volume) of the structure under consideration subject to certain behavioral constraints (mainly on member stresses and nodal displacements or inter-storey drifts) as imposed by design codes. In addition to design code provisions, design requirements on safety against local failure are increasingly considered in recent years. Local failure may trigger progressive collapse of a structure, therefore insensitivity to local failure is an important property of the structure, which needs to be considered during the design process. The present work presents a sizing optimization procedure for collapse-resistant elastoplastic frames. Evolutionary optimization algorithms are employed to minimize structural cost subject to progressive collapse resistance constraints. A method based on the notional removal of key-elements of a frame is used to direct the optimizer towards identifying a structural design, which provides adequate alternate load paths when local failure occurs in the structure. The numerical examples tested demonstrate the effectiveness of the proposed optimization approach. Of particular importance is also the investigation of the increase in the minimum cost achieved (i.e. the need for extra weight/material volume) induced by the additional constraints on progressive collapse resistance.

01297
CADO: a Computer Aided Design and Optimization Tool for Turbomachinery Applications

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This paper presents an optimization tool used for the design of turbomachinery components. It is based on a metamodel assisted evolutionary approach combined with a Computer Aided Design (CAD) library for the shape generation. The analysis of the components performance is performed by Computational Solid Mechanics (CSM) and Computational Fluid Dynamics (CFD). Typical optimization problems include the design of axial and radial compressors/turbines. One important aspect in shape optimization of turbomachinery components is their parameterization. A detailed description of the parameterization and choice of parameters is discussed. A robust geometry generation tool is presented with special care for detailed geometrical features such as fillet radii. The success of automated designs depends as well on the robustness of the grid generation process, which is also discussed. Several examples illustrate the capabilities of the presented approach. The use of optimization techniques allows to speed up the design process and introduces innovative designs.

01300
Optimized vertical configurations of seismic isolation in multi-storey buildings

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The response of multi-storey structures can be controlled under earthquake actions by installing seismic isolators at various storey-levels. By vertically distributing isolation devices at various elevations, the designer is provided with numerous options to appropriately adjust the seismic performance of a building. However, introducing seismic isolators at various storey-levels is not a straightforward task, since it may lead to favourable or unfavourable structural behaviour depending on a large number of factors. As a consequence, a rather chaotic decision space of seismic isolation configurations arises, within which a favourable solution needs to be located. The search for favourable isolators' configurations is formulated in this work as a single-objective optimization task. The aim of the optimization process is to minimize the maximum floor accelerations of the building under consideration, while constraints are specified to control maximum interstorey drifts, maximum base displacements and the total seismic isolation cost. A genetic algorithm is implemented to perform this optimization task, which selectively introduces seismic isolators at various elevations, in order to identify the optimal configuration for the isolators satisfying the pre-specified constraints. This way, optimized earthquake response of multi-storey buildings can be obtained. The effectiveness of the proposed optimization procedure in the design of a seismically isolated structure is demonstrated in a numerical study using time-history analyses of a typical six-storey building.

01304
Evolutionary search based on aged structured population and selfish gene theory

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Genetic Algorithms (GA) based on an elitist strategy deal with an increased probability that high fitted individuals belonging to a dominant species gradually replace lower fitted rivals from other competing species. Besides introducing possible premature convergence, uncontrolled elitism of a GA may be an obstacle to search multiple optima. There are different reasons to preserve an individual into the population. Firstly it would preserve highly fitted individuals. Secondly, it would preserve individuals that are different enough from the genetic point of view relatively to the current best ones, despite their low fitness. These individuals would be worthwhile to keep and to participate into the evolutionary process according to species conservation principles. The proposed approach is based on the strategy that eliminated individuals by the elitist strategy will have a second opportunity to intervene in the evolutionary process. Indeed, all individuals generated in the evolutionary search will belong inherently to an enlarged population with an age structure. The elite concept is not considered in this enlarged population where an individual is eliminated as it reaches the lethal age (natural death). A continuous updated model of generation was adopted for the age structured population. One generation is defined as a discrete time unit to count the individual age. In the population with age structure the transfer of genetic characteristics is conditioned by the candidate age. Assuming that the population maturity and potentiality follows a Normal distribution the parent selection is done according to its probability. Individuals with ages located at the tails of the Normal density function are the youngest and the oldest of the scale, have a very low probability to be selected as parents in the evolutionary process. The evolution of the age structured population is based on the Selfish Gene theory (SG) where the population can be simply seen as a pool of genes and the individual genes fight for the same spot on the chromosome in the genotype. The frequency of appearance of an allele increases the success rate overall. The survival of the fittest depends on genes, not individuals. Unlike traditional GA, an individual in SG theory is not so important to the evolution being appropriated to consider the species

conservation paradigm. The concept of virtual population is used and the SG performs its effects on the statistical parameters of this virtual population along the evolutionary process. Each new solution is implicitly generated by changing the frequencies or the probabilities of the alleles or possible genes. This population evolves to get the best solution using the interaction between the frequencies of the alleles in a same gene group and by changing these frequencies according to the corresponding fitness of individuals. The offspring individuals are inserted into age-structured virtual and current populations according to Lamarckian learning. Finally it is discussed the effects of different learning procedures in the HGA-SG approaches.

01306
Studies on Artificial Neural Networks as Meta-Models in Optimization Tools for Offshore Oil Production Systems

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In offshore oil production activities, risers and mooring lines play important roles. The design of such slender structures is a very important issue for the petroleum industry. Many aspects are involved in the design of such structures, related to safety and cost savings, thus requiring the use of optimization tools. Based in previous works, we concluded that the Particle Swarm Algorithm (PSO) is an excellent option of optimization algorithm. Although the use of optimization methods facilitates the project of these structures, avoiding the necessity of doing an exhaustive parametric analysis, the dynamic analysis of finite elements still must be applied to each step of the optimization algorithm. In this context, this work presents the study of the performance of an hybrid Particle Swarm Optimization (PSO) - Finite Element Method (FEM) - Artificial Neural Network (ANN) computational tool for the project of systems for offshore oil production, using resources of ANN as meta-models to complement and/or to substitute numerical analysis. Firstly, some examples are generated using the particles values in the initial iterations of the PSO algorithm as inputs and its respective responses, calculated using FEM, as outputs. Then, an ANN is used to approximate the responses of the particles in the remaining iterations of the PSO method.

01317
Reconstruction of 3D Surfaces from Cloud Points Based on Deformable Models with Experimental Verification

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This paper describes the development of algorithms to perform the construction of 3D surfaces from point clouds acquired from a laser scanning system. This work was motivated from the need to develop a tool to create 3D maps from geometric defects on the surface of hydraulic turbines to be detected and repaired by a closed-loop controlled robotic welding system. To generate a 3D surface with sufficient accuracy, adaptive filters are used to attenuate and eliminate noise in the cloud points. Triangular meshes

are generated by means of deformable models to be used as a basis for parametric functions (NURBS) that allow more realistic representation of the surface to be modeled. Likewise, the adjustment of NURBS functions through the Newton cyclic iterative method in order to minimize the distance between the structured mesh and parametric functions are described. It is also presented the evaluation of boundary conditions for parametric smoothing functions over the entire surface. Experimental procedures have been specially developed to access the accuracy of the measurement system by finding the center and calculating the radius of high precise standard spherical targets with promising results. Theoretical basis, hardware implementation and practical results are also discussed.

01322
Software Optimization Framework for Algorithm Development and Application to Practical Problems

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Although the use of engineering optimization is growing, more progress is required for optimization to be widely accepted in industry. Despite the fact that innovative algorithms continue to be developed and refined by academic, government, and industrial researchers, most of these algorithms never find their way into the hands of working engineers and are never used to solve real engineering problems. To improve this situation, several actions are needed: • New algorithms and methodologies need to be better tested against a wider range of practical engineering problems • Communication between algorithm developers and practitioners needs to be improved (education, exchange of ideas and requirements) • Better mechanisms are needed for getting successful algorithms into the hands of working engineers • Intuitive user interfaces are needed to make it easier for engineers to choose appropriate algorithms and quickly apply them to their problems In this paper, we describe a new engineering optimization software framework that was designed to help achieve these objectives. This framework provides algorithm developers with a software environment in which they can quickly implement, test, and deploy new and modified algorithms to working engineers. Each algorithm has access to a core set of common capabilities, including: • A common drag-and-drop graphical user interface (GUI) that engineers can use to define the optimization problem (objective functions, design variables, constraints) • Automatic execution of engineering analyses (function and/or gradient evaluations) • Data collection, graphs and plots • HTML based help system that can be utilized to describe the algorithm to end users Once an algorithm is implemented in the framework, it can be tested against a library of engineering test problems, and made available for testing and application by working engineers. Engineers will benefit from the framework because they will have access to a wide range of different algorithms, including those derived from the latest research in the field. Because all algorithms will be accessible through a common GUI, it will be easier for engineers to choose algorithms appropriate for their problem, execute them, and compare the results of one algorithm with another. The framework will be built using the ModelCenter process integration and automation framework as a backbone. ModelCenter is free for academic purposes, and is widely used in the aerospace, defense, and related industries for integration and automation of engineering analyses and processes. Current users include Airbus, Alenia Aeronautica, BAE Systems, Boeing, DLR, JAXA, Lockheed Martin, NASA, Northrop Grumman, and ONERA. The presentation will describe the framework in detail. The specific steps required for implementing, testing, and sharing algorithms will be illustrated. The use of the framework for solving a multi-disciplinary system will be illustrated. The system will be comprised of a centrifugal compressor, an aftercooler heat exchanger, pressure vessel, and tubing and valving to distribute air to an industrial plant. Also included is peripheral equipment such as motors, gearboxes, pumps, and piping. The equipment is powered by a wind turbine. The problem has multiple objectives, namely minimization of cost and environmental effects, and maximization of safety.

01329

Parameter free shape design of thin shells: Efficient and effective, parallel solution techniques for very large design problems

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Further progress has been made in the field of parameter free shape design of thin shells applying the so-called parameter free technique. Coordinates of finite element nodes are directly used as design variables which combines two striking advantages: minimal effort to set up the design problem and almost unlimited dimension of design space. New, sophisticated sensitivity filtering guarantees mesh independent results; the quality of mesh is controlled by Plateau regularization based on ideal element templates. Exact semi-analytic and adjoint sensitivity analysis is the basic key to an efficient and accurate optimization procedure. It appears that basic algorithms like feasible directions and augmented Lagrange methods are best suited for the problems at hand. Finally, a highly efficient, massively parallel code has been implemented. The procedure is applied to the free form design of geometrically non-linear shells including large displacements and instability with respect to minimization of weight and maximization of lowest eigenfrequency. A broad range of applications in architecture, civil, automotive and aerospace engineering will be presented as there are bead design of plates, pressure bulk heads, local effects of load application and the all-over-design of free form thin shells.

01340

Shape Optimization of a Feet Support Using Finite Element Analysis

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In the framework of Eco Veículo by DEM-FCTUC project, there is the need for each part to obtain the desired level of performance with minimum mass. Because of this we need to use a method to optimize each part of the vehicle. Moreover we have a limited time available for development which imposes that the optimization method must produce results in a fast and efficient way, using available means. The use of CAD tools that include stress analysis by finite element method, allow the stress and deformation distributions to be evaluated in a short time for a given load scenario. With CAD tools the mass of a part can be calculated too, and then performance parameters can be defined for stress and deformation using the mass of the part and the maximum stress and deformation. A global performance parameter can be defined based on the performance parameters for stress and deformation, and so the geometric optimization of the part can be done based on the value of the global parameter. Using a spreadsheet a mathematical model can be applied to optimize the shape of the part by changing a specific geometric variable and calculating the global performance parameter. The value of the specific variable that gives the maximum of the global performance parameter is the optimum value for this geometric variable. Then we skip to another geometric variable and use the same method to find its optimum value and continue the same procedure with the other geometric variables of the part until we reach the optimum geometrical shape. Moreover, we used restrictions for

the maximum values of the stress and deformation levels, in each iteration of the process. This method was applied in a real part that had already been built and it allowed to reduce by 3 times the mass of the part and maintain stress and deformation levels within acceptable levels for the material used in the manufacture of the part and functional requirements of the component, so the part performs its function properly and is much lighter. This mass reduction method is easy to use, is pretty fast and can be applied to obtain the optimal shape of many complex parts found in machine construction.

01343
A Two-Step Approach to Multi Spar Composite Vertical Empennage Structure Optimization

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A two-step approach for the structural optimization of a multi spar vertical empennage fully constructed with laminated composite materials is presented, whose output is the composite lay-up over the structure with optimum stacking sequence. For the minimization of structural weight only the critical buckling load factor design constraint is imposed and structural analysis is done for critical maneuver load case. In the first step of the structural synthesis a zone modeling strategy is applied over a design model where groups of four adjacent elements have the same composite lay-up and a single thickness design variable. A thickness gradient criterion is applied to regroup adjacent regions. The zone modeling iterations proceed until the convergence to the final set of zones. Once this set of zones is defined over the structure new detailed laminate properties are assigned to the regions and a new final discrete optimization is carried out, now with angle and thickness discrete variables such that the stacking sequence is optimized and the final laminate presents ply continuity along the zones. The structural optimization software GENESIS® is used in both steps. Result show that the strategy is very effective in producing a manufacturable structure.

01344
Comparison of free stacking sequence approach versus a predefined 0/+45/-45/90 sequence in a typical aircraft wing optimization

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Two ways for performing composite optimization for a typical aircraft wing are compared in the present study using the multi objective genetic algorithm MOGAII. This algorithm is found in modeFRONTIER ®, distributed by ESTECO. The optimization goal is the weight minimization under buckling load factor constraint. In the first method called "N-PLIES" the design variables are the number of plies for each orientation angle, in a pre-defined stacking sequence, in this case

[0/+45/-45/90], using plies with constant thicknesses. In the second method called "T-THETA" the discrete design variables are ply thickness that can assume one of the three values [0, t, 2t] and angles, chosen among [0/+45/-45/90]. In order to guarantee a balanced laminate the design variables are arranged in pairs with the same thicknesses and opposite angles. Also, symmetry with respect to laminate mid-plane is imposed. All laminates were modeled using the "PCOMP" NASTRAN card entry. The differences of each approach are studied in detail, these include: sample space for each method, convergence pattern, computational cost, weight minimization capability, constraining capability when manufacture parameters are considered and others. The results clearly show the effects of the stacking sequence during laminate design in problems involving laminate out-of-plane loading.

01352
Application of a CFD-based tool to optimize an industrial pultrusion process

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Pultrusion is one of several manufacturing processes for producing reinforced polymer composites. In this process, fibers are continuously pulled through a resin bath and after impregnation, the fiber-resin assembly is cured in a heated mold. In order to obtain a composite uniformly cured with minimum energy rate and high production rate, it is necessary an optimization procedure to calculate it. In this work, we propose a CFD-based tool for optimization of a typical industrial pultrusion process. The purpose is to increase production rate of composite material without affecting the quality material and, at the same time, to minimize energy rate consumed during the reaction. To do so, the CFD approach was applied to the phenomenological and kinetic equations coupled to an external optimization algorithm to maximize the objective function, that is written as the difference between process profit and energy cost, subjected to constraints as temperature level and minimum degree o cure to be attained. The algorithm used for this purpose was the particle swarm optimization, PSO, that presents a stochastic strategy to search the optimal point. At each PSO iteration, the CFD model is used as a subroutine in order to evaluate the degree of cure and temperature profile required for objective function evaluation. The kinetic parameters of the cure reaction were estimated experimentally by differential scanning calorimetry, DSC, and adjusted to the kinetic model. Before the optimization study several studies were made to compare the experimental temperature and cure profiles with theoretical results. Then, the validated model was associated with optimization algorithm and the optimal results were compared with the non-optimal ones. We demonstrated that the proposed optimization strategy was successfully in optimizing the industrial pultrusion plant by reducing energy cost and increasing production rate, showing that

this process may be considerably optimized if the kinetic behavior is well known. The proposed algorithm has shown a powerful strategy to future implementations for pultrusion optimization and also may be applied to other composite processes.

01354
A Robust and Reliability Based Design Optimization Framework for Wing Design

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This paper presents the outline of a framework for simultaneous analysis and robustness and reliability calculations in aircraft design optimization, with the option of employing surrogate models. Robust Design Optimization and Reliability Based Design Optimization are merged into a unified formulation which simplifies the setup of optimization problems and aims at preventing foreseeable implementation issues. The code in development expands upon and, in some cases, completely rewrites a previous version of a Multidisciplinary Design Optimization tool that was solely oriented to deterministic problems.

01358
Global Optimal Design of Electricity and Fresh Water Plants

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This paper presents a NLP mathematical model of a Dual Purpose Plant (cogeneration of electricity and fresh water). Precisely, the main goal is to determine a set of thermodynamic non-ideal optimal solutions by applying a deterministic global optimization algorithm proposed by the authors. General Algebraic Modeling System GAMS is used to implement the model and the resolution strategy as well. The considered dual purpose process involves a gas turbine discharging exhaust gas to a backpressure turbine cycle which is coupled to a thermal desalination process and to a condensation turbine cycle. This system has been previously studied by the authors but using local optimization algorithm [1] and consequently it was not possible to ensure the globality of solutions. The obtained global optimal solutions provide preliminary designs that satisfy optimum thermodynamic and process functional criteria.

01359
Equilibrium Stage Mathematical Model for the Optimization of Chemical Absorption of Carbon Dioxide into Monoethanolamine (MEA) Aqueous Solution

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In this paper, an equilibrium stage mathematical model of the chemical absorption process to Carbon Dioxide removal using MonoEthanolAmine (MEA) aqueous solution is presented. Precisely, a deterministic and NLP model is proposed to optimize the operating conditions to remove CO2 from flue-gases in a tray column. The number of trays of the column is assumed as a model parameter while temperature and composition profiles and flow-rates of the aqueous solution and gas streams along the column are considered as optimization variables. For the modeling, the absorption column is divided into a number of segments assuming that liquid and gas phases are well mixed. GAMS (General Algebraic Modeling System) and CONOPT are used, respectively, to implement and to solve the resulting mathematical model. The influence of the main model parameters such as the inlet gas and aqueous amine solution conditions (composition, temperature and flow-rates) and number of trays or height equivalent to a theoretical plate (HETP) on the absorption performance is investigated. The robustness and computational performance of the proposed model as well a detailed discussion of the optimization results will be presented through different case studies.

01364
Review on Process Optimization considering LCA Methodology

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The development of industrial technology has caused the transformation of the environment in different ways, changing the nature and extent of the environmental impacts of industrial activities. One of the main problems associated with these activities is that they may not have an immediate effect and some may have a more global impact on the environment to make their assessment difficult. The general objective of the project, in which this paper is inserted in, is to address the modeling, simulation and optimization of chemical and biotechnological processes considering life cycle analysis LCA methodology. In doing that, the state-of-the-art on process optimization techniques and tools based on LCA is required, which is the goal of the present work. Simulation and optimization methods, which are valuable tools mainly in process systems engineering, are successfully being applied since several decades ago. On the other hand, the LCA methodology is an accepted environmental management tool to holistically, systematically and multidisciplinarily quantify environmental burdens and their potential impacts over the whole life cycle of a product, process or activity. The LCA methodology has been generally applied for (i) strategic planning or environmental strategy development for choosing Best Practicable Environmental Option (BPEO) e.g. comparison of the environmental impacts of different products with the same function and comparison of the environmental impacts of alternative manufacturing processes for the same product;

(ii) comparison of (regional, economical, cultural) scenarios for a given product, process and/or activity; (iii) identification of environmental improvements opportunities such as identifying "hot spots" i.e. parts of the life cycle that are critical to the total environmental impact; and (iv) creating a framework for environmental audits, among others. However, it is well known that the LCA methodology has a subjective component in several aspects, such as the system boundaries, goal definition and scoping. On the other hand, the LCA results are often determined by limited data with unknown reliability. In this context, integration of mathematical optimization techniques with LCA methodology for conceiving environmentally friendly processes, products and/or activities "from cradle to grave", in an efficient and flexible way, with less subjectivism as possible, is an ambitious challenge. Here, an exhaustive literature review on (i) mathematical optimization techniques suitable for process synthesis and design, (ii) LCA applications in process industry, (iii) proposed frameworks and progress made towards integration of both, (iv) specific case studies, will be presented and discussed.

01365
Optimal wastewater treatment plant synthesis and design: problem solution methodology

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In a previous work, a superstructure model developed for process synthesis (plant configuration), design (equipment dimensions) and optimization of operation conditions of activated sludge wastewater treatment plants, in continuous operation, accounting for phosphorus and nitrogen removal, was developed. There, the model was solved using a multiple initial points strategy. The superstructure embeds a chain of up to seven reaction compartments in-series followed by a secondary settler, and allows for flow distribution of the main process streams, i.e. bypasses and recycles among reaction compartments, sludge recycles from the sedimentation zone to any reactor, and fresh feed distribution and external carbon source dosage along the reaction zone. Each compartment operates in aerobic, anoxic, or anaerobic conditions according to its aeration flow rate selected and the streams fed to it. The Activated Sludge Model No. 3 extended with the Bio-P module for computing biological phosphorus removal are used to model the reaction compartments. The performance criterion selected is the minimization of the Net Present Value that includes investment and operating costs, while verifying compliance with the effluent permitted limits. The problem characteristics allowed posing it as a NLP, specifically a nonlinear programming problem with discontinuous derivatives DNLP, as it results in a highly nonlinear system with non-smooth functions. However, the mathematical model is difficult to solve. The superstructure network is complex because it embeds a large chain of reactors to contemplate the most widely used configurations for combined N and P removal. It is well known how complex a network becomes if the number of reactors increases. A distinctive feature of the model is the possibility of flow distribution of the main process streams, which provides flexibility and allows searching for novel or more efficient process configurations. By the other hand, the model used to represent the process units are highly nonlinear and incorporated non-smooth functions. Several locally optimal solutions can be found depending on the initial values set. The present work aims to develop an automatic resolution strategy to address this problem. The potential alternatives to evaluate include a successive initialization method departing from simplified NLP models, the resolution of linear problems to provide good initial points for the larger (rigorous) NLP models, or a combination of both, among others.

01366
A variance-expected compliance approach for topology optimization

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In this talk, we present an stochastic model for topology optimization. We consider an homogeneous material occupying a domain Ω_m in $\R^2$ or $\R^3,$ which is part of a larger reference domain $\Omega,$ some parts of Ω_m are fixed in this reference configuration. We assume that an stochastic external load is applied to this material. Our goal is to minimize the \textit{expected compliance} subject to mechanical equilibrium constraints and total volume. Following the work of *[1]* we derive a new formulation of this stochastic model which has the form of a multiload like problem, and then can be solved by using standard algorithms. Some numerical examples are presented. The stochastic setting introduced in this talk allow us to consider other variants for the optimal topology design problem. We then consider the minimum variance-compliance problem, where the variance of the compliance is included in the model. We present some numerical examples for this alternative.

[1] Alvarez, F. and Carrasco, M. { Minimization of the expected compliance as an alternative approach to multiload truss optimization}, Structural and Multidisciplinary Optimization, vol 29, year 2005, No 6, pp 470--476.

01369
Multidisciplinary Optimization Methodology Applied to Preliminary Design of Subsonic Wing

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This work presents a preliminary subsonic wing design through optimization methodology. This preliminary design consists to determine optimum wing shin shape so that, aerodynamic and structural requirements are met. The optima aerodynamic load distribution is obtained by the combination of aerodynamic twist, given by variation of wing sections along spanwise, and geometric twist, given by variation of angle of attack along spanwise. In order to meet structural requirements, wing sections along spanwise must present an internal area and inertia moments such that it is possible size the wing box structure. Shape of root and tip airfolis are parameterized by two Bezier arcs of high degree representing the lower and upper surfaces. The abscissas of the control points are fixed and the ordinates are treated as design variables. The geometric twist is treated as design variable too. Aerodynamic load is evaluated through a computational code based on lifting line theory, which needs aerodynamic data of root and tip wing sections, which in turn are determined by XFoil aerodynamic solver. In this solver are calculated structural parameters too. As optimization algorithm within this methodology is implemented the Nondominated Sorting Genetic Algorithm II (NSGA-II). The NSGA-II is a genetic algorithm variation developed to perform multiobjective approaches, which uses dominance-based ranking to determine the nondomination level of each individual and applying mutation, crossover and selection evolutionary operations, a new pool of offspring is created, and then combining the parents and offspring before partitioning the new combined pool into fronts. This procedure is repeated until all population individuals are ranked and criterion convergence achieved.

01370
The use of neural network meta-models for analysis and design of manufacturing control processes

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Manufacturing control systems require complex simulation models to carry out performance analysis and there are multiple performance measures of interest. These models typically have large parameter spaces and high variability making direct parameter optimization unrealistic. We demonstrate a methodology for the development of neural network based metamodels and the use of these metamodels to compute optimized tradeoff curves between competing system measures of performance

01371
Optimum design of viscoelastic structures subject to transient loads

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A major challenge in the design of structural components subject to dynamic loading is the optimum design of the optimum transient response of the structure. The reduction in size of lightweight, fuel-efficient vehicles has promoted the use of new engineering materials in sophisticated designs of structural components that may act as energy absorbers in a collision. That makes the use of material optimization for crashworthiness attractive and increasing in popularity among automotive companies. This investigation incorporates optimization approach with modeling of viscoelastic structures to minimize the maximum nodal acceleration of the structure as well as minimize the maximum nodal displacement. Uni-dimensional models demonstrate the complexity of the analytical solution. For the theoretical approximation, the dynamic response of structural members is obtained employing Kelvin-Voigt (solid) viscoelastic models. The design variables correspond to the stiffness and damping coefficient of the material. The proposed optimum material system is the base to design components for more complex applications such as crashworthiness and blast mitigation, and to be employed for topology optimization.

01373
Multiobjective Optimization of Rocket Engine Impulse Turbine using an Evolutionary Algorithm

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The present work urges turbopump rocket designers to achieve best results in their design compromises using Multi-Optimization Evolutionary Algorithm. A multiobjective turbine optimization has been discussed with aim to enhance the results of optimizing a real-life turbine disk in terms of weight reduction. At first, the real-coded NSGA-II has been used to yield a best-fit engine design regarding the mass reduction from weight-sensitive design parameters of a rocket engine impulse turbine. A statistical trend analysis could reveal convergence toward a desired candidate among exploring decision variable bounds through the Pareto-optimal set. Finally, detailed observation of the design results also reveals some important design policies in turbopump design of liquid propulsion rocket engines.

01380
Uniqueness in linear and nonlinear topology optimization and approximate solutions

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All reported results in literature indicate that even simple topology optimization problems, such as the compliance problem, have many local optimum points. Besides numerical instabilities associated to the mesh size in the finite element model, different algorithms and initial designs lead to different topologies. This phenomenon is referred to as non-uniqueness. This paper studies the conditions under which linear and nonlinear compliance problems have a unique solution, providing practical insights on the conditions that lead to non-uniqueness. To this end, three different optimization algorithms are used: OC-SIMP, SQP, and a new control-based optimization (CBO) method. The latter one has been developed to solve for nonlinear compliance problems, but it shows its best performance when solving for problems involving uniform distribution, e.g., uniform strain energy density distribution (USEDD). The solution obtained with the USEDD criterion are approximate solutions to the ones with minimum compliance; however, they can be easily obtained with the CBO method without sensitivity analysis. Furthermore, the results of this investigation show the approximate solutions closely match the exact solutions of the compliance problem. This paper studies the conditions under which linear and nonlinear topology optimization problems for minimum compliance have a unique solution with the use of the popular solid isotropic material with penalization (SIMP) model. Results for linear and nonlinear topology optimization problems are obtained using a distributed control-based optimization approach in a hybrid cellular automaton (HCA) framework. This study is extended to a well-liked technique for topology synthesis based on uniform strain energy density distribution (USEDD). These results are compared with the ones obtained using a well-established gradient-based method, such as sequential quadratic programming (SQP). Results are demonstrated for linear elastic structures and plastic structures, without the use of filters. This paper shows that under some conditions, the approximate results obtained by USEDD closely match the exact solutions of the minimum compliance optimization problem found by HCA and SQP.

01381
Optimum Designing for Robustness of Steel Building Structures

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The robustness of a building structure is defined as its resistance to collapse or its capacity to mitigate damage. Robustness, as a performance objective, is not explicitly considered in mainstream design codes. Current specifications use local member performance as indicators of global system collapse; however, robustness is a measure of global system performance. Design for robustness is highly desired when the structure may be subject to extreme loading conditions, even when these loads are rare events. In such cases, it is imperative to know how the building system will collapse. In particular, it is important to know whether the collapse modes are benign (limited to a reasonable small portion of the structure) or if the collapse is complete (worst case scenario). During the design process, robustness can only be estimated through sophisticated and expensive numerical simulations and its quantification is not limited to a single scalar function. That creates several challenges for the optimization process. The objective of this investigation is to develop a methodology to

optimally design steel building structures for maximum robustness. The multi-objective objective function incorporates the collapse modes. Design parameters of the system are defined as critical columns exposed to extreme loads (e.g., supporting columns). The sudden loss of these structural components determines the collapse modes of the structure. Design variables include the type of bracing (i.e., concentric, eccentric, or none) and the type of connection (i.e., shear or moment). The design optimization process incorporates multi-objective combinatorial optimization in a variable-fidelity framework. This methodology is demonstrated in the optimum design of a four-story, four-bay steal moment frame subject to a constraint in total weight. The results show significant differences with the ones obtained using a more traditional code-based design.

01384
Mass, power and static stability optimization of a 4-wheeled planetary exploration rover

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In 2001 the European Space Agency (ESA) had initiated the Aurora Programme with its primary objective to be robotic and human exploration of the solar system. The most likely targets are Mars, the Moon and asteroids; but a manned mission is only possible after successive robotic precursor missions to test technology in-situ and gather sufficient environmental information. In this context there are two near future missions which will provide surface mobility with wheeled rovers: ExoMars and Next Lunar Lander – NLL. The ExoMars Rover and the NLL Rover are powerful rovers with different capabilities under development, respectively with six and four wheels. This work focuses on a four-wheeled rover, having the NLL Rover as the main example. The chassis of the vehicle is modeled as a multi-body system (MBS), basically composed of a two-bogie suspension and individually steerable wheels. Revolute joints are used in the whole articulated structure. The wheel-terrain interaction permits to switch between rigid and soft soil based on the Coulomb's friction model and terramechanics approach. Dynamic stability can also be analyzed since the wheels are allowed to loose contact with the ground. The physical representation of soil characteristics and ground elevation for each point of the surface is another feature of the simulation model and determines the travelling surface. The MBS model is scalable and under continuous development to increase the representability of a real rough terrain navigation condition. An advantage of the MBS simulations is to evaluate the performance of the rover when the various geometric characteristics of the suspension system (e.g. bogie length) and wheels (i.e. radius, thickness, etc.) are used as design parameters. By optimizing these design parameters it is possible to achieve a lightweight structure with improved efficiency and static stability margins. Two different software packages were used in our modeling/optimization procedure: Dymola (modeling environment) and Matlab/MOPS (optimization environment). MOPS is an optimization toolbox developed at the DLR. As the main performance measures to be optimized we have identified three different ones: average consumed power, overall mass of the vehicle and static stability margin. A compromise between the design parameters could be found in order to achieve satisfying performance measure values. Animations, histograms and time-domain plots are used to evaluate the obtained results. They include the dynamic behavior of the optimized rover and the related performance measures. Sensitivity analysis is employed to quantify the most representative design parameters which could be used as distinguished elements to support design. Besides the rover structure parameters being optimized, the performance of the rover could even be more improved if the motion controllers' parameters are used as additional design parameters. The results gave us an insight about the optimization trends according with the terrain characteristics and are prone to point out the outlook of this design improvement effort. Hence our next step will be to include gradually new design parameters and also new performance measures. The new performance measures would be capable to quantify other aspects which are likewise important in the context of an all-terrain locomotion system.

01386
Novel Approach for Performance Evaluation of Fast Time-Domain Non-Iterative CoSimulation

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Simulation tools are commonly used to predict the physical system behavior in early design steps to avoid expensive re-design cycles and at the same time to reduce the need for (expensive) prototypes. Many simulation tools, targeting different domains, are already available on the market. For each modeled system within a specific domain an individual model description language is used, which results in an analytical system description in form of algebraic equations, differential equations and coupling conditions between them. Further to achieve adequate accuracy domain specific solvers are used. However, most of them focus on a specific domain and thus support domain-specific features only. Especially in the automotive industry systems become more complex due to the need of combining electrical, mechanical and thermal components with different dynamical behavior, i.e. fast and slow dynamics. For example, regarding a hybrid power-train system, the propulsion module, power electronics, energy storage system and cooling circuits are interacting. In contrast, nowadays submodels are used in domain specific simulation tools with tailored solvers. These models can be verified standalone without any model dependencies. However, efficient coupling of those separated tools is necessary in order to achieve reliable estimates and to take into account feedbacks for the entire system behavior. This modular multi-method approach is called co-simulation and offers great potentials. In this work we concentrate on a novel performance analysis of a non-iterative coupling methodology. A common characteristic of these strategies is that coupling quantities of subsystems must be predicted over subsequent macro step which leads to less accurate simulation results. First, for the necessary different extrapolation techniques (hold, linear, quadratic) adequate uncertainty models are developed and evaluated. The dependency between system dynamics and scheduling is drawn. Then we present an approach, which opens new possibility to automatically derive performance dependent macro step sizes. Optimization is used to a-priori compute the maximum macro step sizes of the coupled system based on user defined performance measures. Finally, the proposed approach is examined by an automotive example control system. Suitable macro step sizes determine the accuracy of the co-simulation. By the herein presented approach the time domain performance can be predicted. Please threat as strictly confidential!

01387
Robust design and optimization of compact multi-column chromatographic processes

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Preparative and process-scale chromatography have been used for decades in the pharmaceutical and fine chemistry industries, for the separation and purification of a wide range of substances. These processes are always subject to uncertainties not only in their operating parameters but also in their design parameters. Because of uncertainties in the design parameter and perturbations in the operating parameters, chromatography is constantly facing the challenge of manufacturing products with the highest degrees of purity and integrity, and overall process economy. In the present work, a general procedure for robust design of multicolumn chromatographic processes under uncertainty is presented and validated experimentally. The best solution is chosen only among candidate solutions that are robust feasible, that is, remain feasible for all perturbations

from the uncertainty set; this set includes both operating and design parameters. This methodology gives rise to a robust approach to optimal design in which the nominal NLP problem is replaced by a worst case NLP problem. Computational tractability is ensured by formulating the robust NLP problem with only the vertices of the uncertainty region that most adversely affect the critical product specifications---purity and recovery; the worst-case vertices are located by means of an iterative procedure. The NLP problem and its robust counterpart are constrained by the steady periodic solution of a set of partial differential equations that model the dynamics of the chromatographic columns. Both models are formulated with a multicolumn-single-switching-interval model and converted to large, sparse, algebraic system using a full-discretization approach for steady periodic dynamics. The resulting NLP problems are solved by an efficient interior- point solver. The procedure is successfully employed to find robust operating conditions for the linear separation of two nucleosides on recently developed two-column chromatographic processes. The robust operating conditions have been validated experimentally at pilot scale.

01389
Material grading for enhanced dynamic performance of bars in axial motion

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This paper presents an exact method for enhancing the dynamic performance of bars in axial motion using the concept of material grading. The natural frequencies are maximized under equality mass constraint in order not to violate the economic feasibility requirements. The composition of the material of construction is optimized by defining the spatial distribution of volume fractions of the material constituents using either continuous or discrete distributions along the bar length. The major aim is to tailor the material distribution in the axial direction so as to maximize the frequencies and place them at their target values to avoid the occurrence of large amplitudes of vibration without the penalty of increasing structural mass. The resulting optimization problem has been formulated as a nonlinear mathematical programming problem solved by invoking the MatLab optimization toolbox routines, which implement the method of feasible directions interacting with the associated eigenvalue problem routines. As a case study, a bar with Fixed-Fixed boundary condition has been thoroughly investigated. It was shown that the use of material grading concept can be promising in maximizing the natural frequencies and producing efficient economical designs having optimal stiffness and mass distributions as compared with their corresponding baseline designs.

01400
Optimization of Runner Axial Hydraulics Turbine

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This paper aims to present a methodology for parametric optimization with the objective of improving the performance of turbomachinery. In this study will be used a hydraulic turbine runner axial geometric variations of the stagger angle. The flow is calculated with the aid of CFD tools / FLUENT ®. The methodology consists in building automatic mesh geometries and parameterized by script or editing commands written in language Tlc / Tk, which will be interpreted by the commercial software ICEM-CFD ®. The boundary conditions will be introduced through auxiliary file Journal type. The mesh and geometry parameters such as solution flow were integrated with sub-optimization programs such as commercial nodeFRONTIER®, aiming to improve the overall efficiency.

01402
Topology optimization of structures subjected to contact conditions

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Generalized topology optimization of structures has been an area of intense research work for the last decades. Although the high level of development of the field, models for topology optimization focusing particular aspects and problems still have a special interest. It is the case of the model proposed in this paper where it is presented a three-dimensional computational model for topology optimization of structures subjected to contact conditions. This model assumes a material distribution approach, optimizes a measure of the structural compliance under multiple loads, subjected to an isoperimetric volume constraint. Due to the existence of contact, the objective function is investigated and the equilibrium equation is properly expressed to include the contact conditions. The necessary conditions for optimum are derived analytically based on the Augmented Lagrangian associated with the problem. The stationarity of the Lagrangian with respect to the design variable yields a linear elastic problem with additional displacement constraints on the contact boundary, obtained from the solution of the state problem. The model is approximated numerically through a suitable finite element discretization and solved by a first order optimization method. The developed computational model was tested in several three dimensional numerical applications. The results illustrate the influence of the contact condition in the structures topology and show the applicability of the model. Besides the application on structural optimization, the model has a special interest for biomechanics applications, particularly for orthopaedic implants. The structural optimization model is adapted to study the bone remodeling after an arthroplasty. In this problem the interface bone/implant requires a contact approach and the contact model proposed in this work has a special interest in this field. Numerical examples in this area are also presented.

01405
Optimal Design and Operation of Transmission Gas Pipelines

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Natural gas is increasingly being used as an energy source. Natural gas transmission pipelines transport large quantities of natural gas across long distances and operate at high pressures. This study deals with optimal design and operation of transmission gas pipelines, the objective function is given by a nonlinear function of flow rates and pressures. The optimization problem has been solved with number of decision variables and the number of constraints to find the optimal design variables and operations of transmission pipelines over flat

terrain. The objective function is included installation cost of pipelines, compressor stations, fuel consumption in compressor stations, maintenance, labor and supervision. The software computer program "Lingo" is used to obtain the solution procedure for optimal design and operation of transmission gas pipelines

01408
A gradient-based, parameter-free approach to shape optimization

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When your boss assigns you the task of optimizing the geometry of a component, wouldn't it be nice if you could return to your finite element model and press the optimization button to complete this task. Such a dream however, requires that the finite element node coordinates be parameterized, e.g. by dimensions, and this is seldom the case. Of course one could use the independent node movement approach, wherein finite element node coordinates are used directly as design variables; this allows the most freedom for shape change and avoids the time-consuming parameterization preprocess. However, this approach lacks a length scale control that is necessary to ensure a well-posed shape optimization problem and avoid numerical instability. Motivated by the success of filtering techniques that impose minimum length scales in topology and shape optimization , we propose a consistent filtering scheme to introduce a length scale and thereby ensure smoothness in shape optimization while preserving the advantages of the independent node movement approach. In the top example we optimize the shape of a hole in a bi-axially loaded plate. As seen in the figure, when we eliminate our filtering strategy at iteration xx and revert to the independent node movement approach the design morphs from one with smooth boundaries into one with jagged boundaries which are clearly mesh dependent. As seen in the lower examples, the algorithm is readily applied in both two- and three-dimensional geometries and is verified via analytical optimization results.

01409
Material Microstructure Optimization for Macroscopic Dynamic Response

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We use topology optimization to design the material microstructure field for desired macroscopic dynamic response. Each material point in the structure is comprised of a sequentially ranked laminate consisting of two isotropic materials; the laminate parameters are subsequently optimized. Explicit formulae are used to obtain the homogenized elasticity tensor and its sensitivity with respect to the laminate parameters. These in turn are used in a macroscopic explicit dynamic finite element analysis to compute the response. The cost and constraint functions and their sensitivities are evaluated next and this information is supplied to a gradient-based optimizer which updates the values of the laminate parameters. This multistep procedure is repeated until the optimization converges. In the examples illustrated below we subject a plate to an impulse load. The objective of the top design is to focus the energy to a desired location whereas the objective of the bottom design is to minimize the energy that is transmitted to the bottom surface of the plate. The white arrows in the figures show the movement of the high energy regions through the structure.

01411
Blade Shape Optimisation for Rotor - Stator Interaction in Kaplan Turbine

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This paper presents an algorithm for simultaneous stator and rotor blade shapes optimisation. The algorithm takes into account the interaction between stator and rotor of a model Kaplan turbine. Evolutionary

algorithms (EA) are used as an optimisation method together with artificial neural networks (ANN) for objective fitness function approximation. This is due to high computation demand of CFD calculation. ANN allows for significant calculation time reduction. The advantage of EA over other methods is that it seeks for global rather than local optimum. Reynolds averaged Navier-Stokes (RANS) equations are solved together with two additional transport equations. For this case the standard k-e turbulence model is chosen due to its robustness and popularity. An interesting blade shape description is given which proves useful for optimisation. The optimisation criterion (objective fitness function) is politropic loss coefficient for the whole stage (two stators plus rotor).

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01417
Integrated genetic algorithm as a design space optimizer with a filtering mechanism into the car sub-frame topology design

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Topology optimization is a way of finding the optimum material distribution of a structure. In the topology optimization, the basic shape, the maximal volume and the material type of the structure of design space are normally predefined. In this project, instead of a fixed design space we implement an alterable design space. The whole design space is discretized into several sub-design spaces. Each sub-space can have different choice of shapes, thickness, and material type and so on. The aim is to find the optimal combination of sub-spaces for the whole design space so that the cost and the weight of the designing part can be minimized in the related topology optimization. Since there is no gradient information available in this problem, as the simulation runs as a black-box commercial simulator, a probability based optimization method, genetic algorithm (GA), is used here. A penalty function has been integrated into the GAlib which act as a filtering function. This filtering function removes the bad individuals from the design space which allow the optimization process to converge faster. For each decided design space during the optimization, a topology optimization is run as the simulation for design space optimization. The software for topology optimization comes from Volkswagen, which are known as Medina (a pre- and post processing system for FEM) and OptiStruct (advanced finite element based software for both structural analysis and design optimization). The fitness of the simulation is calculated based on the data collected from the result file of OptiStruct. In this thesis OPTIMUS is used to integrate the GA optimizer and the topology optimization tools together into one general framework. The optimization and simulation process is parallelized to decrease the time consumption.

01425
An Integrated Quantitative Framework for supporting the design of injection moulds

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The injection mould is a high precision tool responsible for the production of mostly plastic parts used everywhere. Its design is considered critically important for the quality of the product and efficient processing, as well as, determinant for the economics of the entire injection moulding process. However, typically, no formal engineering analysis is carried out during mould design stage. In fact, traditionally, designers rely on their skills and intuition, following a set of general guidelines, which does not ensure that the final mould design is acceptable or the best option. At the same time, moulds makers are now highly press to shorten both leading times and cost, as well as to accomplish higher levels of mould's performance. For these reasons, it is imperative to adopt new methods and tools that allow faster and higher integrated mould design. To that end, a new approach based on the integration of well-known quantitative techniques, such as Design for Six Sigma (DFSS), Structural Equation Modelling (SEM), Axiomatic Design (AD) and Multidisciplinary Design Optimization (MDO) is presented. This approach tackles the design of an injection mould in a global and quantitative approach, starting with fully understanding of customer requirements and converting them into optimal mould solutions. In this sense, one first endeavour was carried out, through structural, thermal, rheological and mechanical domain integration, where all different analysis modules were inserted and optimized through an overseeing code system. The loop of this platform begins with an initial mould solution, defined as a parametric CAD model. Then, each mould phenomena was described by a high-fidelity model through the inclusion of numerical simulations codes (e.g. Moldflow®), or by developed analysis codes. The results attained highlight the great potential of the proposed framework to achieve mould design improvements, with consequent reduction of rework and time savings for the entire mould design process.

01436
Exact Hessian for CFD optimization

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Using AD (Automatic Differentiation), an Hessian operator is built for an industrial Euler 3D code. Quasi-Newton vs Newton approachs are compared on both constrained and unconstrained optimizations. Using exact second order derivatives (Newton approach) allows us to catch the optimum in more efficient way than BFGS approach. In particular, a strategy to make the optimizer robust has been implemented. For constrained problem, we use Interior Point Algorithm (IPA). For industrial demonstration, we choose the ONERA m6 wing in transsonic domain.

01453
Shape optimum design of insulations using smoothed fixed grid finite element method

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Shape optimization is an interesting problem in engineering design since it is essential in practical applications ranging from the design of mechanical structures to the design of fins. Solutions of such problems can improve the performance of the original designs. However, one of the challenges in shape optimization problems is developing an efficient method to determine the optimal shape. It is because the existing solution processes normally require a great amount of computation time. In fact, the most numerical methods such as finite element method used in the solution of shape optimization processes are based on boundary-fitted computational meshes. The main drawback of such methods is that the mesh must be modified in

each iteration where domain boundary undergoes some changes. This difficulty is addressed in the present paper in which a technique based on non-boundary-fitted meshes is used for the solution of variable domain problems. In this paper, the optimum shape design of an insulation which covers an object is considered. The objective of insulation is to reduce the heat transfer between the object and its surroundings and the main goal of the optimization problem is to minimize the total volume of the insolent used for the insulation. As the constraint of the optimization problem, the total heat loss from the object is limited to a prescribed level. In the present paper only the steady state case is considered and a convective boundary condition is supposed on the exposed surfaces. To manipulate the shape variations a boundary parameterization technique is adopted and a mathematical programming approach based on conjugate gradient method is used as the optimization algorithm. In this paper, the smoothed fixed grid finite element method which is based on the non-boundary-fitted meshes is used for the solution of the temperature field and finding its sensitivity coefficients with respect to design parameters. In this method the gradient smoothing technique is used to evaluate domain integrals numerically. The most interesting feature of using gradient smoothing technique in non-boundary-fitted meshes is the simplification of integration over internal parts of the boundary intersecting elements. Direct differentiation method is also used in this work to obtain the shape sensitivity of the temperature field. By using non-boundary-fitted meshes, the internal elements will undergo no changes during the boundary perturbation and therefore only the boundary intersecting elements will participate in the shape sensitivity analysis. Finally, some numerical examples are solved to show the effectiveness and the applicability of the proposed method. Keywords Shape optimization, Smoothed fixed grid finite element method, Non-boundary-fitted meshes, Shape sensitivity analysis

01454
Chaos particle swarm optimized pid controller for the inverted pendulum system

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This paper will focus on the application of the chaos embedded particle swarm optimization algorithm (CPSO) into one of the popular problem setups in the engineering application area of control systems, which is called the inverted pendulum. The inverted pendulum is composed of a cart and a free moving pendulum. By adjusting the cart position, the pendulum can be maintained at upright position. The position of the cart system is controlled via PID controller, which is a linear control method. The performance of the PID controller depends on its parameters. Thus, in this study, the parameters of the PID algorithm are determined by CPSO, which can be used in order to obtain the global optima of any system.

01467
Topology optimization of a nonlinear wave propagation problem

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The method of topology optimization is used to create optimized distributions of materials in structures subjected to steady-state wave propagation. The novelty of the proposed method is the ability to handle nonlinear materials with intensity-dependent material coefficients. The applicability of the method is demonstrated by the design of a one-dimensional optical diode. The method of topology optimization

has previously been used to distribute materials with linear properties in structures subjected to steady-state wave propagation, such as e.g. in [1] for optimal distribution of elastic materials and [2] for electromagnetic/optical materials. In this work the optimization problem is extended to deal with a nonlinear Helmholtz equation in which the position-dependent material coefficients are explicitly indicated to be functions of the wave intensity. This type of nonlinear behavior is e.g. found in optical materials possessing a non-instantaneous Kerr-type nonlinearity (see e.g. [3]). For instance, planar TM-polarized optical waves are governed by a Helmholtz equation in which the refractive index is given as $n = n_L\sqrt{1+\gamma|u|^2}$, where n_L is the linear refractive index and γ is a nonlinear coefficient. A standard Galerkin finite element procedure is used to convert the model into a set of discretized nonlinear equations which are solved for the discretized complex field using an incremental Newton-Raphson procedure. The model is parameterized by element-wise continuous design variables and the adjoint approach is used to compute the design sensitivities. The mathematical programming tool MMA [4] is used to get design updates based on the computed sensitivities. Results are presented for the design of a 1D nonlinear diode. Conditions are considered in which the structure is loaded in one end and the output recorded at the opposite end. As objective we wish to maximize the difference between outputs in the situations where input/output positions are interchanged. Further work will consider two-dimensional problems including distribution of two linear materials (air and a linear dielectric) and a nonlinear dielectric material.

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01470
Shape optimization of machine parts made of PRMMCs using approximate low cycle fatigue models (B. Wilczynski, Z. Mróz)

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Introduction. Metal matrix composites (MMCs) are promising materials for applications in automotive, aerospace, and other industries. In particulate reinforced MMCs (PRMMCs) non-metallic particles or whiskers are incorporated in metallic alloys to improve their mechanical properties. The fatigue behaviours of PRMMCs are very important factors for these engineering applications. We generally have the following points that characterize the low cycle fatigue (LCF) life behaviour of PRMMCs: (1) The microstructure of almost all commercially available PRMMCs have relatively uniform particle distribution. (2) The reinforcement particle volume fraction strongly influences crack initiation and crack propagation time. (3) The LCF life of the PRMMCs follows a Coffin-Manson relationship as well. (4) The LCF failure mechanism is essentially a matter of crack growth. (5) The local plastic strain around the crack tip plays an important role in governing crack initiation and crack growth process in PRMMCs. When machine parts are subjected to cyclic loading, cracks and therefore failures generally initiate at notches. Although it can be assumed that the bulk of a PRMMCs component remains elastic, the stresses in the metallic matrix in the vicinity of these concentrations may exceed the yield stress of the material. The modification of the notch shape via optimization process significantly increases the time to fatigue failure. Problem formulation. Shape optimization of notched machine parts made of PRMMCs with respect to low cycle fatigue life is discussed in this paper. The optimization task is set as follows: for a given boundary conditions, external loading and material properties find such shape of a notched part for which the minimal number of cycles to failure reaches the maximum value at some critical BEM or FEM nodes (these nodes are equivalent to a location of critical planes in Local Strain Approach). This is the known max-min approach with discontinuous objective function. Using the known bound (beta) formulation, the problem is converted to the simple max problem, with linear objective function and linearized constraints. Algorithm and computer program. The multisurface Mróz fatigue plasticity model and many approximate fatigue models named as Neuber type correction rules (Neuber, Molski and Glinka, Ye et al., Sethuranian and Gupta methods and their generalized models, both uniaxial or multiaxial variants) used to compute the actual strain-stress field in the notch zone are the main components of the fatigue analysis module. The response of PRMMCs is based on an analytical homogenization methods (Eshelby's equivalence principle and Mori-Tanaka theorem). Number of cycles in crack initiation phase is computed using an analytical model which has been proposed by Zhang and Chen. This proposal is an extension of Ding et al. LCF life prediction model limited only to the fatigue crack propagation process. These formulas are given in explicit form and allow on consideration total fatigue process, i.e. crack initiation and crack propagation. Several numerical examples illustrate possibilities of applications of the proposed algorithm to fatigue shape optimization of machine parts made of PRMMCs.

01471
Aerodynamic Optimization of Supersonic Nozzle Exploiting Dynamic Meshes and Sensitivity Analysis

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The aim of paper is the aerodynamic shape optimization of a supersonic nozzle. Presented optimization process exploits method of dynamic meshes and sensitivity analysis, which became well known and commonly used in field of FEM [1]. In compare to FEM, application of sensitivity analysis in CFD is usually limited by both, large number of needed runs either the large time consumption of single run. These demands usually exceed capability of current work-stations. Multiparametric optimization exploiting sensitivity analysis in CFD became inapplicable, thus. The method of dynamic meshes initializes flow properties in recently formed mesh (new run of sensitivity analysis) by the use of afore-computed run. After that, converging process requires only incomparable small number of iteration steps as deformation of newly formed mesh is limited to acceptable small mutation [2]. Moreover, sensitivity analysis enables the reduction of optimization space as only important parameters for objective function can be sorted out. The new procedure is designed for sensitivity analysis. Analysis is carried out for set of defined points (vectors) within parametrical space. Computations of the objective function for single points are not executed in random order, but the path of minimal deformation (passing all points from discretized parametric space) is found. Original and terminal shapes need to be assorted at the very begin. Euclidean distance of two adjacent shapes enables the formulation of deformation path in between. Sequence of shapes (vectors) gaining minimal sum of Euclidean distances of neighboring member is to be called the path of minimal deformation, subsequently. The evolutionary algorithm is used to find the minimal deformational path itself (problem known as the Travelling Salesman Problem). This procedure requires incomparable small number of iterations needed for complete sensitivity analysis. Consequently, optimization by the use of evolutionary algorithm is ready to be accomplished for the reduced optimization space (non-important parameters after sensitivity analysis are suppressed). As a result, the multiparametric optimization of aerodynamic elements became feasible. Described method abilities are proved by the executed shape optimization of a supersonic nozzle. Acknowledgement: This project was realized with financial support of Czech Science Foundation, grant no: P101/10/1709 „Nozzles and Diffusors in Ejectors".

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01477
Design of Optimal Hygrothermally Stable Laminates with Extension-Twist Coupling by Ant Colony Optimization

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Laminated composite materials allow for tailoring of their elastic properties through deliberate selection of the orientation of their constituent laminas (referred to as ply angles). Among the achievable properties is a coupling between in-plane and out-of-plane deformation modes. Extension-Twist is a specific type of coupling which has applications in rotor blades to change the angle of attack with a change in rotor speed. The optimal Ply-angles for E-T coupling have been obtained in previous work using Sequential Quadratic Programming. Since the Objective and Constraints are highly nonlinear, there exist multiple local and global solutions. This work tried to explore through the use of Ant Colony Optimization (ACO), a global optimizer, whether there are any better designs than those obtained in previously work. It was verified that the E-T couplings obtained in previous work global optimal. In addition, ACO produced new global optimal designs which were similar to the previous designs in terms of objective and constraint satisfaction.

01479
Multiphysics simulation using reduced order models in a Multidisciplinary Design Optimization context

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The main target of the study is to solve a multidisciplinary problem using Reduced Order Model in an optimization and robustness context. To implement the methodology, we took the thermal engine-cooling problem for its multiphysics aspect. In order to make up the exchange between the hydraulic and thermal fields, the approach explored in this work is based on the Proper Orthogonal Decomposition (POD), which permits to reduce the full vector fields using a linear combination of the proper vectors representing roughly the "high fidelity" models (LeGresley, 2004) Once we reduced our models, the interface is modeled by using kriging models between the scalar coefficients of POD linear combinations (Filomeno Coelho, 2008). We iterate between the two models using Fixed Point Iteration (FPI) in order to get a converged thermal field of the engine. The next step of the study is the use of this methodology to optimize engine operating parameters (inlet flow, thermal flux etc...). Two learning strategies are implemented for the progressive enrichment of the set of POD basis vectors. Usually it takes 6 days to solve an engine-cooling high fidelity problem but our methodology gives an approximate solution in 6 minutes (the cost of the initial DOE evaluation has to be taken into account also, but this stage is embarrassingly parallel). In other words an optimization and robustness problem involving a large number of function evaluations can be tackled, within the delays imposed by the engine development cycle. In our presentation, we apply the coupling methodology to a study problem issued from the actual engine simulations, but with simplified geometry. As the results seem promising, we continue with a full engine model.

01482
A Monte Carlo Solution for Stochastic Programming Problems with Recourse

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Two-stage stochastic linear programming problems, also known by stochastic linear programming problems, are often defined to incorporate in a linear programming model the uncertainty related with the change over time of the parameters of the problem. Since there are decisions that need to be made prior to the data observation, the aim of the model is to optimise decisions that are made in two-stages. For this purpose, the mathematical formulation of these problems involves two-linked problems: the first problem that defines the decisions that have to be taken before the realisation of some random effects (first stage decisions), and the second problem that evaluates the decisions that will be taken after the realisation of the random parameters (second stage decisions). The second-stage decisions are influenced by the first stage ones and can often be seen as corrective actions that have to be taken to minimise the consequences of the deviations of the equilibrium of the system that the decision maker wants to control. The optimal solution is determined minimizing a cost function that involves the costs associated to the first-stage decisions and the expected costs associated to all possible realizations of the second stage variables. Therefore, it has to be obtained considering a variety of future alternative realizations of the random parameters, requiring, usually, the characterization of a multidimensional probability distribution. The solution of stochastic linear programming problems is more often than not difficult to obtain due, essentially, to two main motives. The first is the size of the problem originated by the random data, which grows exponentially with the number of outcomes considered. The second is related with handling general probability distributions. Therefore, the first step is often to construct discrete distributions, close enough to the original one. The initial problem is then replaced by a computationally tractable approximation. This approach raises issues on the quality of the computed solutions and on the computational effort to achieve a given level of optimality with respect to the original problem. The aim of this article is to show that the Monte Carlo method can be used efficiently to solve a two-stage stochastic linear programming problem in which the random parameters are described by at least two random correlated factors. The Monte Carlo method is used to evaluate paths of the random parameters consistent with the properties of their distribution. In the searching procedure, the tentative values of the ideal first stage variables are generated indirectly using an auxiliary problem, which ensures compatibility with the restrictions. The inputs of this generator are random parameters of the state variables, which are not subject to complex restrictions since they are only bonded by their physical domain.

01488
Prediction of Microelement Fertilizers Mix for Optimize of Wheat Yield with GMDH-type Neural Network Model

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Wheat is the chief carbohydrate source which is taken to be human's food too. Considering the irregular population augmentation in the world the provision of food stuffs is a predicament of intense significance. prediction of wheat yield using different quantity microelements is an important issue as a key parameter in

increase of wheat production .Group Method of Data Handing (GMDH) algorithm is self-organizing approach by which gradually complicated models are generated based on the evaluation of their performances on asset of multi-input-single-output data pairs .The GMDH was firstly developed by Ivakhenko as a multivariate analysis method for complex system modeling and identification. in this way , GMDH was used to circumvent the difficulty of knowing priori knowledge of mathematical model of the process being considered .The main idea of GMDH is to build an analytical function in a feedforward network based on a quadratic node transfer function whose coefficient are obtained using regression technique. In fact ,real GMDH algorithm in which model coefficient are estimated by means of the least squares method has been classified in two complete induction and in complete induction, which represent the combinational and multi layered iterative algorithms, respectively.

01489
Path-Linking Genetic Algorithm for Multi-objective Flexible Flow Shop Scheduling Problems

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In many high-tech industries, the production lines belong to a general type of flow shop configuration with machine-dependent setup times, where each manufacturing stage has a number of identical machines. This paper presents a Path-Linking Genetic Algorithm (PLGA) to determine a set of well distributed efficient solutions for this problem with three minimization objectives – makespan, maximum tardiness, and total number of tardy jobs. The performance of PLGA is compared with NSGAII and SPEA2 through a set of test instances generated based on real world data from the Cell manufacturing process of TFT-LCD products. The experimental results indicate that PLGA excels its counterparts in terms of several proximity and diversity measures.

01503
Sheet Metal Stretch Forming Simulation & Optimization for Springback

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Using simulation and optimization techniques as a tool in the design of sheet metal forming processes has been investigated. Genetic Algorithm (GA) in Search Optimization is an adaptive heuristic search method based on population genetics; it has been proved useful for many engineering problems. Stretch forming is one of the forming processes that have been investigated. Simulate a sheet metal stretch forming is a valid way to calculate and demonstrate springback. There are many FEM (Finite element Method) programs to simulate sheet metal forming processes, for each forming process many formability problems could appears, these problems usually are associated with wrinkling, fracture and springback. The aim of for a good process design is to avoid these problems. In every industrial sheet metal forming process it exhibit some stochastic behavior normally due to uncertainties variations on material properties, geometry and other process parameters. To deal with these variations the forming process must be designed to avoid them, is then when simulation and optimization techniques bring solutions. In this work effort has been made to simulate and sheet stretch forming by bending an aluminum sheet to determine the springback. ABAQUS FEM simulation software has been used for the simulation model. Also a GA program using MATLAB to minimize springback has been made. A simple parabolic die curve shape has been used to simulate stretch forming and springback. Some data has been assumed or defined, also provided from the laboratory examples. The GA program has been constructed over the MATLAB genetic algorithm toolbox. It has been show that GA can reduce springback and contributes with the forming process design.

01508
A Hybrid Grouping Genetic Algorithm for Integrating Cell Formation and Cell Layout in Cellular Manufacturing System

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In this paper, a comprehensive mathematical model is proposed for designing cellular manufacturing system. The model integrates cell formation and cell layout problem with consideration of alternative routes. The model attempts to minimize intercellular movements distance unit subject to satisfying demand requirement for the parts, limits on machine capacities, and limits on the size of the cells. The model identifies machine cells, sequence of them in the linear layout, and quantity of each part that will follow each process route. Also, a constraint enforcing work load balancing among machines is included in the model. Due to the complexity and combinatorial nature of this model, a combination of grouping genetic algorithm (GGA) and linear program (LP) is proposed to solve the model. Machine cells and their respective location in the layout are simultaneously determined by GGA. Consequently, the production quantity of each part in each route is determined by LP sub-problem. A numerical example is used to test the computational performance of the proposed algorithm.

01514
Global Cost Optimization of Post-Tensioned Prestressed Concrete I-Girder Bridge System

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In this paper, cost optimum design of a simply supported post-tensioned prestressed concrete I-girder bridge system (precast girder with cast-in situ reinforced concrete deck slabs) is presented. For a particular span of the girder and width of the bridge, the design variable parameters considered for the cost optimization of the present bridge system are various cross sectional dimensions of the girder, tendon size i.e. no. of strands per tendon, total no. of tendon, tendon configuration and layout along the span, spacing of girders e.t.c. The objective function under consideration is minimization of the total cost of the bridge system considering the cost of materials including fabrication and installation. Explicit constraints on design variable parameters are derived from geometric requirements, minimum practical dimension for construction, architectural consideration and code restrictions and implicit constraints are considered according to AASHTO Standard Specifications (AASHTO 2002). As the present optimization problem is characterized by having multiple local minima a global optimization algorithm which is capable of locating directly with high probability the global minimum and minimizing directly an objective function of mixed continuous, discrete and integer variables without requiring information on gradient or sub-gradient. A computer program is coded in Visual C++ to describe the design of the bridge girder with all the features of the girder, the objective function, the implicit constraint functions, explicit constraints and for analysis of the structure and then linked to the optimization algorithm. A design recommendations and aids for post-tensioned I-girder bridge system are developed based on optimized results to achieve a feasible and acceptable design. The proposed cost optimum design approach has been demonstrated through a real life project (Teesta Bridge, Bangladesh) which leads to a considerable cost saving while resulting in practically viable optimal design.

01519
A Parallel Approach to Resource-Constrained Task Scheduling Problem

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The task scheduling problem (TSP or SP) is a well known topic. Basically it consists of a group of task that should be executed (activated, started) somehow, spending the least time possible. The classic problem consider, besides tasks, the precedence and the processing units (PU) in which those tasks will be executed. These units might have similar characteristics (homogeneous environment) or not (heterogeneous). For every task, a PU must be chosen to execute a particular task and at what moment that will happen. This work presents a parallel implementation to solve resource-constrained task scheduling problems (RCTSP or RCPSP). This approach is based on a well known technique where from the moment when a task is activated until the last considered period, a quantity of resources called profit (associated to the activated task) is available at each period. Thus, the quantity of available resources, at a given period, will depend on what tasks were activated until this period and when it happened. Some heuristics were used to handle this problem including concepts of GRASP and Evolutionary Algorithms. Based on the OpenMP and Message Passing Interface (MPI) patterns, this work showed the benefits of using parallel methods to speed-up the overall time spent to find a solution without compromising its quality. Also, a comparative analysis was done, between a stand alone OpenMP application, a stand alone MPI application and a hybrid implementation using MPI and OpenMP. Several experiments analyses were done with a variety of cases. These consist in a different amount of tasks and different levels of dependency between them. Tests showed satisfactory results, which, in some cases, the total speed-up obtained is proportional to the number of cores and/or machines (network nodes or cluster nodes) available. This way, the computational results showed that the proposed approach is an efficient way to solve the TSP.

01524
Parallel solution of contact shape optimization problems with Coulomb friction based on domain decomposition

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We shall first briefly review the FETI based domain decomposition methodology adapted to the solution of multibody contact problems in 3D with Coulomb friction. These problems play a role of the state problem in contact shape optimization problems with Coulomb friction. We use a modification of FETI that we call Total FETI, which imposes not only the compatibility of a solution across the subdomain interfaces, but also the prescribed displacements. For solving a state problem we use the method of successive approximations. Each iterative step of the method requires us to solve the contact problem with given friction. As a result, we obtain a convex quadratic programming problem with a convex separable nonlinear inequality and linear equality constraints. For the solution of such problems we use a combination of inexact augmented Lagrangians in combination with active set based algorithms. The unique feature of these algorithms is their capability to solve the class of quadratic programming problems

with the spectrum of the Hessian matrix in a given positive interval in O(1) iterations. The algorithms enjoy the rate of convergence that is independent of conditioning of constraints and the results are valid even for linearly dependent equality constraints. The discretized problem with Coulomb friction has a unique solution for small coefficients of friction. The uniqueness of the equilibria for fixed controls enables us to apply the so-called implicit programming approach. Its main idea consists in minimization of a nonsmooth composite function generated by the objective and the (single-valued) control-state mapping. The implicit programming approach combined with the differential calculus of Clarke was used for a discretized problem of shape optimization of 2D elastic body in unilateral contact. There is no possibility to extend the same approach to the 3D case. The main problem is the nonpolyhedral character of the second-order cone, arising in the 3D model. To get subgradient information needed in the used numerical method we use the differential calculus of Mordukhovich. Application of Total FETI method to the solution of the state problem and sensitivity analysis allows massively parallel solution of these problems and stable identification of rigid body modes which are a priori known. The effectiveness of our approach is demonstrated by numerical experiments.

01528
Applying Computational Intelligence in the Design of Moored Floating Systems for Offshore Oil Production

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With the advance of oil exploitation in deep and ultra-deep water, the use of floating production systems, based specially in ships and semi-submersible platforms, becomes more and more frequent. Floating systems are more susceptible to dynamic actions, resulting from environmental actions, than fixed platforms. Also due to the high indulgence of these systems, numerical tools had to evolve in order to consider not only the dynamic effects as well as the non-linear effects due to the large displacements which the unit is exposed to. In order to keep the floating units in position, mooring lines are used. The main characteristic of these lines is the slenderness in relation to length. The structural analysis is complex due to the high non-linearity originated form the slenderness. The mooring system must assure a rigidity such that the movement of the unit is minimal, without the involved forces exceeding pre-established safety limits. The dynamic behavior of the structure is represented by time series of the parameters of interest, such as: efforts, tensions, displacements, etc. The current tendency considers the use of dynamic simulation tools in the domain of time and a high number of analyses must be performed, demanding high computational time. The objective of this research is the application of surrogate models based in computational intelligence in order to predict the series, replacing the dynamic analysis with finite elements. In this way, the purpose is to find results for mooring lines configurations as good as those achieved in a dynamic analysis with finite elements, in considerably less time.

01530
Techniques for automatic generation of topologies applied to strut-and tie method

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The strut-and-tie method (STM) has been applied in the ultimate strength design of disturbed regions in reinforced concrete structures. Although this model needs the general shape to be used in design, many possible STM model shapes may be usually identified. The choice among these available options may not be trivial, especially if the geometrical discontinuity of the structure is complex. Thus, a series of formulations based on topology optimization of continuum have been proposed for automatic generation of models' geometry. This work presents some formulations of topology optimization associated to the inductor elements as proposed by Pantoja et al (2009). Different models automatically obtained can attest the efficiency of these formulations in obtaining the topology to be used by the STM.

01535
A Method to Improve the Calculation of the Bicriteria Pareto Frontier

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If the optimization design problem considers multiple conflicting objectives, Pareto-optimality results in a number of trade-off optimal solutions shaping the Pareto frontier. Each of these solutions to the multicriteria problem represents a point in the boundary of the feasible objective space, such that the improvement in one of its components results in the worsening of any other component. In calculating these points it is important to get their uniform distribution and not include non Pareto or local Pareto solutions. The goal of this paper is to study methods of calculating the Pareto frontier and to purpose improvements towards obtaining a well-distributed and well-representing set of points for a bicriteria problem. Moreover, this work tries to realize the relationship among the design variables associated with the Pareto solutions, in order to get insight in changing one solution by another solution.

01537
Multidisciplinary Optimization of the De-boost Hybrid Motor for the Brazilian Recoverable Satellite

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This work presents a multidisciplinary optimization technique applied to the design of a hybrid rocket motor for the de-boost system of a small recoverable satellite. For some specific missions, hybrid rocket technology may become a better choice due to its inherent advantages over more traditional chemical propulsion systems.

The Brazilian Recoverable Satellite Platform (SARA) relies on a propulsion system for orbital de-boost. We considered a hybrid motor as propulsive technology. After that an optimization algorithm was developed to help propose a motor design. The hybrid motor was based on liquefying fuel (solid paraffin) and nitrous oxide propellants, following the experience of the Hybrid Propulsion Team from University of Brasilia – Brazilin operating such propulsion systems. The multidisciplinary configuration optimization technique was entirely based on geometrical operating parameters of the motor, rather than performance to facilitate further design and fabrication. Results from the code presented a hybrid motor which was considered a competitive alternative for the de-boost engine if compared to the traditional chemical systems, solid and liquid bipropellant.

01544
Optimization of linear and non-linear one-dimensional visco-elastic isolators for passive vibration control

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Recent progress in material processing and manufacturing have motivated increased interest of the scientific community in material optimization. It is obvious that better solutions can be identified by material optimization combined with other optimization methods than for instance by strict shape optimization of a given material. Tailoring material properties to achieve the optimal response to a given solicitation provides an important input to the new materials development. Results are relevant not only in cases when the new material can be readily produced. Other results can be understood as future changes for material processing. This contribution is focused on to optimization of material parameters characterizing one-dimensional passive vibration isolator. It is assumed that a mass of a given value is connected through a passive isolator to a fixed support. The mass is excited by a time dependent set of forces. The objective is to determine the isolator characteristics which will provide an optimal dynamic performance of the system. Following engineering practical requirements, the reaction exerted by the support and the displacement exhibited by the mass are the decisive criteria for optimization. Therefore the cost functional involves the minimization of a weighted average of the maximum transient and steady state response amplitudes for a set of predefined dynamic loads. The optimal one-dimensional isolator mechanical characteristics, can be thus specialized depending on the material model assumed. Methods of discrete material models are implemented. Two approaches are presented. In the first one the design space is composed by non-linear load-displacement curve of each spring contained in the discrete material model, while all dampers are linear viscous. Dynamic stability is assured by non-decreasing load-displacement curves. In the second approach all springs and dampers are linear and tailoring is enabled by adjusting a negative stiffness component and an additional tuning mass. As proven by Lakes and co-workers, extreme material properties (i.e. exceeding properties of each constituent) in terms of the stiffness as well as damping, is possible to reach when at least one spring component of the discrete model exhibits negative stiffness. In this approach the dynamic stability must be verified by standard methods. For the first approach a computational tool in Matlab environment was developed. Several material models can be implemented. The complex stiffness approach is used to formulate the governing equations in an efficient way. Steady-state solution is obtained by an iterative process based on the shooting method. Extension of the shooting method to the complex space is presented and verified. Optimization is based on generic probabilistic metaheuristic algorithm, simulated annealing. For the second approach analytical solution is presented in complex space. Then the optimization is performed by parametric and sensitivity analyses. The results obtained can facilitate the design of elastomeric materials with improved behaviour in terms of dynamic stiffness. Both approaches confirm important role of quasi-zero stiffness and negative components in passive vibration control.

01551
Mathematical framework for the open pit mine planning problem

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The general open pit mine planning problem can be essentially formulated as follows: given an estimation of the value (grade) distribution in situ, the decision-maker needs to determine the sequence of extraction in order to define the economic sequence of blocks (basic units of extraction), satisfying logical, physical and capacity constraints and maximizing the total discounted benefit of the exploitation. The traditional models for this problem have been constructed by using discrete 0-1 decision variables, giving rise to large-scale combinatorial and Mixed Integer Programming (MIP) instances. In this talk we present these discrete approaches and we also propose a new mathematical framework for the open pit mine planning problem, based on continuous functional analysis. For this, we introduce a continuous approach which allows for a refined imposition of slope constraints associated with geotechnical stability. The framework introduced here is posed in a suitable functional space, essentially the real-valued functions that are Lipschitz continuous on a given two-dimensional bounded region. We derive existence results and investigate some qualitative properties of the solutions.

01553
Optimal design of adaptive hybrid active-passive sandwich structures

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The use of piezoelectric patches is a common and widespread technique for vibration reduction and attenuation that allows for the development of efficient vibration control strategies in a wide frequency range when applied to composite laminated sandwich structures with viscoelastic core. On the other hand, this combination of active and passive damping treatments can be a challenge when optimal design for vibration reduction is at stake, often leading to a problem where continuous and discrete design variables coexist. In this paper we describe recent developments in the optimization of such laminated sandwich structures with viscoelastic core and exteriorly bonded piezoelectric patches. Our objective is to reduce vibration levels by increasing damping, both actively and passively. The design variables are chosen among the geometric and material parameters of the sandwich structure as well as control gains. The position of the patches is also a design variable when determining optimal patch locations for maximum vibration attenuation. The design constraints include, stress failure criteria, maximum displacements, maximum voltage in the piezoelectric patches, and weight restrictions. Optimization is conducted using essentially gradient based techniques, such as the Feasible Arc Interior Point Algorithm and, when appropriate, evolutionary strategies, such as genetic algorithms. Modelling and analysis of the dynamic behaviour of the sandwich structures is conducted using a plate/shell finite element developed specifically for optimization applications, incorporating frequency dependent material data, as well as the piezoelectric capabilities and associated control laws. Applications are presented and discussed and, whenever possible, results are compared with alternative solutions, obtained using different numerical models and optimizers.

01554

Optimization of precast reinforced and prestressed concrete bridge sections using the genetic algorithms technique

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This work presents a developed program for cost optimization of precast prestressed concrete bridge cross-sections using the Genetic Algorithms technique. From the known general geometrical parameters of the bridge, such as deck width and bridge span, the optimization process, using the developed program, is triggered to find out the optimal solution which lead to the number of girders, girder size, the required number of prestressing strands, the slab thickness and slab steel. Two examples of actual constructed bridges, found in the literature, were optimized using the developed program. The obtained results have proven the efficiency of the developed program.

01555

Optimal design of reinforced concrete «T» beams under ultimate loads

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The present paper deals with the structural design optimization of reinforced concrete beams under ultimate design loads. First, an analytical approach of the problem, based on a cost-safety criterion and a reduced number of design variables, is developed. Then, the optimization procedure is applied to the design of reinforced concrete beams of both rectangular as well as « T » cross-sectional shapes. It is shown, among other things, that the problem formulation can be cast into a non linear mathematical programming format. Also, the feasible solution spaces and the optimal solutions are discussed using graphical as well as numerical solutions. Typical examples are presented to illustrate the applicability of the formulation in light of the current French BAEL "Béton Armé aux Etats Limites" regulatory design framework (a slightly different version of the corresponding Euro- code 2 provisions). The results have then been confronted to those derived from the classical design solutions of RC beams with prismatic cross sections. The optimal solutions show clearly that substantial savings can be made in the predicted amounts (and hence the global costs) of construction materials to be used (essentially concrete and reinforcing steel).

01556

Using of neural network and genetic algorithm in multiobjective optimization of collapsible energy absorbers

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In this article,the multiobjective optimization of cylindrical aluminum tubes under axial impact load is presented. Absorbed energy and specific absorb energy are considered as objective functions while

the mean crush load should not exceed allowable limit.The geometric dimentions of tubes including diameter and length of tube are selected as the design variables.The Non-dominated sorting Genetic algorithm –II (NSGAII) is applied to obtain the Pareto optimal solutions.A back-propagation neural networks(ANNs) is constructed as the surrogate model to formulate the mapping between the variables and the objectives.The finite element software ABAQUS/Explicit is used to generate the training and test sets for the ANNs.Validating the results of finite element model,several impact tests are carried out with drop hammer.

01563
Optimization of energy absorption characteristics of corrugated aluminum tubes

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The protection of structure under impact loading often necessitates the need for energy absorber, devices designed to absorb the impact energy in a controlled manner and hence protect the structure under consideration. Thin-walled tubes are widely used as energy absorber in various vehicles and moving parts. The objective of the present study is to optimize the energy absorption characteristic of tubes with corrugation. The corrugations are one of the dominant factors in influencing the deformation mode and they reduce fluctuations in the load–displacement curves for circular tubes. Experimental and numerical investigations were carried out to optimize corrugated aluminum tubes for their use in design for energy absorption. Geometrical parameters, such as corrugation amplitude, corrugation wavelength, number of corrugation and tube wall thickness were considered to obtain the design space. Various set of numerical simulations were carried out using ABAQUS. From the numerical results, mathematical models were created using response surface methodology (RSM). The mathematical models developed using experimental data and the numerical data were used as objective functions for optimization of the corrugation geometry. The mathematical models were also used to predict the energy absorbed and deformation. The influence of various design parameters on energy absorption of corrugated tube has been analyzed and is discussed.

01564
Structural optimization using artificial bee colony algorithm

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This paper presents an artificial bee colony (ABC) algorithm for structural optimization of planar and space trusses under stress, displacement and buckling constraints. In order to improve the performance of the classic ABC algorithm, modifications in neighborhood searching method, onlooker phase, and scout phase are proposed. Optimization of different typical truss structures is performed using both the classic ABC and the modified ABC (MABC) algorithms. In comparison with the classic ABC algorithm, the MABC algorithm reaches lighter designs with a better convergence rate in all examples. The numerical results, which are compared with previously reported results in the literature, indicate the efficiency of the proposed MABC algorithm.

01566
Cost Optimization of Reinforced Concrete Plates

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In civil engineering in the traditional design of reinforced concrete (RC) members a trial and error process is usually applied. An assumed cross-section is checked for strength, serviceability and other requirements of the design code. If the requirements are not satisfied a new cross-section is adopted and repeatedly checked. This design process does not take into account the cost of the structural element and thus usually lead to its unnecessary over dimensioning. Structural optimisation is an effective technique that yields economical and rational design and leads to effective cost reductions The paper presents the cost optimization of reinforced concrete on two sides simply supported rectangular plates under uniformly distributed load. The task of the optimization was to obtain the cross section and reinforcement area of the most economical plate for a defined span and load. The optimization was carried out for spans from 5 to 10 m and variable uniformly distributed imposed load of 0 to 20 kN/m2. Different concrete and steel grades were also included in the optimization. The plates were designed in accordance with Eurocodes for both the ultimate and serviceability limit states. A detailed objective function of the plate's manufacturing costs was given including the material and labour cost items. The manufacturing costs include the material costs of the concrete, reinforcement and formwork panels. The labour costs were added together from the costs of the cutting, placing and connecting of the reinforcement as well as from the labour costs for concreting of the plate, consolidating and curing of the concrete. The cost objective function is defined in an open manner and thus could be modified to take into account different economical conditions. The structural optimization was performed by the nonlinear programming approach, NLP.

01567
Parametric Studies on Dynamic Analysis of Reverse Curved Cable-stayed Bridges

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Cable-stayed bridges with modern distinctive styles are increasing in number worldwide. These bridges are now built in more unusual styles for structural and aesthetic reasons. Modern high speed highway systems have created complex roadway alignments which control the bridge geometry and have thus resulted in bridges with skewed supports and curved alignments. To meet the demand of increasing highway complexity, horizontally curved bridges are to be adopted. Curved cable-stayed bridges are becoming more popular in modern highway system including interchanges due to aesthetic desirability, superb torsional rigidity of box girders, uninterrupted traffic and faster rate of erection during construction. The unique structural styles of these bridges not only beautify the environment but also add to the difficulties in accurate structural analysis. The bridge analyses discussed in this paper are for innovative long-span reverse curved cable-stayed bridges. Several models consisting of multi-cell concrete box girder and having range of centre span between 200m to 600m are studied. Parametric studies on cable-stayed bridges are performed for investigating the individual influence of different parameters such as span of bridge, offset of

pylons, tower typologies, number of planes of cables, etc. The influence of such kind of parameters on the analysis and the structural behaviour of cable-stayed bridges have been examined in the study. Though static analysis of bridges is well defined, the results are not very realistic. Dynamic response of bridges is, however, a complex phenomenon and is less understood in curved bridges. In order to enhance our understanding in this area, non-linear dynamic analysis is performed on a reverse curved cable stayed bridge to obtain dynamic characteristics such as natural frequencies, mode shapes etc. Results indicate the occurrence of many closely spaced modal frequencies with spatially complicated mode shapes. Twelve global modes are identified, in which the girder motion dominated most of the modes. The introduction of curve alignment induces significant torsion in deck which increases with pylon offset. The complex behaviour of the cable-stayed bridge gets more complicated with the curve alignment.

01570
CO2 Optimization of Reinforced Concrete Cantilever Retaining Walls

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This paper describes a methodology to design reinforced concrete (RC) cantilever earth-retaining walls typically used in road construction based on minimum embedded CO2 emissions. The traditional approach to design does not fully optimize the use of materials. However, structural optimization methods are a clear alternative to designs based only on experience. Here, the design involves optimization by a simulated annealing (SA) algorithm applied to two objective functions, namely the embedded CO2 emissions and the economic cost of reinforced concrete walls. The formulation of the problem includes 20 design variables: four geometrical ones dealing with the thickness of the kerb and the footing, as well as the toe and the heel lengths; four material types; and 12 variables for the reinforcement set-up. All the structural constraints have been imposed using Spanish codes, as well as habitual recommendations in this type of projects. Results from the SA algorithm application indicate that embedded emissions and cost are closely related and that more environmentally-friendly solutions than the lowest cost solution are available at a cost increment which is less than 1.4%. In addition, it is verified that a reduction of 1 euro in cost causes a reduction of 2.20 kg of emissions of CO2. Further, the economic walls use in average 4.9% more concrete than the best environmental solutions, though the latter solutions need 1.8% more steel. Finally, the methodology described will enable structural engineers to mitigate CO2 emissions in their RC structural designs.

01571
Application of the micromechanical models for estimation of the optimal design of metal-ceramic composites.

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Metal-ceramic composites produced by melt infiltration of the ceramic preform were studied. The ceramic preform of the studied materials is manufactured through freeze-casting process. The microstructure of these materials can be presented as distribution of the lamellar domains. Micromechanical models were used for the calculation of the effective elastic properties of the domains. The minimum compliance problem was solved for sample subjected to the four-point bending test. The optimal orientation and volume fracture of the micro constituents were identified using different element models. The difference between the initial and optimized design was analyzed. The convergence of the provided optimization procedure was very rapid.

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01572

Shape and topology optimization in problems of electromagnetic waves propagation

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Our work deals with mathematical modelling of electromagnetic waves in dielectric nanostructures. The aim is to simulate numerically optical properties of specific configurations involving nanoparticles coated by other materials. The optimal design of such ``coatings" is the main focus of this study. For this purpose classical methods of the shape and topology optimization are employed, whereby the merit of particle "invisibility" is approached using extinction efficiency minimization. A two- and three-dimensional mathematical models for the propagation of electromagnetic waves in a heterogeneous medium are derived from Maxwell's integral laws, assuming time-harmonic fields and linear constitutive laws. Two-dimensional model is based on the Helmholtz equation for the scattered Hertz potential. Three-dimensional model is based on the vector wave equation for the scattered magnetic field intensity. The computational domain is truncated by a fictitious border, where the transparent absorbing boundary conditions are imposed. The weak forms of the governing equations are discretized using finite element methods (based on triangular and quadrilateral finite elements in two dimensions, Nédélec hexahedral elements in three dimensions). Problems of optimal topology are treated by the SIMP method (Solid Isotropic Material with Penalization), whereas the domain method is used for the shape optimization. Sensitivity analysis of cost functionals with respect to the design variables developed and implemented numerically along with algorithms for topology and shape optimization based on the method of moving asymptotes. Due to an enormous computational costs needed to solve three dimensional state problem equations, a parallel algorithm was proposed providing almost linear speed-up with respect to the amount of computational cores of cluster processors. Several numerical simulations in two dimensions are presented. The extinction efficiency of multi-layered particle using shape optimization was minimized. Using means of topology optimization optimal material distribution of the design layer having low refractive index was found. Consequently, the result of the topology optimization was verified and further smoothed using shape optimization. Properties of a cloaking layer having optimal topology were studied using numerical simulations based on a 3D computational model.

Optimization in Identification and Inverse Problems

2

01006
Inverse Problems for the Determination of Rheological Parameters of Inelastic Viscous Fluids

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Non Newtonian fluids, which present several relevant engineering applications, are characterized by their complex micro-structures. A great variety of constitutive models has been proposed in the last decades, trying to characterize the mechanical behavior of these fluids, since they form a wide class of real fluids, encompassing suspensions of particles (e.g. blood, paint, ink, and food products), polymer melts and solutions. The generalized Newtonian model (GNL) is a modification of the classical Newtonian law in order to accommodate a shear-rate dependent viscosity, predicting, in this way, phenomena such as shear-thinning, shear-thickening and viscoplasticity. The Carreau-Yasuda equation is a well-known example of a GNL model employed to predict the behavior of many fluids of industrial interest. It depends on five rheological parameters, namely a zero-shear-rate viscosity, an infinite-shear-rate viscosity, a dimensionless power-law index, a fluid time constant and a scalar parameter to fit the constant and shear-thinning viscosity regions of the Carreau flow curve. The aim of this work consists on the application of a stochastic algorithm originally designed for engineering optimization - namely, the Generalized Extremal Optimization, or simply GEO - for the solution of inverse problems in the field of non-Newtonian fluid mechanics. This algorithm is included in the framework of meta-heuristic global search methods, with the major advantage of requiring just one free parameter to be adjusted. In this work we are interested in the determination of rheological properties of Carreau-Yasuda fluid flows, through the solution of inverse problems using synthetic experimental data related to the velocity profile. For that purpose, some applications were considered, concerning shear-thinning, shear-thickening and viscoplastic fluid flows. The direct solution is obtained via a finite element methodology, namely the Galerkin Least-Squares (GLS) method. The zero and infinite shear-rate viscosity, the power-law index, the time constant and the fitting scalar parameter have been searched within the range of interest.

01048
Engineering Optimization Modelling

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In the engineering area it is quite often necessary to formulate, model and solve problems. The more representative and realistic modelling of engineering systems are nonlinear modelling. Usually this involves defining an objective function that someone wants to optimize subject to

constraints. In this work is presented the weighting coefficients method – Bilich method which consists in encoding directly into the objective function information which is usually encoded in the form of constraints. This procedure is especially helpful in nonlinear modelling and nonlinear dynamics. It is explained the advantages of the use of weighting coefficients in contraposition to the disadvantages of the use of constraints in engineering mathematical programming. It is shown how some special cases of objective functions such as multinomial distribution (discrete functions) and gamma and exponential distributions (continuous functions) with constraints can be represented by an equivalent function with weighting coefficients. Finally a general proof of the weighting coefficients method is derived. In conclusion, a new manner in modelling and optimizing engineering systems and problems is presented that have many advantages vis-à-vis the formulation with constraints. One disadvantage or most probably one opportunity to see formulation of problems in a different way is that this new approach demands a lot more of creativity in formulating problems than before.

01052

Generalised diffusion based regularization for inverse problem in images processing

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Due to the ill-posedness of inverse problems, it is important to make use of most of the a priori informations while solving such a problem. These informations are generally used as constraints to get the appropriate solution. In usual cases, constrains are turned into penalization of some characteristics of the solution. A common constraint is the regularity of the solution leading to regularization techniques for inverse problems. Regularization by penalization is affected by two principal problems: - as the cost function is composite, the convergence rate of minimization algorithms decreases - when adequate regularization functions are defined, one has to define weighting parameters between regularization functions and the objective function to minimize. It is very difficult to get optimal weighting parameters since they are strongly dependant on the observed data and the truth solution of the problem. There is a third problem that affects regularization based on the penalization of spatial variation. Although the penalization of spatial variation is known to give best results (gradient penalization and second order regularization), there is no physical underlying foundation. Penalization of spatial variations lead to smooth solution that is an equilibrium between good and bad characteristics. Here, we introduce a new approach for regularization of ill-posed inverse problems. Penalization of spatial variations is weighted by an observation based trust function. The result is a generalized diffusion operator that turns regularization into pseudo covariance operators. All the regularization informations are then embedded into a preconditioning operator. On one hand, this method do not need any extra terms in the cost function, and of course is affected neither by the ill-convergence due to composite cost function, nor by the choice of weighting parameters. On the other hand, The trust function introduced here allows to take into account the observation based a priori knowledges on the problem. We suggest a simple definition of the trust function for inverse problems in image processing. Preliminary results show a promising method for regularization of inverse problems.

01124
A Bayesian inference approach to estimate elastic and damping parameters of structures subjected to vibration tests

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In the present work, a Bayesian approach is employed to solve an inverse problem of parameter estimation aiming at computing the stiffness and the viscous damping coefficient of a two degree-of-freedom spring-mass-damper system. Simulated measurements derived from the solution of the corresponding forward problem corrupted with noise are used for the estimation process of the target parameters. In this preliminary work, the model parameters are regarded as correlated random variables with Gaussian distribution. The errors in the simulated experimental data are additive and also Gaussian distributed with zero mean and unknown covariance matrix. With these hypotheses about the unknown parameters and measurement errors, the posterior probability density function becomes a multivariate Gaussian distribution which is completely specified through the mean values and covariance matrix of the parameters and thus analytically tractable (for the current work, the parameter space is two dimensional). The mean values of the parameters are computed from the maximization of the posterior probability density function. For independent noise samples and non-informative prior, maximization of the posterior probability distribution becomes equivalent to the maximization of the likelihood function or the minimization of the weighted least-squares norm. Assuming independent noise samples with equal variance it is also possible to estimate the unknown (a priori) variance of the experimental error. Finally, with the mean values and covariance matrix of the model parameters, Monte Carlo simulations are performed in order to provide the confidence regions for the time-domain predictions provided by the model.

01134
A modified search procedure for permutation-based ant colony algorithm for resource constrained scheduling

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Different methods have been adopted to solve Resource constrained scheduling problems (RCPSP); nowadays meta-heuristic approaches are used widely and successfully in this area. Serial schedule generator scheme (SGS) has been proven to be a successful way for solving RCPSP with different objective functions. Permutation based representation has been used by most of the meta-heuristic approaches for the problem as a requirement for SGS. In this paper, a lexicographic permutation generator (LPG) routine has been suggested to decrease searching space for an ant colony optimization -ACO-algorithm. In the proposed ACO the selection of permutation is transformed to finding a number as a representative for the permutation. Ant decides on the permutation first and builds its schedule using SGS. To show the efficiency of searching algorithm and decision variable definition a case study has been solved using proposed model. The objective here is to find maximum profit for the different credit limits and associated with different durations. The model has shown to be capable of producing validated results.

01136

An efficient parameter identification approach of large-scale dynamic systems by a quasi-sequential interior-point method based on multiple data-sets

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Industrial mathematical models are increasingly used in process control and optimization. Based on chemical, physical and thermodynamic principles, the models are usually described with a large number of nonlinear differential-algebraic equations (DAEs) in which model parameters must be identified based on measured data-sets. The quality of the parameter identification plays an essential role in the online model utilization, such as in the model predictive control (MPC). Therefore, multiple records from a series of dynamic curves are needed to increase the accuracy of the parameter identification. In this work, we consider dynamic parameter estimation and data reconciliation problems based on the error-in-variables method (EVM) approach. EVM approach for parameter identification has been shown to be superior to standard least-squares techniques, and it also has the advantage that both parameter identification and data reconciliation problems can be solved simultaneously. To obtain more reliable parameter estimates, usually a series of measured data sets from different operating points will be used for the estimation. The proposed approach is formulated by converting the original parameter estimation problem, which is formulated as nonlinear DAEs constrained optimization problem, into a large-scale NLP problem by implementing collocation on finite elements. It is noted that in this formulation the model equations and associated variables for each measured data set i (1, …, N) have to be included and treated simultaneously. Therefore, it leads to a NLP problem with a very high dimension which cannot be addressed efficiently by existing solution approaches and commercial software. In our work, an approach to parameter identification for steady-state systems [1] is extended to dynamic systems. This allows an efficient identification of parameters in large-scale dynamic models. A three-layer computation framework is developed. The upper layer serves to optimize the model parameters, the middle layer for optimizing the input variables and the lower layer for calculating the state variables. The overall problem is decomposed into sub-problems for each data set. Each sub-problem is then solved by the quasi-sequential method [2] with improvement to take advantages of the interior-point method. In this way, a parallel computation scheme is made possible. The work will be presented with theoretical development and results of identifying time-independent and time-dependent parameters of several chemical engineering models.

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01172

An iterative reconstruction of source functions in a potential problem using the method of fundamental solutions

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The identification and reconstruction of source functions from boundary data is an inverse problem with many applications in nondestructive testing. In this work, we address the reconstruction of characteristic source functions in a potential problem, from the knowledge of full and partial boundary data. The inverse problem is formulated as a transmission problem and the goal is to retrieve the boundary where the transmission conditions are considered. This inverse problem is solved using a direct approach based on the Cauchy data reconstruction using the Method of Fundamental Solutions and the Levenberg Marquardt method (direct approach). A second optimization method will also be addressed and we will present some numerical simulations in order to compare both methods.

01185
Identification of structural and transport parameters of soils from column tests

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Application of optimization techniques for identification of structural and transport parameters of soils: permeability, effective porosity, dispersivity and sorption factors is discussed. Permeability is identified from two and three column tests of U-shape system and appropriate analytical model of flow. The method allows for making experiments with single soil sample or two samples of different permeability. The sources of data for identification of the transport parameters are results obtained from column tests for inert and sorbing ions migrating through different soils. The solutions of pde problems are based on finite element method for non-steady transport. Different loading modes and models of boundary conditions as well as scale effect are considered. The procedures use both global and local optimization methods.

01192
Optimization of a tube bundle immersed in a fluid

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For many heat exchangers, the main component is a bundle of metallic tubes fixed elastically at their ends and immersed in an incompressible inviscid fluid like water. It is important to study the free oscillations of the tubes around equilibrium, and the influence of the fluid on the respective eigenfrequencies. In the present talk we present a method, based on Bloch wave techniques, for computing the eigenfrequencies of such a bundle of tubes and for maximizing the lowest one. As the oscillations are small, the motion of the fluid can be supposed to be irrotational and thus the state of the fluid is fully described by the pressure of the fluid. It satisfies a Laplace equation in a two-dimensional domain (a cross-section of the heat exchanger), and thus the eigenfrequencies of the system are defined in terms of eigenvalues of an operator involving the Laplace equation in the area occupied by the fluid and a specific boundary condition at the contact with the tubes. Since typical heat exchangers are made of many tubes (hundreds or thousands) it is not feasible to solve the full Laplace equation. This is why Bloch techniques are used: an infinite number of tubes is considered, periodically arranged, and the oscillations are supposed to have a periodic component superimposed over a plane wave. For each wave vector describing the plane wave, two cellular problems are solved in order to characterize the

eigenfrequencies of the system. Two of the authors have designed a general approach for solving numerically partial differential equations involving periodicity conditions, in the context of inverse homogenization problems. The code deals with the most general notion of periodicity in 2D, defined by two arbitrary linearly independent vectors. For the present work, the code has been adapted in order to treat Bloch conditions. Because of manufacturing requirements, the tubes should have all circular cross-section and should be all identical. This is why shape optimization is not an appropriate tool. The use of topological gradient is not advisable either, since it applies to infinitesimal inclusions only. An optimal arrangement of the tubes is searched for, with the goal of maximizing the lowest eigenvalue, by varying the periodicity vectors and also the number and positions of the tubes in the periodicity cell. A steepest descent algorithm is used, based on the derivative of the lowest eigenfrequency (or eigenfrequencies) with respect to the vectors defining the periodicity and with respect to tube positions. The algorithm tracks the evolution of critical wave vectors (those giving rise to the lowest eigenfrequencies). Numerical examples will be presented.

01196

Application of a hybrid optimization method for identification of steel reinforcement in concrete by electrical impedance tomography

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In this paper we consider the problem of detection of inclusions in concrete by the Electrical Impedance Tomography (EIT). The EIT can be used as a non-destructive technique to evaluate concrete structures. In this technique, electrical current is injected between electrodes placed on the external boundary of the structure and electrical potentials are measured at the other electrodes. Such measures are used to achieve an image of the conductivity distribution inside the structure, which is a non-linear inverse problem. The aim of the present work is to identify the position and size of the steel bars in a section of the concrete structure. In this case, we adopt a two dimensional model for the problem, assuming the number of bars, their size and position in the section as unknowns. In order to solve the inverse problem, the set of inclusions that minimizes the difference between measured boundary potentials and computed ones is searched. The forward problem, in which boundary potential values are computed for a given current injection in a body with known conductivity distribution, is solved by the Boundary Element Method. Such problem is governed by Laplace's equation that comes from simplifications of Maxwell's equation. In previous works, a deterministic gradient-based optimization method was used to solve inclusion detection problems in which the number of inclusions is "a priori" known. In the problem considered here it is assumed that the number of inclusions is unknown, demanding a strategy that can handle integer optimization. A hybrid optimization strategy that combines the advantages of Genetic Algorithms (GA) and the Levenberg-Marquardt method is proposed. First, a real code Genetic Algorithm is used to find some approximations for the solution of the identification problem. In this step, the unknowns are the number of steel bars, their size and position. In a second step, solution candidates found with the GA are given as initial guess to the Levenberg-Marquardt Method in order to improve the approximation of the inclusions size and position. In this second step, the number of inclusions is maintained fixed. Although the GA require a large number of evaluations of the

minimization function to reach the minimum, the convergence to a local extrema can be avoided. On the other hand, the Levenberg-Marquard method is faster and converges to the solution if a good initial guess is provided. Therefore, the hybrid strategy proposed tries to take advantage of the best features of both methods. In order to test this strategy, numerical experiments are presented. Since the measured data are not available, the boundary potential measurements are obtained computationally. So, in order to make the above described experiments more realistic, potential measurement errors are numerically simulated considering the Additive White Gaussian Noise model.

01209
Parameter Identification of the Soil-Water Characteristic Curve of Brazilian Residual Soils Using Hybrid Optimization Methods

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In the last decades, theories have been formulated to interpret the behavior of unsaturated soils and found to be consistent with the experimental response. Besides, several techniques for field and laboratory testing have been developed, as well. However, the experimental determination of unsaturated soil parameters is costly, time-consuming, requires particular test equipments and experienced technicians. As a result, these theories application are limited to academic researches and are barely used in engineering practice. To overcome this issue, several researchers proposed equations to mathematically represent the experimental behavior unsaturated soils. These propositions are based on physical indexes, soil characterization, and current laboratory tests or are simply curve fitting. The relationship of the volume of water in the soil pores and soil suction, conventionally referred to as the soil-water characteristic curve (SWCC) is an useful tool in the prediction of the engineering behavior of unsaturated soils. The usual S-shape of the SWCC may be defined by four parameters: saturated volumetric water content, residual volumetric water content, air-entry value or bubbling pressure and volumetric water retention capacity . There are many equations to mathematically represent SWCC. Some are based on the assumption that its shape is directly related to the pore distribution, and, consequently to the grain size distribution. Others assume that the curve can be directly estimated from physical properties of soils. These proposals are simple and convenient for practical use, but are substantially incorrect since they disregard the influence of moisture content, stress level, soil structure and mineralogy. As a result, most of them have limited success depending on soil types. Nonetheless, all propositions present a number of parameters that are calibrated by curve fitting of the experimental data. Besides, it is not unusual to include the residual volumetric water content or the corresponding soil suction among these parameters, since some laboratory tests are limited to a narrow soil suction range. This work presents the results of the use of implicit inverse problem techniques to assess the parameters of the equation proposed by Van Genuchten. This proposition has already proved to be adequate to fit the experimental data of Brazilian Residual soils. The optimization problem was solved using first a global optimization method (Genetic Algorithms) with only a few iterations to find a point close to the global optimum and a gradient based local method (Levenberg-Marquardt) to refine the solution. The method was applied to residual soil experimental curves from different sites in Brazil. Despite the relatively low number of parameters to be determined, the results indicated that the global optimization method was not efficient to assess the global optimum and a hybrid method was the best approach.

01211
On the Multi-Mode, Multi-Skill Resource Constrained Project Scheduling Problem (MRCPSP-MS)

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In this paper we describe an extension of the Resource-Constrained Project Scheduling Problem (RCPSP). A literature review is presented to place our research in its proper context. The problem presented here belongs to the class of the optimization scheduling problems with multi-level (or multi-mode) activities. This means that the activities can be scheduled at different modes, each mode using a different resource level, implying different costs and durations. Each activity must be allocated exactly one unit of each required resource and the resource unit may be used at any of its specified levels. The processing time of an activity is given by the maximum of the durations that would result from a specific allocation of resources. The objective is to find the optimal solution that minimizes the overall project cost, while respecting a delivery date. A penalty is included for tardiness beyond the specified delivery date. We present a formal description of the problem and a mathematical model for it. We also introduce the implementation algorithm for the problem. The implementation was designed using the JAVA language, and the algorithm proposed is based on a branch and bound procedure, using breadth-first search (BFS) project network traversing, among some heuristic rules to filter large subsets of fruitless candidates relative to resource levels combinations.

01219
Estimation of Nominal and Parametric Uncertainty Models for Debutanizer Towers in Oil Refineries

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The debutanizer tower is used in an oil refinery plant to stabilize the raw naphtha producing the liquefied petroleum gas (LPG) and the light naphtha. Generally, this tower has two control objectives: LPG quality specification, related to volume fraction of pentane and heavier components (C5+), and stabilized naphta quality specification, related to its vapor pressure. Many works dedicate efforts in the development of advanced process control strategies to guarantee the maximum productivity regarding the quality limits of both products, but three factors increases significantly the complexity of an efficient control: (i) the non-linearity and the complexity of the dynamic behavior of this equipment; (ii) difficulties that are inherent of many refinery process and related to disturbances in petroleum; and (iii) heat exchange network reusing the enthalpy of product streams to pre-heat the feed. A possible control strategy for this application is the multivariable robust control. This strategy is insensitive to differences between the actual system and the model of this system, used to design the controller. These differences are referred to a model/plant mismatch or simply model uncertainties. The design specifications of the controller are satisfied even for the worst-case uncertainty. For a correct implementation of such robust control algorithm, the development of an appropriate strategy for the estimation of nominal and parametric model is mandatory. This work presents a framework for the development of reduced nominal and additive uncertainty models using a sequence of likelihood parameter estimations. The first step – dynamic experiments – is the generation of local step tests by using a process simulator (e.g. UNISIM®) at different operational conditions.

The second step – plant model estimations – corresponds to one parameter estimation for each tested operational condition to determine linear time invariant plant models, valid in the neighborhood of each test. The third step – nominal model estimation – is a parameter estimation to obtain a linear time invariant nominal model in Laplace domain that best represents the mean behavior considering all possible plant models for a certain range of the frequency domain. The forth step – uncertainty model estimation – is a parameter estimation to obtain a additive uncertainty model in Laplace domain that represents largest distance between the nominal model and the plant models for a certain range of the frequency domain. This parameter estimation framework for the determination of nominal and uncertainty models is programmed in Matlab® with a friendly user interface and using basic optimization functions available in Matlab® Optimization Toolbox.

01237

Identification of Dynamic Model of Damaged Beam

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The article presents the results of experimental and analytical al investigations of an essentially non-linear dynamic system. The main concept of this paper is that, if a given type of damage converts a linear system into a non-linear system, then any observed manifestations of nonlinearity serve to indicate that damage is present. In most of the previous analyses, damages are characterized by changes in the modal parameters, for example, natural frequencies, modal damping ratios and mode shapes. The calculating process is done using data from the structure in some initial and usually assumed undamaged condition, and then is repeated at periodic intervals or after some potentially damaging event that triggers the assessment process. Structural parameters such as stiffness matrix constructed from identified modal parameters may also be used for damage detection and localization. These methods have prevented their use in most "real-world" applications. At first, it involves fitting a linear physics-based model to the measured data from both the healthy and potentially damaged structure. Often these models do not have the fidelity to accurately represent boundary conditions and structural component connection, which are prime locations for damage accumulation (Doebling et al. 1996). Also, this process does not take advantage of changes in the system response that are caused by non-linear effects. There is also research using other damage-sensitive features without the need to identify the modal parameters, such as novelty analysis with auto-regressive models. The construction of mathematical model satisfactorily describing or predicting operation of object, process or system is an integral part of any problem of prediction of dynamic behavior of mechanical systems. There are many types of damage that can cause an initially linear structural system to respond to its operational and environmental loads in a non-linear manner. One of the most common types of damage is cracks that subsequently open and close under loading. This type of damage may include fatigue cracks and cracks that result from excessive deformation. Vibration-based structural health monitoring consists in detecting damages in structures from changes in vibration features obtained from periodically spaced measurements. The author proposes to expand the phase space by taking into account the phase planes, namely, "acceleration – displacement" and "acceleration – speed". An interest taken into accelerations in dynamic systems is conditioned by the fact that these accelerations more sensitive to high-frequency components in oscillating processes. The author has defined behavioural peculiarities of phase trajectories and their mappings in the expanded phase space. It has performed the structural analysis of the phase trajectories obtained in the test records for oscillations of creaked beam in the expanded phase space.

01239
Estimating water-sided vertical gas concentration profiles by inverse modeling

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The solution dynamics of gases in liquids in the case of wind-stress induced turbulence challenges both experimenters and theoretical modelers. The gas concentration profiles in the water-sided mass boundary layer, which is as thin as 30-300 μm, are of particular interest. Appropriate modeling requires high-resolution measurements of concentration fields within this boundary layer. With conventional laser induced fluorescence LIF measurement techniques, it was only possible to measure concentration profiles in one vertical plane parallel to the main flow direction or a horizontal plane parallel to the surface up to now. In this paper, we present a new approach of determining profiles in several depth layers of the boundary layer in a plane perpendicular to main flow by a combination of an experimental setup and mathematical optimization techniques. The concentration field in the boundary layer is made visible by a fluorescent indicator for dissolved gas. The water-sided distance to the surface is marked by an additional dye that absorbs the fluorescent light as a function of the wavelength. So the light from each depth layer shows a different spectral composition. A spectrometer positioned above the surface sees the integral spectrum over all depths. This constitutes an inverse problem with Poisson-type noise and ill-conditioned design matrix for the identification of the depth-dependent gas concentrations from the measured integral spectra. We compare the results of classical least squares estimation with those of different robust estimation methods and analyze the identifiability with respect to the number of resolved depth layers.

01243
On Resource Complementarity in Activity Networks - Further Results

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We address the issue of optimal resource allocation, and more specifically, the analysis of complementarity of resources (primary resource or P-resource and supportive resource or S-resource) to activities in a project. We developed a mathematical model capable of determining the ideal mixture of resources allocated to the activities of a project, such that the project is completed with minimal cost. This problem has a circularity issue that greatly increases its complexity. We have developed a procedure which we illustrate by application to small instances of the problem, using complete enumeration over the decision space. The development of a more computationally efficient procedure awaits the second phase of this study.

01265
Simultaneous Estimation of Location and Timewise-Varying Strength of a Plane Heat Source Using Differential Evolution

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In the present work the Differential Evolution Approach (DE) is used to estimate unknown location and timewise-varying strength of a plane heat source placed inside a plate with insulated boundaries. The direct heat problem is solved by using the Orthogonal Collocation method. Transient temperature recordings computed at the boundaries of the region, modified by adding random errors, served as simulated experimental data for the inverse analysis. Then, test cases are presented aiming at illustrating the efficiency of this methodology in the treatment of an inverse heat conduction problem. The preliminary results indicate that the proposed approach characterizes a promising methodology for this type of inverse problem.

01299
Modeling of an inverse problem for damage detection using stochastic optimization techniques

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In this work, the inverse problem of identifying the presence and location of holes in a plate structure, with parameters described as random variables, is modeled using stochastic optimization techniques. The direct problem of obtaining the distribution of stresses in a plate containing damage can be modeled through the boundary element method for elastostatics. Identifying and locating the damage is an inverse problem, which can be solved using optimization procedures. For that, several numerical models can be created simulating the damage at different locations, and the values of the mean stress or the octahedral stress at pre-defined locations can be obtained numerically. By comparing the various sets of numerical stresses with the values of the measured stresses at the same locations, for a real damaged structure, a functional can be created from the differences between the numerical and the real stresses. The minimization of this functional will lead to the identification of the damage parameters, such as its type, size and location. Several parameters of the model, such as its geometry, material properties, boundary conditions, size and location of the damages, etc, are subject to uncertainties in a real structure. To account for the uncertainty in the model parameters, a stochastic treatment is done for the related random variables. Based on the uncertainties in the input variables, the uncertainties in the response variables can be assessed through response surfaces techniques. In order to obtain the response surfaces, a design of experiments approach is used, to consider the influence of each factor in the results obtained. A model for the variance of the functional is also obtained, leading to a second objective function to be minimized. The purpose of this work is to find a Pareto front of optimum values for this multi-objective optimization problem, and to use decision making procedures to evaluate optimum values considering various weights, or priorities, for each objective function. The multi-objective problem is solved by genetic algorithm.

01337
Output-only modal analysis of a beam-like structure using piezoelectric material (PZT/PVDF)

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Actually, the modal analysis of structures has its theoretical basis well-founded and its applications is a reality, including the output-only based modal analysis techniques that is becoming consolidated technique for new applications areas where is not possible or difficult to obtain the response of the model. Aiming at extend its area of application new kinds of sensors and actuators have been proposed and a field that has been emerged is that of the denominated smart materials. This paper discusses a development and implementation of procedure to obtain the modal parameters of a beam-like structure in an output-only modal analysis using smart material, more specifically, PZT and PVDF, as sensor. The results will be compared with the modal data obtained by a modal analysis and also by an output-only modal analysis using ordinary sensors aiming at evaluating the potentiality of the propose.

01349
Inverse problem of optimal layout of point chemical sources in the isotropic porous inhomogeneous media

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A problem of optimal layout of point chemical sources in the isotropic porous 3D media with single-phase two-dimensional filtration of almost incompressible chemical liquid compound is considered. Similar problems appear for the best placement of point chemical sources (or a network of point chemical sources) with the aim of obtaining the maximum for heat or gas energy feedback. Likewise and with slight modification such problems appear when developing new fields of multiproduct liquid admixtures and when restructuring the already producing fields (for instance, see [1-4]). It is shown that having assumed the coordinates of the placed chemical sources to be the controlled parameters, the problem can be considered as a parametric problem of optimal management of the distributed systems with point sources, moreover, the governing parameters-actions are the amount of liquid chemical compound (for single-phase filtration) and/or gas (for two-phase filtration), flowing from all point sources within a certain time period, and the meaningful constraints and the optimisation criteria in the mathematical model are being formed taking into account topological, technological and economical factors. Solvability of the developed mathematical model is studied. Issues of existence and uniqueness of a solution for the problem of optimal layout of point chemical sources (or for a network of point chemical sources) in the isotropic porous 3D environment are considered. The set

of minimum additional conditions which can be easily realised technically is formulated. Fulfilment of them provides a unique solution for the formulated inverse optimisation problem. For solution this completely formulated inverse problem together with initial constraints and additional requirements it has to be discretized, and after determination of the gradient of functional of the discretized problem with respect to the parameters to be optimized, the effective first order numerical optimisation methods are used.

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01350
Hybrid Global-Local Optimization for the Parameter Estimation of Parameters in Kinetic Models

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The estimation of parameters in kinetic expressions for time series data is essential for the optimization, design and control of many Chemical Systems. The objective is to minimize a weighted distance measure between the observations and predictions taken from the model. In this work a hybrid local-global optimization strategy, implemented in FORTRAN, will be presented for addressing the parameter estimation problem. The approach involves the use of integration routines to determine the values of the states for a given set of model parameters values. The local optimization routines used in this work are the well-known Levenberg-Maquardt and Simplex methods. The global optimization routines are a genetic algorithm and the repulsive particle swarm method. The formulation of different strategies will be presented, and their properties which allow for the development of the customized global optimization algorithm will be discussed. The cases of study are recent kinetic models for the enzymatic hydrolysis of lignocellulosic biomass.

01382
Impact Loading Identification of a Complicated Structure

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In this paper, the theoretic model of impact loading identification to act on a running automatic machine is built up first. A set of the experiment devices is designed. It is easy to test in the laboratory and the locale. To be applicable to various structures, with which it is able to obtain its dynamic characteristic and to respond data of the system accurately. In order to measure more vibration signals synchronously and automatically, the testing system is designed and set up. It is also examined through the simulating loading testing. In order to improve the accuracy of the loading identification, a series of techniques to reduce outside noise interference are put forward. The responded signals to the automatic machine in physically work are tested and analyzed. It is made use of frequency respond function of structure excited simulating loading, to complete loading identification on the system in the actual work. Finally, contrasted with traditional theoretic compute and the tested method, the identification technique is perfected.

01393
Improving the speed performance of an Evolutionary Algorithm by a second-order cost function approximation

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In a FE model updating procedure, the uncertain model properties are adjusted such that the numerical predictions correspond as closely as possible to the measured data. To obtain unknown parameters, an optimization problem is solved where the objective function to be minimized is defined by the distance between parameters obtained from experimental tests and those given by a numerical model. Success of the application of the updating method de-pends on the definition of the optimization problem and the mathematical capabilities of the optimization algorithm. Global optimization techniques, as Genetic algorithms and Evolution approaches are con-sidered very efficient numerical methods. Unfortunately, Genetic and Evolutionary algorithm have the disadvantage to require a large number of cost function evaluations. Moreover, be-fore detect global minimum, several number of evaluation must be performed in order to ob-tain prescribed precision. Instead of applying the optimization algorithm directly to the objective function, the Re-sponse Surface Methodology approximates with a surface the objective function. The main disadvantage is the fact that due to the use of second-order polynomials, a local minimum is usually reached when the objective function presents several local minima. In Structural identification problems, rarely the cost function shape is known because of it is not explicitly defined. So, the choice of the optimization algorithm is the key of success. For this purpose and in order to improve speed rate of global optimization techniques, the re-sponse surface methodology combined with the Differential Evolution Algorithm to perform dynamic structural identification. Differential evolution (DE) algorithms are parallel direct search methods where N different vectors collecting the unknown parameters of the system are used in the minimization proc-ess. The vector population is chosen randomly or by adding weighted differences between vectors obtained from the old population. In the modified algorithm, a new parameter vector can be also defined as the minimum of a second-order polynomial surface which approximate the real cost function. Performance in term of speed rate is improved and higher precision of results is obtained by introducing the second-order approximation in DE. Moreover, when objective function presents only one (global) minimum, second-order approximation provide to find the solution with the lowest number of iteration. On the other hand, the global minimum is reach since multiple search points are used simultaneously. DE algorithm shows its efficiency when sev-eral design parameters must be researched and close to the solution, quadratic approximation gives higher accuracy. DE is compare with the modified algorithm to perform a FE modal updating of a steel rail-way bridge. The objective function is defined as the difference between the dynamic proprie-ties (in term of vibration frequency and mode shapes) of a simplified model and an more accurate model, the latter representing the "real" behaviour of the structure.

01427
Electrical Impedance Tomography: a bayesian-topological approach

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Electrical Impedance Tomography (EIT) is an inverse problem used to estimate the resistivity, or more generally the body impedance distribution from boundary measurements by electrodes. This approach

has been used in geophysical science, industrial processes, non-destructive testing and various medical applications such as detection of breast cancer and lung function monitoring, for example. On the other hand, the topological sensitivity analysis was developed as a promising proposal for solving inverse problems, since it provides the sensitivity of the creation of a singular perturbation, as source terms, insertion of holes or inclusions in domain. However, this tool did not provide efficient reconstruction algorithms since the highest values of topological derivative are on boundary of the domain. This work adopts the view of the Bayesian approach, where the inverse problem is reformulated as a problem of statistical inference, to develop an algorithm for the reconstruction of EIT. It also takes in account the topology optimization of a functional associated to the Khon-Vogelius criterion. In this way, through an appropriate choice of prior probability density to initialize the algorithm, this procedure allows the application of the concept of topological derivative in inverse problems context and gives the posterior probability distribution at each step of the algorithm in a straightforward way . Reconstruction of 2D examples using numerical data are presented.

01442
Parameter Estimation for Semi-parametric Models With Cmars and its Applications

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The extension of traditional linear models is the class of Generalized Linear Models (GLMs). GLMs are known as a very popular a statistical modeling tool because of the flexibility to the variety of statistical problems and the availability of software to fit the models. The particular form of GLMs are the semiparametric models in that the usual parametric terms are augmented by a single nonparametric component of a continuous covariate. One of the great advantages of semiparametric models consists in some grouping (linear and nonlinear or parametric and nonparametric) which could be done for the input dimensions or features in order to assign appropriate submodels for them specifically. In this study, we consider CMARS for the nonparametric part to estimate smooth function. CMARS is an alternative technique to multivariate adaptive regression splines (MARS) by the framework of conic quadratic programming. For the parametric part, least square estimation with Tikhonov regularization is used. The applications of this study will be performed and implemented in finance, science and technology.

01456
Fast Tikhonov regularization parameter choice in the numerical treatment of linear inverse problems.

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In a Tikhonov regularization scheme to solve discrete linear ill posed inverse problems, choosing the parameter value is a key task. In this work we study searches in the L-curve providing a parameter choice which avoids critical horizontal and vertical sections of the L-curve, but approximately calculated to perform a fast selection. Numerical results are shown comparing the inexact scheme with other searches, specifically with the given in Hansen regularization toolbox \cite{Hansen}.

01487
Design of an airfoil from a given pressure distribution using an approximate inverse operator

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This contribution describes a numerical solution of an inverse problem for a flow around an airfoil. Its aim is to design an airfoil shape based on a given pressure distribution on its surface. The pressure distribution affects forces acting on the airfoil, so it is possible through its modification to obtain shapes which satisfy requested parameters. The method is suitable to solve problems in subsonic regimes. The main idea of the method is a combination of a direct and an approximate inverse operator. Using both operators, the resulting shape is corrected in each iteration until the desired precision is achieved. The direct operator means, in this notation, a solution of a 2D flow around the airfoil. There is some degree of freedom when choosing the model. In this case, the Navier-Stokes equations completed with a k-omega turbulence model are used. A stationary solution of this system is obtained by an implicit FVM. The approximate inverse operator is based on the thin-airfoil theory for a potential flow. The airfoil is described by a mean camber line and a thickness function, which ensures the capability to deal not only with thin airfoils. Numerical examples are presented.

01490
On Method of Fundamental Solution for Nondestructive Testing

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Nondestructive testing in engineering is an inverse Cauchy problem for Laplace equation. In this paper the problem of nondestructive testing is expressed by a Laplace's equation with third-kind boundary conditions. In order to find unknown values on the boundary, the method of fundamental solution is intruduced and realized. Because of the ill-posedness of studied problems, the TSVD regularization technique in combination with L-curve criteria and Generalized Cross Validation criteria is employed. Numerical results are shown that the TSVD method combined with L-curve criteria is more efficient than the TSVD method combined with GCV criteria.

01491
Archived Simulated Annealing with Two-Phase Matching Improvement for Unrelated Parallel Machine Scheduling to Minimize Fuzzy Makespan and Average Tardiness

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The research investigates several strategies incorporated into simulated annealing (SA) to solve unrelated parallel machine scheduling problems with two maximization fuzzy objectives – total completion time (makespan) satisfaction and average tardiness satisfaction. These strategies

include matching-based decoding schemes, acceptance probability rules, and random and fixed weighted vectors for objectives. In particular, a two-phase matching decoding scheme is devised to cope with the search direction on the two objectives and improve the solution quality. Four acceptance probabilities of neighborhood solutions based on the following rules are considered: weighted sum objective, multiplication of individual objective evaluations, minimum individual objective evaluation, and number of dominated solutions in the archive. An experiment was conducted to evaluate the performance of SA using different strategies on two instance sets of moderate to large sizes generated by a method in the literature. The experimental results indicate that (1) a two-phase decoding scheme that uses max-min matching first and Hungarian method second will significantly improve proximity quality; (2) dominance-based SA will produce enhanced diversified local efficient solutions.

01493
Parameter estimation for affinity hydration model of cement paste

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This contribution deals with estimation of input parameters for affinity hydration model of cement paste. Concrete, one of the most used engineering materials, obtains many properties from cement paste. Also, the final reliability and durability of construction depends strongly on the heat released during the hydration process of cement paste. However, the prediction of hydration heat is rarely used in engineering models. One of the reasons is a complexity of the hydration process and difficulty in obtaining input parameters. The affinity hydration models express the rate of hydration by temperature-independent normalized chemical affinity, where hydration is considered under isothermal conditions. The model used in this contribution is an analytical form of normalized affinity [1]. It has only four parameters. Two of them do not relate to the chemical basis of the hydration process and are the target of our estimation procedures. The other two parameters can be determined from the chemical composition of cement paste. One is the ultimate hydration degree and the last one represents a micro-diffusion of free water through formed hydrates. The target of estimation is to find a set of input parameters, which gives the best agreement between response of the affinity model and available experiments. To achieve this, the forward mode of inverse analysis will be used, where the error function(s) based on differences between experimental data and simulations will be defined and minimized. Two approaches will be compared. The first one is based on one error function and an application of the genetic algorithm GRADE with CERAF method [2]. In the second approach, more than one error function will be defined, which allows to emphasize different important parts of the hydration process. To optimize this problem, the multi-objective genetic algorithm NSGA2 [3] will be employed. The parameter estimation for a set of experimental data will be presented and obtained hydration curves will be compared with results from another, more complex, hydration model. The financial support by the research project MPO FR-TI1/612 is gratefully acknowledged.

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01501
Mechanical Properties of Nanocomposite Laminated Structures by Modal Method

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The Finite Element model of the laminate plate is used to approximate the experimental modal results by a optimization procedure. From the modal properties the tensile and shear modulus, the Poisson coefficient of a woven orthotropic composite plate were determined by this method. The plates used in the experiment are made of S2-glass/epoxy with 16 layers are manufactured by vacuum assisted wet lay-up. The matrix of the nanocomposite has been obtained by adding 0%, 1%, 2% nanoclays in weight into epoxy matrix. Remarks are made about the results, analysis methodology and its limitations.

01517
Sensitivity Analysis of a New Parameter for Diagnosing Gas Turbine's Performance Deterioration

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The goal of gas turbine performance diagnostics is to accurately detect, isolate and assess the changes in engine performance, engine system malfunctions and instrumentation problems from knowledge of measured parameters taken along the engine's gas path. Many methodologies and implementations of the basic concept have been investigated by other authors. In this study, a non-linear gas-path analysis (NLGPA) model is used to evaluate a new parameter for detecting, isolating and assessing the considered engine-faults. Each engine's gas-path component's faults are quantified, taking into account measurement noise. A thermodynamic model of the behavior of a 2 shaft gas turbine was used as a case study.

01548
Application of artificial neural networks in solving inversion problem of surface wave method on pavements

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Surface wave method is an in-situ nondestructive testing procedure for estimation of elastic moduli and layers thicknesses of layered structures such as pavements and natural soil deposits. In this research "Matlab" has been employed for applying artificial neural networks in solving inversion problem of surface wave test dispersion curve and estimating the soil profile. Multi layer neural networks

along with back propagation training procedure are used to carry out the required inversion process. The networks are trained using the Steepest Descent Gradient Algorithm, Conjugate Gradient Algorithm and Levenberg – Marquardt Algorithm. Eight training functions have been employed and assessed in three, four and five layer networks. The most optimized network with the least error rate and iteration number for convergence was selected and tested for certainty. By employing the selected optimum network, a number of real cases have been studied and the results obtained have been compared with the available actual data. The results show very good match indicating that the selected back propagation neural network is capable of providing a useful tool for carrying out the inversion process of surface wave method.

01557

Robustness analysis of the parallel-hybrid method for structural damage identification

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One of the most interesting applications oh the inverse problem theory involves the monitoring of structural integrity through the identification of damage. The basic idea remains that measured modal parameters (notably frequencies, mode shapes, and modal damping) are functions of the physical properties of the structure (mass, damping, and stiffness). Therefore, changes in the physical properties, such as reductions in stiffness resulting from the onset of cracks, loosening of a connection or more in general due to the aging of material, will cause detectable changes in these modal properties [1]. In the present study is shown original results front a robustness analysis for three methods applied in intent to solve the inverse problem of structural damage estimation. This analysis is in function of damage quantity and intensity. The methods are: i) GCM (Alifanov approach) [2], ii) Genetic Algorithm + GCM (Hybrid method) [3], and iii) Parallel Genetic Algorithm + GCM (Parallel-Hybrid method) [4]. The non-unique execution of the methods provides different scenarios to assess the damage, all with the possibility of experimental evaluation (inspection) [5]. The Conjugate Gradient Method (GCM) as originally formulated does not usually produce satisfactory solutions in inverse hyperbolic problems, due to non-elimination of uncertainty (fluctuations, noise) in the initial conditions though the time. The hybridization solves this problem, not just reducing the overall average estimation error, but also reducing the upper bound of the error. The use of parallel implementation of genetic algorithm reduces the computation time of the solution, and increases their effectiveness due to epidemic operator [4]. One constraint for the strategies is the need to work with very fine discretizations [6]: alternative solutions are listed.

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01562
Assessment of Air Quality and Control of Emission Rates

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Mathematical methods based on the adjoint model approach are given for the air-pollution estimation and control of emission ratres from the sources in an urban region. A simple 2D (vertically integrated) advection-diffusion-reaction model with industrial (point) and automobile (linearly distributed) sources and its adjoint model are used to illustrate the application of the methods. Of course, the methods can be applied to any 3D pollution transport model. Dual pollution concentration estimates in ecologically sensitive zones are derived and used to develop two non-optimal strategies and one optimal strategy for controlling the emission rates of enterprises. A linear convex combination of these strategies represents a new sufficient strategy. A method for detecting the enterprises, which violate the emission rates prescribed by a control, is given. A method for determining an optimal position for a new enterprise in the region is also described.

01565
Life Cycle and Gradient Based Optimization Applied to Estimation of Aircraft Aerodynamic Derivatives by the Output-Error Method

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In this work Life Cycle Optimization (LCO) and the Levenberg–Marquardt (L-M) algorithms are applied to identify the aerodynamic derivatives of a fixed wing aircraft by minimizing the mean square error between the flight data observations and data obtained by a nonlinear simulation model. Two different optimization methods are investigated to accomplish the inverse problem of aerodynamic parameter identification of the longitudinal motion of a jet trainer aircraft within the framework of the output-error methodology. This methodology combines natural based algorithms, in particular, the Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) in the frame work of the LCO. The results of LCO are then combined with a gradient based L-M optimization algorithm. A cascade-type scheme is proposed using both optimization algorithms, aiming to take advantage of the global search capabilities of LCO and the local search capabilities of L-M. Finally, the experimental investigation illustrate the possibility of using present techniques in real world environment. The results are very encouraging in the sense that with little knowledge of the aircraft aerodynamic derivatives, it is possible to startup the local search gradient based algorithm, which is very sensitive to initial values of parameters.

Numerical Optimization Techniques

3

01010
Comparison Between the Cebeci and Smith and the Baldwin and Lomax Turbulence Models – Final Results

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The present work is the final part of the study that aims a comparison between the turbulence models of Cebeci and Smith and of Baldwin and Lomax applied to aeronautical and aerospace problems. The Jameson and Mavriplis algorithm is used to perform the numerical experiments. The algorithm is symmetrical, second order accurate in space and time, and the temporal integration is accomplished by a Runge-Kutta type method. The Reynolds average Navier-Stokes equations are solved, using a finite volume formulation and a structured spatial discretization, and the models of Cebeci and Smith and of Baldwin and Lomax are used to describe the turbulence effects in the flow properties. The physical problems of the transonic flow along a convergent-divergent nozzle and the "cold gas" hypersonic flow around a double ellipse configuration are studied. A spatially variable time step is employed to accelerate the convergence of the numerical scheme. The numerical results are compared with experimental or theoretical solutions. These results have demonstrated that the Baldwin and Lomax model is more severe in the nozzle problem, while the Cebeci and Smith model is more severe in the double ellipse problem and more accurate in both examples.

01011
Comparison Between Two-Equation Turbulence Models Applied to Aerospace Problems

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In the present work, the Van Leer flux vector splitting scheme is implemented, on a finite-volume context. The 2-D Favre-averaged Navier-Stokes equations are solved using an upwind discretization on a structured mesh. The Jones and Launder k-ε and the Wilcox and Rubesin k-$\omega 2$ two-equation models are used in order to close the problem. The physical problems under studies are the low supersonic flow along a ramp and the moderate supersonic flow around a blunt body configuration. The implemented scheme uses a MUSCL procedure to reach second order accuracy in space. The time integration uses a Runge-Kutta method of five stages and is second order accurate. The algorithm is accelerated to the steady state solution using a spatially variable time step. This technique has proved excellent gains in terms of convergence rate as reported in Maciel. The results have demonstrated that the Wilcox and Rubesin model have yielded more critical pressure fields than the ones due to Jones and Launder. The shock angle of the oblique shock wave in the ramp problem and the stagnation pressure ahead of the blunt body configuration are better predicted by the Wilcox and Rubesin turbulence model.

01012
Comparison Among Different Artificial Dissipation Models Applied to a Generalized Coordinate System – Laminar Viscous Case

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The present work is the third part of the study that aims a comparison among four different artificial dissipation models implemented in the approximated factorization diagonal algorithm of Chaussee and Pulliam. The isotropic scalar linear and nonlinear models of Pulliam and the anisotropic nonlinear scalar and matrix models of Turkel and Vatsa are analyzed. The Navier-Stokes equations, on a finite

difference context and using a generalized coordinate system, are solved in the two-dimensional space. The physical problems of the supersonic flows along a compression corner and around a blunt body configuration are studied. A spatially variable time step is employed aiming to accelerate the convergence of the diagonal algorithm of Chaussee and Pulliam. Effective gains in terms of convergence ratio are obtained as demonstrated in Maciel. The results have demonstrated that the anisotropic scalar nonlinear artificial dissipation model of Turkel and Vatsa predicts the most accurate solutions. This work consists in the third stage to study turbulent flows using a symmetrical algorithm and different artificial dissipation models. In the next paper of this study (the fourth), the turbulent simulations will be performed with the Cebeci and Smith model, aiming to better highlight the main characteristics of the dissipation models of Pulliam and of Turkel and Vatsa. Finally, in the fifth paper of this study, the turbulent simulations will be performed with the Baldwin and Lomax model, aiming to rectify or to confirm the analyses of the fourth paper.

01030
Contribution of the New Optimization Method of a quadratic Program to the separable programming

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Abstract: The aim of this study is to find the exact solution of a quadratic programming problem with linear constraints of an objective quadratic function written in the canonical form. This paper describes a new method which is based on splitting the objective function into the sum of two functions, one concave and the other convex; a new feasible constraint set is built by a homographic transform, in such away that the projection of the critical point of the objective function onto this set, produces the exact solution to the problem on hand. Notice that one does not need to transform the quadratic problem into an equivalent linear one as in the numerical methods; the method is purely analytical and avoids the usage of initial solution. The technique is simple and allows us to find the coefficients of the convex function while moving from one summit to another. The proved theorem is valid for any bound, closed and convex domain; it may be applied to a large number of optimization problems. The obtained results are of great importance to solve separable programming cases, Portfolio Management, in MVS...

01044
Joint Chance Constrained Programming for Hydro Reservoir Management

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In the electrical industry, when looking at offer-demand equilibrium problems in hydrothermal systems such problems are often processed using price decomposition techniques. The hydraulic reservoir optimization sub-problem can then be considered to be a typical instance of a large-scale combinatorial network flow problem. The combinatorial nature of such problems is due to complex dynamic constraints on the watershed controls. For these reasons, such problems are often considered in a deterministic setting. In this paper, we will investigate the impact of adding uncertainty on inflows to the hydro-sub-problem without combinatorial constraints. We will formulate the flow constraints using joint probability constraints. We will consider inflows with a persistency effect and examine the impact of the "Gaussian" assumption for such inflows. Finally, we will compare, on an example, the obtained open-loop strategies with those obtained, when the probability constraints are approximated by conic quadratic constraints. The advantage of the latter approximations is that they require no assumptions on the law of the inflows at the price of giving conservative solutions.

01063
Topology Optimization of a Continuum with Bimodulus Material

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An evolutionary approach is adopted to obtain the optimal topology of a structure with bimodulus material which tension modulus is different from compression modulus, e.g., concrete and cast iron in civil or mechanical engineering. The constitutive properties of such materials depend on local stress state. Many times of structural reanalysis are required to obtain the accurate stress field. Therefore, traditional methods are inefficient to solve topology optimization of a structure with such kind of material. To improve the efficiency, the Reference-interval with material-replacement method is used and the essentials of the method are as follows. First, the optimization of a structure is considered as the adaptive remodelling of bone under the same loading conditions. Second, according to the concept of dead zone in bone remodelling theory, a reference interval of strain energy density (SED) is adopted to control the update of the design variables. Third, a material-replacement scheme is suggested to simplify the structural analysis by finite element method (FEM), i.e., the double-modulus material is replaced with two types of isotropic materials to find the approximate strain and stress fields of the original structure. The moduli of the isotropic materials are equal to the tension modulus and compression modulus of the original material, respectively. Fourth, the design variables are updated by comparing the current reference interval of SED and the local effective SED which is obtained through the approximate strain and stress fields. Final, the reference interval changes frequently in iterations to content the active constraints in optimization. Numerical examples are given to show the performance of the current approach.

01064
GRASP and ILS Approaches to the Equipment Selection Problem in a Just in Time Environment Involving Two Decision Variables

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This work presents a new proposal for the resolution of the equipment selection problem in a Just in Time environment, through the aplication of a GRASP and a ILS algorithms. The resolution of this problem consists in a simultaneous determination of the number of machines that must be used in S stages and of the production sequencing of a list of P products in such a way to minimize the total costs of the production. The computational results are reported, including the total times of production for each alternative generated and the solutions made by the algorithms. Beyond this, considering the adoption of these solutions, we are able to make a multicriteria analysis about the problem in question.

01076
Stress- and strain-based multifreedom constraints for periodic media optimisation

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The mechanical behaviour of structures is a function of its shape and topology as well as of the materials from which it is built. The design of the material microstructure of composite materials influences the behaviour of the macrostructure and its optimisation approaches. In this scope, a standard topology optimisation approach may be extended to optimise structures built from materials such as composite, functionally graded or cellular materials. Moreover, a similar approach can lead to the most adequate material microstructure for a certain macrostructure requirement. An ideal material distribution may be obtained using adequate boundary conditions and evaluating the resultant material properties. In this work, the authors optimise the microstructure of periodic media based on stress or strain fields resulting from linear elasticity macroscale problems. To do so, a set of adequate boundary conditions is needed. The periodicity of the deformed unit-cells is guaranteed using general homogeneous multifreedom constraints (MFC) whereas the stress or strain-based optimisation renders different requirements. The stress approach uses an equivalent loading state over the unit-cell, applying natural (Neumann) boundary conditions. The strain approach uses essential (Dirichlet) boundary conditions, equivalent in this case to the use of non-homogeneous MFC. With this in mind, the authors present the numerical implications and implementation strategies of this approach. Two and three-dimensional examples are presented, solving the optimisation problem with variations of a power-law method.

01088
A higher order path-following method for stability-constrained optimisation of shallow trusses

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A higher order path-following method for stability-constrained optimisation of shallow trusses Anikó Csébfalvi In this paper, a higher order path-following method is presented to tackle the structural stability constraints within truss optimisation. The general truss optimization problem is formulated as a discrete or continuous minimal weight design subjected to several constraints which require the computation of the structural response. The proposed path-following method [1] is based on the perturbation technique of the stability theory [2] and a non-linear modification of the classical linear homotopy method [3]. The nonlinear function of the total potential energy for conservative systems can be expressed in terms of nodal displacements and the load parameter. The equilibrium equations are given from the principle of stationary value of total potential energy. The stability investigation is based on the eigenvalue computation of the Hessian matrix. In each step of the path-following process we get information about the displacement, stresses, local, and global stability of the structure. With the help of the higher-order predictor-corrector algorithm, we are able to compute an arbitrary load deflection path and detect the different type of stability points. During the optimization process, a truss is characterized by its maximal load intensity factor along the equilibrium path. Within the predictor step, an implicit ODE problem and in the corrector phase a non-linear equation system has to be solved. The first-order derivative is obtained from the null-space of the augmented Jacobian matrix. The higher order derivatives

need the Moor-Penrose pseudo-inverse of the augmented Jacobian matrix. The equilibrium path computation terminates if the procedure reaches the applied load level, a singular point or any other constraints violating point on the equilibrium path. In order to demonstrate the viability and the efficiency of the proposed approach computational results are presented using ANGEL hybrid metaheuristic as optimization method.

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01093
A study of efficiency of Reliability-Based Design Optimization Methods.

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This paper describes the behaviour of several Reliability-Based Design Optimization methods. These optimization techniques are applied to solving design problems in structural engineering where a cost function, like the weight or the volume must be minimized subject to probabilistic constraints written as limit state functions. Generally, these RBDO methods are classified in three groups: double-loop methods, single loop methods and decoupled methods. Traditional double-loop methods are inefficient and cannot converge when the probabilistic constrains are highly non linear. Because that, researchers have developed advanced double-loop methods based in performance measure like HMV, HMV+ and PMA+, decoupled methods like SORA and single-loop methods like SLSV and others. These RBDO methods have been coded in a computer toolbox including procedures in the areas of structural analysis, structural reliability, design sensitivity analysis, mathematical programming and Monte Carlo simulation. Some configurable options have been considered: both analytical and structural problems can be solved. In structural problems, actions or external forces, material properties, and geometric variables of the structural members are considered like random variables. Sensitivities can be calculated analytically by direct differentiation method or numerically by finite differences method. Plane and spatial trusses are considered. Reliability constraints included in probabilistic optimization problems are displacement constraints, stress constraints and buckling constraints at level member. Several distribution functions can be chosen for the random variables (Normal, Lognormal, Weibull, etc.). Correlations between random variables are considered using the Pearson correlation coefficients matrix. Probabilistic optimum designs obtained are verified by Importance Sampling-based Monte Carlo Simulation. Important conclusions about computational efficiency, convergence, accuracy, generality and robustness of the RBDO methods are obtained running structural analysis with the computer toolbox coded.

01099
Particle Swarm Optimization and the Efficiency Frontier for the Problem of Expansion of an Electrical Network

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The increasing demand for electricity implicates in frequent expansion of distribution systems. It is necessary a long-term planning that respects the dynamics of the evolution of demand and the

availability of financial resources. Planning is to determine the necessary investments and what the proper configuration of the network in each stage of the planning horizon to achieve the goals. The definition of multiple objectives features intended to meet the needs of both dealers and consumers, in addition, the multiobjective approach can identify the efficient frontier that represents a collection of trade-offs between the objectives set out, among which the decision maker may choose to play the one that best suits their priorities. This paper presents a model of multi-objective mixed integer programming (MIP), which considers two conflicting objective functions, related costs and lost power for the expansion planning of distribution networks for electricity. Technical and operational constraints are imposed so that the solutions meet the specific characteristics of electrical networks. The model proposed in this work was inspired from [1]. Some adjustments were made to allow multi-criteria approach to the problem and others in order to adapt it to operate in networks operated by a concessionaire of Paraná, Brazil. The model applies to a primary network to the existing distribution and operating in good condition which is known forecasts of load increase or emergence of new points of demand for different periods of the planning horizon. Assumes prior knowledge of the branches that can be added to the network with the options of gauges and the definition of what nodes are capable of installing the distribution substation. The proposal to use an exat method to solve such a model has been successful when applied to a small network presented in [1], but proved to be restrictive in the application in real networks due to their size and characteristics of non-linear inherent power grids. To overcome this difficulty, was used Particle Swarm Optimization (PSO) presented in [2], to find solutions good enough for the problem under discussion. Since the decision variables of the model are binary, to allow the efficient resolution of even using PSO, we defined a way to assign continuous variables to binary variables where PSO updates are applied. The resolution of the model using the PSO adapted to the problem of expansion and associated with the technique presented in the study allowed the creation of multi-stage planning for the expansion of networks larger than those handled by exat methodology, resulting in a successful approach to the frontier of efficiency.

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01103
Solving Any Nonlinear Problem with a Linear MILP Model

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Although the author is an Electrical Engineer he got interested in optimization problems using the GAMS software. Rapidly he understood the limitations of the nonlinear solvers, like the necessity to have an initial feasible solution and the high probability of the solver being trapped in a local optimum and since 2004 he solved a set of complex nonlinear problems using MILP models. From the solution of the optimization of AGVs (Autonomous Guided Vehicles) Network resulted techniques of implementation of logical functions over variables of the model only with algebraic expressions and the division of two model variables with the aid of auxiliary binary variables. From the solution of generation of optimal error correcting codes resulted a first sketch of the automatic relaxation of a set of constraints, after improved in the solution of university timetabling with soft (that can be relaxed) and hard (that cannot be relaxed) constraints. We claim that our solution is the optimal solution to the well know problem of maximal constraint satisfaction. Finally from the solution of the generation of additive-multiplicative magic squares resulted in a technique of multiplication of a set of variables of a MILP model. Obviously these latter techniques can be extended to implement any nonlinear operation over a set of variables of a MILP model. Finally we propose new ways to implement nonlinear solvers based on meta-heuristics and Neural Networks, since our techniques require relatively big computational resources for moderate size problems.

01105
Integer Solutions to Cutting Stock Problems

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This work deals with a real-world industrial problem of reel cutting optimization, usually called Cutting Stock Problem that can be described as follows: find the most economical way of cutting the master rolls (with large width) into rolls with smaller widths previously specified by customers together with the quantity they need. Several formulations are possible (see for example [1]). We consider two integer linear programming models for the one-dimensional cutting stock problem that include various difficulties appearing in practical real problems, such as upper bounds on the amount by which the demand may be oversatisfied, a limit on the maximum waste allowed in each cutting pattern (i.e. list of items to be cut from a master roll) and a limited number of cutting knives. Our primary goal is the minimization of the trim loss or the minimization of the number of master rolls needed to satisfy the orders. In particular, we study an approach based on the classic column-generation procedure by Gilmore and Gomory [2] for solving the LP relaxations and an extra column-generation procedure before solving a final integer problem. For our computational tests we use data sets from the paper industry and randomly generated examples. The models are compared with respect to solution quality and computing time.

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01110
Using full homogenization to optimize the nonlinear behavior of concrete reinforced structures

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The layout of steel bars in concrete reinforced structures is optimized for compliance minimzation, using the full homogenization approach. The outcome of this is used to derive a strut-and-tie truss model, the performance of which in the presence of cracking is evaluated with the ATHENA software. Results are presented for some well studied problems, for some of which there is plenty of experimental data. In some cases just compliance minimization gives a very good strut-and-tie model, while in other cases a more subtle objective function should be used.

01123
The adaptive ground structure approach for topology optimization of large-scale trusses

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The purpose of this work is to develop the efficient method for topology optimization of large-scale trusses. The classical problem of plastic layout optimization is considered. The traditional approach of using a fixed ground structure is attractive due to the possibility of linear formulation of the optimization problem but in practice it leads to a very huge and often intractable task. This trouble may be overcome by adaptive generating and solving of a number of successive and much smaller problems. The initially rare ground structure may iteratively be improved by adjusting the region of the solution and then adding the new potential nodes and bars. The main goal of the adjusting phase is the prediction and exclusion of unnecessary "dead-regions", which however will not be fully prohibited for later iterations. The reduction as well as the expansion of the solution-region has to be included to avoid stopping the progress of optimization process at the false-local minimum. The second phase of the iteration consists in addition of the new potential nodes and members. To complete this task the method proposed by Gilbert and Tyas (2002) will be incorporated with some modifications. Concluding, the systematic strategy for member adding and removing will be presented in the paper. The efficiency of the method will be verified in the representative test examples.

01126
Efficient Heuristic Algorithms for the Weighted Graph Partition Problem

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This work proposes heuristic algorithms for the resolution of a real weighted graph partition problem. In this paper, the problem consisted of the modularization of software, based on its architecture. As in other clustering problems, this problem was mapped by a graph partition into subgraphs, being each one of them associated to one cluster. By reviewing the literature it was possible to observe that some algorithms were purposed based on structured systems software, which Data-Flow Diagrams (DFDs) are represented by directed graphs without use of weights. In order to work with object-oriented software, this paper purposes a new modeling, which uses undirected weighted edges. Initially, aiming to solve this problem, it was applied a graph G(V,E) associating units of object-oriented software (such as classes, interfaces and enums) in vertexes of G; besides this, it was used the edges of G to represent the existent relationship (such as simple association, composition, aggregation and inheritance) among the units of the submitted system. In order to obtain interesting modularization solutions, each edge was signed with its correspondent weight, based on its kind of relationship. In this way, classes with inheritance relationship must have higher weight than classes with simple association, for example. For the solutions' evaluation the same fitness function used by works of the review of literature was applied but, in this case, it was necessary to consider the weighted of the edges. The MQ (Modularization Quality) corresponds, basically, to the

difference between the intra and inter-connectivity, being its range from -1 to 1. In order to maximize the value of fitness' solution and reach best results, this function rewards clusters with high intra-connectivity and, at the same time, penalizes solutions with many dependencies among its clusters (inter-connectivity). Several experiments analyses with real and artificial data were used; real data were mapped through by proposed graph model, while the artificial data were the same used by the works of review of literature, but mapped to undirected and weight graph. Moreover, the experiments considered some versions of heuristic algorithms, composed by procedures of local search, path relinking and constructive heuristics. Still about the experiments, each version was run over the same set of data ten times. In order to obtain more detailed results, the best versions were submitted to a new experiment, the empirical probability distributions of the random variable time to target solutions, which two targets were used (medium target: average of the solutions and the hard target: corresponding to the best solution found). For this, the best algorithms were run a hundred times over the selected data. The computational results showed that the proposed algorithms are efficient alternative to solve this problem, in which the new procedures improve the solution´s quality in small computational time.

01156
Prediction of Electromagnetic Fields in Biological Media: Critical Analysis

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The prediction of electromagnetic fields can be made analytically or with the help of numerical methods implemented computationally. Studies of situations with simple analytical modeling is feasible, but where you need large number of simulations, regions comprising different materials and complex geometries, is indicated the use of numerical methods. The vast majority of methods for predicting field produces solutions of Maxwell's equations, which are the basis of electromagnetism. Among these, the Transmission Line Modeling Method - TLM and finite difference method - FD, which both solve Maxwell's equations in time domain. Computer simulations of propagation of electromagnetic fields, performed with the TLM and FD methods can be achieved in a short or expensive time, being one of the parameters determining the temporal variation the frequency of electromagnetic fields adopted. Procedures for the TLM simulation at low frequencies, as well as using FD methods due to the characteristics of the methods and the need for abundant performance computing (processing and memory) is legally uncertain, since they require a long period of time for be realized and in some cases are impractical due to the need computational unavailable. Seeking predict the electric field at a low frequency from the output of a simulation at a high frequency, we evaluate the use of a methodology for frequency scaling in the form of critical analysis, honoring some bibliographies. Evaluations showed that for the use of this methodology in their formulations approximate, it is necessary to conduct studies describing the behavior of electromagnetic characteristics of the medias involved in the frequency range considered, validating or invalidating the approximate formulations of the methodology for such cases. The complete formulation and the formulations of the approximate method of frequency scaling have been used in attempts to predict low frequency fields, using data obtained from simulations with the TLM, conducting studies according to the information of references and also with variations of these, in which the use of frequency scaling did not provide accurate results. Special mention should also be noted that perhaps for the use of the methodology of frequency scaling should be considered features not described in the papers consulted.

01159
An Implicit Smooth Reformulation of Complementarity Constraints for Application to Robust Structural Optimization

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This paper presents a reformulation of the MPEC (mathematical program with equilibrium constraints) problem. It is known that various problems in structural and mechanical engineering can be formulated as MPECs. Particularly we here focus on MPECs arising from the robust optimization of elastic structures as a specific application. However, the presented implicit formulation is applicable to any MPEC problem in the complementarity form. Since a standard constraint qualification is not satisfied at any feasible solution of an MPEC, various smoothing methods, as well as regularization schemes, have been proposed. Here we propose a smoothing method based on the smoothed Fischer--Burmeister function, in which the smoothing parameter is also considered as an independent variable in the course of the optimization. In conventional methods the smoothing parameter is treated as a constant, and then a sequence of smooth optimization problems is solved by gradually decreasing the smoothing parameter to zero. However, in such an approach there exists no proper decreasing strategy of the smoothing parameter, which may possibly cause numerical inefficiency: Too rapid reduction of the smoothing parameter is not adequate in order to avoid the nonsmoothness of the complementarity function (e.g. the Fischer-Burmeister function), but too slow reduction might result in the unnecessary increase of the number of subproblems to be solved. For adjusting the smoothing parameter to the convergence process, we treat the smoothing parameter as an additional variable, and consider to add an additional constraint condition to the smoothed MPEC reformulation. It is noted here that the additional constraint condition is designed so that the smoothing parameter can work as a measure of the residual of the complementarity constraints and the smoothing parameter is guaranteed to vanish at the optimal solution. Then it is expected that the smoothing parameter is automatically adjusted according to the decrease of the residual of the complementarity constraints in the course of optimization. Moreover, the smoothing parameter vanishes automatically at the convergent solution, and hence the complementarity constraints are satisfied exactly. This is a key idea of the implicit reformulation presented in this paper. It is well known that a standard constraint qualification is not satisfied at any feasible solution of an MPEC, and hence standard nonlinear programming approaches are likely to fail. This is nothing but the motivation to consider a reformulation for MPECs. For the presented implicit reformulation, we show that the linear independence constraint qualification (LICQ) is satisfied, if the original MPEC problem under consideration satisfies the so-called MPEC-LICQ. This means that the presented reformulation can be solved by using a standard nonlinear optimization approach, e.g. the sequential quadratic programming (SQP) method. Numerical examples of robust structural optimization are presented in order to demonstrate that the presented MPEC reformulation can be solved by using a standard nonlinear programming approach.

01162
Pareto Optimal Set of Multi-objective Optimization Problems Involving Quadratic Functions. Part I: Unconstrained Problems

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The greatest challenge in multi-objective optimization is to get a complete view of the Pareto set and the corresponding Pareto frontier for conflicting objective functions. Although the idea involved is simple, the implementation of any procedure to solve a general problem is not an easy task. Evolutionary algorithms are

widespread to find candidates to the Pareto optimal set. Usually, they supply a discrete picture of what is called Pareto frontier even if this frontier is continuous. In this paper, we propose a direct method to solve the multi-objective problems getting a discrete picture of the Pareto set in the hyper-dimensional decision space, assuming that the objective functions are quadratic. Some illustrative examples are used to highlight the method.

01173
A Multicriteria Decision Aid Software Application for selecting MCDA Software using AHP

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In the business world, a good decision may be the success of an organization. To decide, sometimes, is not an easy task, mainly when we have multiple criteria. A bad decision can mean the collapse of an organization. In the current climate of turbulence, the companies, in order to become competitive in an increasing demanding market, have to know how to make decisions right. This work begins to present a review of the literature on the main techniques proposed in multicriteria decision making. Then it presents the results of a research on the software tools available in this field. These software tools were then characterized and classified and their main characteristics summarized. The next step was to construct a software application to help organizations in the selection of the right multicriteria Decision Aid (MCDA) software available, among the ones previously collected. The multicriteria technique used for the selection was the Analytic Hierarchy Process (AHP) from Saaty. The programming language used to develop the application was Microsoft Visual Basic 2008 Express Edition. The software tool developed allows the user to access all the information about the software tools available, showing the web page of each application and allowing one to view other related information. The criteria selected were: "Compatibility between Operating Systems", "Cost of a License", "Interaction with user", "User Manual and Tutorials", "Application Examples", "Online Help" and finally "Free Version". After inserting the pairwise comparisons required by the AHP between pairs of criteria, the software is able to select the best alternative software tool among the ones available. An example application of the algorithm is presented to illustrate the use of the program.

01176
Globally Convergent Cutting Plane Method for Nonsmooth Nonconvex Minimization

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Nowadays, solving nonsmooth (not necessarily differentiable) optimization problems plays a very important role in many areas of industrial applications. Most of the algorithms developed so far deal only with nonsmooth convex functions. In this paper, we propose a new algorithm for solving nonsmooth optimization problems that are not assumed to be convex. The algorithm combines the traditional cutting plane method with some features of bundle methods, and the search direction calculation of feasible direction interior point algorithm [Herskovits 1998]. The algorithm to be presented generates a sequence of interior points to the epigraph of the objective function. The accumulation points of this sequence are solutions to the original problem.

01191
Robustness analytic estimation for robust design optimization

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Robust design optimization aims at taking into account uncertainties in an optimization problem, in order to find solutions insensitive to parameter variations. We will focus on uncertainties related to design or environmental parameters, given as probability density functions on an interval. The robustness of a solution can be assessed from the mean and variance of the objective function in the neighborhood defined by the uncertainties. Most of the time, these statistics are estimated via costly Monte-Carlo sampling approaches. Our purpose here is to study different methods to compute robustness measures analytically, thanks to metamodels. Design optimization often deals with expensive black-box functions, so the computation of robustness measures can be quite tough. This is why the use of metamodels turns out to be necessary to avoid large numbers of black-box function evaluations. We will compare two different metamodel-based methods to compute robustness measures such as mean and variance, using for the first one a local model (polynomial chaos expansion) and for the other one a global metamodel (kriging). Polynomial chaos expansion has been introduced in stochastic optimization to account for parameter uncertainties in differential equations. It can also be used in a non-intrusive way when the problem is described by black-box functions. Building a local polynomial chaos model is interesting in robust optimization as it provides directly the mean and variance of the function in the area of interest. But a fact that seems to be less known is that some global metamodels can also give these values analytically, such as standard polynomial approximations, kriging models or radial basis function networks for instance. A global approach can be advantageous as it allows to reduce the total number of function evaluations during the optimization whereas a local model has to be rebuilt around each point considered. Researches have also been done to set up more global polynomial chaos models, so we will try to decide which method performs the best in a robust design optimization process. These analytical computation methods will be applied to an industrial test case about combustion chamber optimization. We run a robust optimization of the system considering uncertainty on the fuel distribution between the different injectors.

01214
Multi-objective optimization using environmental and economic targets in process operation

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This work shows how the use of multi-objective mixed integer non linear approaches can support a decision making strategy in process operation, when conflicting targets such as reducing cost and environmental impacts are pursued. Environmental and economic objective functions are used simultaneously to select the operating conditions of an ethylene steam and power plant. The life cycle potential environmental impact and the operating cost of the utility plant are minimized simultaneously. The main continuous operating conditions are the temperature and pressure of the high, medium and low steam headers. Binary operating variables are introduced to represent discrete decisions such as the selection of: (i) alternative pump drivers such as electrical motors and steam turbines and (ii) boilers which are on or off, and their auxiliary equipment such as feed pumps and air fans. Thus a bi objective Mixed

Integer Nonlinear Programming problem is formulated and solved in GAMS. A rigorous modeling of the utility plant is formulated in GAMS, where the power and steam demands of the ethylene plant are known (Eliceche et al, 2007). In Multi-objective optimization there is a set of solutions, where one objective cannot be improved except at the expense of another objective. This set of compromise solutions are generally referred as non-inferior or Pareto optimal solutions. In this work different multi-objective methods such as: utopia point distance minimization, weighted sum and global criteria method were implemented. The general approach is to convert a bi objective optimization problem into a single objective. Only the global criteria method by Dantus and High (1999) was previously implemented for multi-objective Mixed Integer Non Linear Programming problems. Most of points of the Pareto curve were obtained with the Dantus and High (1999) method. The following GAMS options were used: DICOPT as the outer approximation algorithm; CONOPT3 to solve the Non Linear Programming sub problem and CPLEX to solve the Mixed Integer Linear Programming sub problem. The trend is to select steam turbines rather than electrical motors as pumps drivers, to reduce environmental impact and operating cost. This is due to the fact that a Hydrogen rich residual steam coming from the top of the demethanizer column is recycled and mixed with natural gas to be burned in boilers and furnaces of the utility plant. Hydrogen has a high heat of combustion, does not produce carbon dioxide in the combustion (it is a cleaner fuel) and does not have an external cost. This is a plant where improving process efficiency, green house emissions and cost can be reduced simultaneously if a life cycle approach is followed.

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01233
Stacking Sequence Optimization of Laminated Cylindrical Shells for Buckling and Free Vibration Using Genetic Algorithm and Neural Networks

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In the present work, genetic algorithm (GA) and artificial neural networks (NN) are used to optimize the stacking sequence of a laminated cylindrical shell with natural frequency and buckling load as the objective functions. Vibration analysis is based on fully three dimensional elasticity equations and the stability solution is presented using equations governed by the Donnell type of approximation. Artificial neural network models are developed and tested to predict the natural frequency and buckling load of the structure. A genetic algorithm then uses the trained neural network prediction models to obtain the maximum fundamental frequency and critical buckling load, simultaneously. Optimization is performed for the shell geometry with different sets of thickness to radius and length to radius ratios. The results obtained, using the NN-GA combination are compared with those using the GA directly. A satisfactory verification is observed meanwhile a considerable reduction is achieved in computational time.

01235
On increasing the efficiency of gradient optimization routines

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Solution time of a nonlinear optimization problem described by a quadratic objective function and quadratic constraints may be substantially shortened with correct transformation of decision variables when gradient optimization method is applied. If the Hessian matrix A of an objective function: ½*Xt*A*X+B*X+C is

positive definite, one may simply decompose this matrix into lower and upper triangular components using standard Cholesky decomposition procedure and thus introduce a new set of decision variables: Y=Lt*X This leads to a new optimization problem described by unitary Hessian matrix. Decomposition procedure is numerically stable and performed only once at the beginning of the optimization routine. The change of variables very significantly decreases the number of iterations required to arrive at the solution of optimization problem at hand with any given precision, as author's experience shows. Unfortunately, this method may be applied only when Hessian matrix of the original optimization problem is nonsingular. In case of singular Hessian matrix A a modification of this approach is thus proposed. Namely instead of Cholesky method one may use Singular Value Decomposition (SVD) on matrix A. Thus again after transformation of decision variables one arrives at an objective function described by Hessian matrix having only units or zeros (corresponding to singular eigenvalues of A) on the diagonal. Besides, after the decomposition all the new decision variables corresponding to zero Singular Values may be dropped from further calculations, as they do not affect the value of objective function. Thus in addition to the increased convergence ratio, additional speedup of the optimization procedure may be obtained, as the optimization problem size is decreased. This modified method has been successfully applied to solve an engineering problem of computing residual stresses in a body subject to cyclic loads exceeding its elastic bearing capacity. Results of calculations for several loading cases, resulting in different sizes of the optimization problem (number of decision variables and constraints) will be presented at the conference.

01248
Flow control using plasma actuators

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Nowadays, many different procedures are used for decrease the fly costs. One can know that if the Drag coefficient decrease, the fuel consumption will also decrease, providing an smaller fly cost. The main strategy for decreasing the Drag coefficient is controlling the boundary layer transition. In the present work, plasma actuators are used to cancel the Tollmien-Schilichting waves (TS waves), retarding the turbulence in a flat plate, intending applications on aircraft wings on future. Numerical results were compared with experimental data. The empirical calibration model was used as a mathematical model for the plasma actuator. Another models are still being investigated. A probe located on the plate indicates the amplitude of the TS waves, and an optimization model was used for controlling the voltage applied to the control actuator. Numerical simulations used Large Eddy Simulation as a turbulence model, Finite Volume for domain discretization, Central Difference Scheme and Multi-grid.

01256
Topology Optimization and Control for Vibration Suppression for a Cantilever Beam

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This work presents a structural topology optimization methodology for a cantilever beam, which includes an optimal control design for reducing vibrations. The topology optimization in this paper uses homogenization design method, based on the concept of optimizing the material distribution, through a density distribution.

A Continuum finite elements modeling is applied to simulate the dynamic characteristics of the structure. The modal basis is used to derive an optimal control. The cost functional is the strain energy of the structure and the control energy. The location for the actuator in the beam was chosen based in a known fact that the best place for one actuator is as close as possible to the fixed size of the structure, which bears the maximum stress induced by the first and most significant mode. Results of numerical simulations for a cantilever beam model are presented and discussed.

01270
Critical study of design parameterization in topology optimization; the influence on local minima

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In the past decade, SIMP-based topology optimization methods have become increasingly popular. They offer the designer the possibility to perform design optimization in an early stage of the design process for a wide range of applications. The specific design parameterization used in SIMP is the result of many attempts to eliminate numerical artifacts in the results of topology optimization problems. However, any choice of design parameterization also influences the shape of the response functions. For a gradient-based optimization method it is important to obtain a smooth and, if possible, convex response. This research aims to point out relevant consequences of using the SIMP design parameterization in combination with density filters on the response functions. In this contribution we show the effects of the power of the penalization and the size of the density filter on the response functions. The introduction of penalization has two effects. Firstly, increasing penalization introduces an increasingly strong immobility of the boundary of the structure. Secondly, the introduction of a density filter is not only useful to avoid checkerboard patterns, control minimum member size and achieve mesh-independence, but it also reduces the immobilizing effect that penalization has on the mobility of the boundary of the structure. This effect and its dependence on the power of the penalization and the size of the density filter are illustrated using several elementary numerical examples involving compliance minimization. The results are expected to be relevant for any type of structural topology optimization

01272
Investigation of Instabilities Arising in Element Connectivity Parameterization

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In structural topology optimization of e.g. compliant mechanisms or actuators, it is often necessary to include geometrical and/or material nonlinearities. For such challenging problems, the Element Connectivity Parameterization (ECP) approach has shown to offer several key advantages over

conventional density-based formulations: 1. Higher robustness and better numerical convergence in situations where void elements are severely deformed, 2. No need for arbitrary material interpolations in case of nonlinear materials, and 3. Straightforward sensitivity analysis in case of nonlinear materials. However, in our numerical experiments, we have encountered situations where also finite element analysis using the ECP approach fails to converge on certain intermediate results in the course of topology optimization processes. This analysis failure results in premature termination of the optimization process. In order to develop a solution to this problem, we aim to first methodically identify and investigate it. In this contribution, we introduce the encountered analysis failure and present an analysis of its origin, in the 2D setting. First the concept of ECP is described in detail. The ECP approach is characterized by introducing additional zero-length linear elastic links between the degrees of freedom of adjacent element in a finite element mesh. The stiffness of these links is defined by the design variables. By assigning a high link stiffness, elements are essentially connected, while lowering the link stiffness gradually results in disconnected elements. In other words, elements connected through high link stiffnesses approximate solid material, and those connected by links with low stiffness approximate void. As the design variables only act on the link stiffnesses, they do not affect the elements or the actual material properties used, which relates to the mentioned advantages 2 and 3. The first advantage, robustness against distortion, arises from the fact that the linear links account for most of the displacements in (near-)void elements, while the relatively stiff element they connect to deforms only very slightly and does not suffer from numerical problems due to excessive distortion. Our investigation shows, however, that under predominantly compressive loading, the ECP formulation may also suffer from local instabilities. The additional freedom that ECP introduces by adding compliant links between the elements, in certain situations can cause those elements to be insufficiently restrained, and an instability best described as a local snap-through bucking can occur. This local instability, typically involving only a single element and the links connected to it, can in fact trigger a negative tangent stiffness mode on system level, leading to the described analysis failure in the employed Newton scheme. We present various numerical examples as well as an analytical analysis of this instability problem. We also outline ways to circumvent or stabilize it, which could further extend the range of nonlinear problems that can be solved using topology optimization.

01281
Multiple Resources Allocation under Stochastic Conditions in Projects with Multimodal Activities

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A "multi-modal" activity is one which can be performed in several modes, or levels, of resource(s) allocation. In this paper we assume that the activities are multi-modal, and each activity may require several resources for its execution. We also assume that the resources may be constrained on their availability over time, and that each activity has its own work contents as a continuous random variable for each of its required resources. We are concerned with establishing a suitable strategy that will focus on the universe of activity modes, selecting only those that will be relevant for the most probable overall project cost. In other words, we choose the most probable modes of activity execution among the theoretical continuum of modes; and propagate the consequences of that choice throughout the project. The proposed approach relies on the partitioning of the work content domains into classes. Using these classes, we address different probabilities for each feasible allocation.

01289
Optimal Preventive Maintenance Scheduling of Multilevel Mechanical Systems Using Genetic Algorithms

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This work proposes a practical approach to optimize preventive maintenance scheduling of multilevel mechanical systems. Because such systems contain a large number of degradable components subject to different loading conditions, three types of schedules-no maintenance, minimal maintenance, and replacement, are considered simultaneously. The minimal maintenance action restores a degraded component to the partial level of the original condition and thus the reliability decreases with the number of minimal repair activities. A simplified model of evaluating dynamic reliability of the component after minimal maintenance is formulated based on quantitative assessment process. The multilevel factor is taken into account while formulating the maintenance cost in addition to the three activities-combinations. A simple genetic algorithm is formulated to find the optimum allocation of the suitable maintenance schedule in a multilevel mechanical system. The numerical examples show the effectiveness of the proposed approach of preventive maintenance scheduling.

01293
Optimization of k-ε turbulence models for incompressible flow around airfoils

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A simple optimization is made for several widely known k-ε turbulence models by using random search to find improved sets of closure coefficients on each model for this specific type of flows. This preliminary work tries to show if the optimization of these parameters also implies an improvement on different airfoils. The results show this hypothesis is valid. INTRODUCTION At very high Reynolds number turbulent flows the ratio between the lengths of the bigest and the smallest eddies is often around a million, and because of that Navier-Stokes Direct Numerical Simulation (DNS) will probably still be unafordable for decades [1] keeping turbulence models essential. Among them, since the seventies for high Reynolds number flow the most used are the k-ε models or combined models that use them in high Reynolds number flow regions. This models close the RANS (Reynolds averaged Navier-Stokes) system of equations by approximating turbulence using the kinetic energy of the turbulence k and its dissipation rate ε with two model equations whose coefficients are tuned by minimizing errors over a wide variety of flows [2,3]. This fact provides generality but produces large errors at particular flows. This is the case of incompressible flows around airfoils at high Reynolds numbers, where large errors in the drag force are yielded, this is seen for instance by comparing k-ε model results for the aerodynamic coefficients for NACA airfoils on finite element meshes with wind tunnel experiments [4]. Above suggests that k-ε turbulence models can be achieved for this particular type of flow by optimizating closure coefficients. This method should improve the behaviour of the model for similar problems. The optimization variables are the closure coefficients. The function to minimize contains the errors on flows around a set of airfoils at several angles of attack. Afterwards the results are applied to an alternate set of airfoils to check if they also improve for these airfoils. Both sets of airfoils include a wide

variety of geometries. CONCLUSIONS The obtained results show the interest of the optimization of these parameters. Future work include the improvement of the optimization by using more powerful methods, as genetic algorithms, hill-climbing or gradient methods.

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01312
A direct method to determine the maximum loadability bifurcation point in power systems

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In terms of mathematical formulation, the maximum load supplied in a power system represents a static bifurcation point of the nonlinear equations that model the electric network in steady state. This point, beyond which these equations have no real solution, can be determined through the Continuation Methods, as shown in [1,2], or alternatively through the so-called Direct Methods [3]. The determination of the maximum loadability point through direct methods can be modelled as a parameterized optimization problem, whose solution provides the right and left eigenvectors corresponding to the minimum eigenvalue of the singular Jacobian matrix of the power network nonlinear equations. This work proposes a method to the direct computation of the critical loadability point. This calculation is formulated as a static optimization problem, which is directly solved through Newtons method, combined with a strategy of decomposition of the coe±cient matrix of the linear system solved at each iteration proposed in [4]. For this purpose, the electric network equations are expressed in rectangular coordinates, whose quadratic form is suitable to the application of the solution method. The following important issues are addressed to: 1) the in°uence of the initial solution with respect to the robustness of the iterative process; 2) the e®ect of the decomposition in the speed of convergence; 3) the use of a step size to prevent the divergence of the iterative process. Numerical results obtained with power systems ranging from 6 to 2916 buses (corresponding to linear systems with 24 to 8000 equations) show the main features of the proposed method.

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01313
Controlling feature geometry in topology optimization

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This paper presents a technique for constraining the shape and length scale of features in topology optimization. Current topology optimization methodologies assume a monolithic, free form design approach. However, many engineered materials and structures are composed of discrete objects or components with fixed range of length scales. For example, material structures containing fibers or particles which may be used to enhance

strength or multifunctionality of the material. Feature shape control is thus essential to ensuring topology optimized solutions are meaningful and physically realizable. Achieving such control on continuum domains is challenging as features form via the union of elements of like phase. The proposed technique is based on the Heaviside Projection Method (HPM). Topology is encoded in element-wise relative densities following the traditional SIMP logic. However, element densities are a function of auxiliary independent design variable fields that are projected onto element space using combinatorial regularized Heaviside functions. Shape and length scale are controlled intrinsically and solutions are near-discrete topologies. The technique is demonstrated on elastic design problems.

01315
Topology optimization of structures with random stiffness

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Topology optimization is an engineering design tool that can be used to identify optimal distributions of material across continuum domains. It allows for the introduction and removal of structural features and is thus capable of generating new, high performance design ideas. The cost of this freedom is that design spaces are large and discrete. Problems must therefore be simplified to facilitate solution, which often entails assuming deterministic design conditions. Such assumptions in the setting of formal optimization may lead to designs that are ultra-sensitive to fabrication flaws and are thus suboptimal when considering real-world engineering conditions. This talk presents an approach for efficiently incorporating geometric and material property uncertainties into the topology optimization methodology. Such uncertainties may arise from fabrication flaws and use of heterogeneous materials. The method is based on a recently developed perturbation approach that is extended to continuum domains by using correlated random fields. The uncertainties in stiffness are converted into mathematically equivalent systems of random loads that can be handled efficiently with adjoint sensitivity analysis as in other multi-load case works. The algorithm is demonstrated on mechanical stiffness design problems and verified using a Monte Carlo optimization approach. The results demonstrate that (i) including geometric and material uncertainties can have dramatic impact on design and (ii) the perturbation approach yields similar results to those found using Monte Carlo optimization approaches at a fraction of the computational cost. Extensions and limitations of the proposed methodology are also discussed.

01324
Bidirectional Wavelet-Based Adaptive Mesh Generation for Dynamic Optimization

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In this work we present a bidirectional adaptive control vector parameterization strategy for real-time dynamic optimization of chemical processes. The discretization technique is based on a multiresolution representation of the control vector using wavelet series. The proposed algorithm uses an automatic

procedure to refine or to coarsen the mesh in order to achieve the required accuracy minimizing the computational effort. The sequential direct approach, where only the control variables are discretized, was used to solve the optimization problem. In this approach, for a given value of the control vector, the system of differential-algebraic equations is integrated at each iteration. The optimal results of the control variables at one discretization level are used as initial guess for the optimization at the new adapted mesh. The need to refine or coarsen the mesh depends on the dynamic process behavior, as unexpected disturbances that can affect the quality of approximation and consequently the discretization strategy. The method was applied to several illustrative examples to demonstrate the efficiency of the bidirectional adaptation compared to the unidirectional approach, where the problem parameterization is generated by repetitive solution of increasingly refined mesh, and to a uniform discretization of the control variable. We demonstrate that the proposed strategy is capable to identify accurate discretization meshes which are more economical than the available approaches.

01334
Optimization of tube hydroforming process under uncertainty

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In metal forming processes, different parameters (Material constants, geometric dimensions, loads ...) exhibits unavoidable scatter that lead the process unreliable and unstable. In this paper we interest particularly in tube hydroforming process (THP). This process consists to apply an inner pressure combined to an axial displacement to manufacture the part. During the process a bad choice of the loading paths can lead to failure. Deterministic design optimization (DDO), are unable to optimize the process with taking into account to the uncertainty. In this work we introduce the Reliability Based Design Optimization (RBDO) to optimize the process under probabilistic considerations to ensure a high reliability level and stability of the process and avoid the occurrence of such plastic instability. Taking account of the uncertainty offer to the process a high stability associated with a low probability of failure. In this paper we define the loads parameter (i.e. inner pressure vs. axial displacement) mean values like a design parameter to be optimized. The limit state function takes advantages from the Forming Limit stress Curve (FLSC) that is insensitive to the strain path and history strain used as a failure criterion to detect the occurrence of necking\fracture and wrinkling. FLSD is considered a reliable failure criterion compared to the forming limit curve (FLC). To demonstrate the effectiveness of our methodology a numerical example of THP was proposed to optimize the loading path under probabilistic constraints defined with the use of robust central composite design.

01336
High contrast topology optimisation design by using nonlinear PDE filters

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Regularisation is necessary to ensure the existence of a solution in topology optimisation problems. A large number of techniques have been proposed in the past. Two of them, the mesh independent sensitivity and the mesh independent density filtering, have gained vast popularity in the research community, as well as in the industry. Recently the authors proposed an alternative formulation of these techniques based on the solution of the Helmholtz partial differential equation (PDE). The solution

obtained by applying the PDE regularisation, without any further amendment, consists of large regions with intermediate grey material. Such a solution is often difficult to interpret from the physical point of view. The practical realisation requires well defined bounds between the different materials or between the void and the material in the design. The Heaviside Projection can be utilised to obtain high contrast in the solution. Here we propose an alternative which is a natural extension to the Helmholtz density filter. The main idea is to introduce non-linear diffusion coefficient in the Helmholtz PDE. The coefficient depends on the gradient of the density field. The high contrast is achieved by diffusing the material in the regions where the magnitude of the gradient is small, and preserving the edges of the design by decreasing the diffusion in the areas with large gradients. The filter behaviour is demonstrated for various topology optimisation problems in linear elasticity.

01345

Population Diversity Control in Metaheuristic Techniques Using the Discrete Wavelet Transform

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Due to difficulties in obtaining exact solutions of optimization problems of practical importance in the productive sectors, metaheuristic techniques have been highlighted as promising approaches in many situations. Although not guarantee the optimality of their solutions, these methods provide acceptable solutions, even for complex problems. The ease of programming and the computational efficiency of these numerical techniques are its main advantages over the basic heuristic methods and deterministic optimization methods. However, despite the computational advantages of the technique, the methods based on metaheuristics have some difficulties such as to define the size of the population and to preserve the diversity of this population. According to the literature, a small population can cause premature convergence of the algorithm which is an important issue in applying genetic algorithms to solve problems and it is generally caused by the lack of diversity of the population. Then again, a very large population may demand too much processing time for a good solution is found. On the other hand, when it is applied in a data set the wavelets functions create a sparse approximation of the data by eliminating redundancies between the data values. Therefore, the wavelets can be applied in order to select appropriate individuals from a population in metaheuristic methods, as is done in this work. The idea is to use the discrete wavelet transform to explore possible correlations between individuals in a population of the Genetic Algorithm (GA) in order to eliminate redundancies between the individuals and ultimately reduce the number of objective functions evaluations necessary for convergence. The wavelet transform is applied to the population at the beginning of each generation, except at the first, decimating 50% of individuals. Individual survivors are evaluated and subjected to conventional operations of the AG. The method was applied to an unrestricted optimization problem of a function with several local minimum and various combinations of population size, and number of generations has been tested. The average number of the objective function evaluations and performance after 20 simulations were analyzed and compared the results of the traditional GA. Efficiency results, which is measured by the rate of convergence in 20 simulations according to the number of objective function evaluations are presented. The results show that the use of wavelet transform in GA, as is being proposed, is feasible for the test case. Though the GA wavelet not reaches 100% of efficiency it has, in general, the best results for a small number of objective function evaluations. Moreover, the less oscillatory convergence behavior shows that the new approach is less sensitive to variation in population size, indicating greater robustness of the method.

01347

A Graphical Methodology for Comparison of Evolutionary Optimization Algorithms

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A lot of work has been done in recent years on the comparison of numerical optimization algorithms. However, almost all available contributions are aimed at "scientific" comparison. A practical usage of proposed methodologies as well as meaningful explanation of their results is rather limited. Therefore, a humble goal of our work is to limit an attention only to practical parts of already known approaches. First, our proposed methodology compresses the whole "performance" curve (also called progress plot). Since almost all optimization algorithms are stochastic, e.g. thanks to a random starting point, one hundred performance curves are obtained for each optimization algorithm for the sake of statistical meaningfulness. Traditionally, statistical tests are utilized to show superiority of investigated methods using distribution of objective values obtained. These methodologies are shown insufficient in case of several optimization algorithms. Here we present a very simple metric called Relative Winning Score that counts only winners at discrete steps of those independent runs. Since RWS shows percentage of success, it can be easily visualized up to a high number of methods as well as benchmarks. Finally, to show the applicability of the proposed methodology, the performance of three optimization algorithms is investigated on a suite of three sizing structural optimization benchmarks. Acknowledgements The financial support of this work by MPO research project FT-TA4/100 is gratefully acknowledged.

01395

Interior points methods for linear multicommodity network flow problem

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This article studies the linear multicommodity network flow problem. This kind of problems are widely used as a modeling tool in many fields, as the transportation problem, logistic problem, etc., where different products have to send from a set of supply nodes to a set o demand nodes, with a linear cost objective functions, using the same network. This problem is usually very large linear programming problem. The network, given as traffic equilibrium network, has m nodes, n arcs and k commodities. In this work, we use the interior-point methods for solving the multicommodity network flow problem, formulated as a linear programming problem, and a numerical implementation of the primal-dual interior-point method is designed to solve this kind of problem. Most of the procedures to solve the linear programming problem, and in particular the multicommodity network, use the Cholesky factorizations solver, where the factorization applies to the matrix of the linear system. In this study, we use the AINV scheme, where the factorization applies to the inverse of the corresponding matrix, that is, if we have the linear system, say Gx = d, for some G symmetric positive definite matrix, the AINV method builds an approximate factorization of the inverse of G in the form inv(G)= Z inv(D) Z(T), where Z is a triangular unitary matrix and D is a diagonal matrix, and inv(.) indicates a inverse of any matrix and Z(T) is a transpose of matrix Z. This method showed to be a robust one, although the computational times could be large. At each iteration of the interior-point method, the corresponding linear system is solved, if it is expressed by the normal equations, (that is, a corresponding matrix is symmetric positive definite), by using the AINV algorithm alone or combined with the preconditioned conjugate gradient algorithm. If the linear system is expressed as an augmented indefinite system, it is solved by using the AINV algorithm combined with an indefinite preconditioned conjugate gradient algorithm. The above algorithms are implemented using the FORTRAN language, and numerical experiments are conducted for networks of different dimensions, that is,

with different m nodes, n arcs or links and different k numbers of products. The computational results show the effectiveness of the interior-point method for this class of network problems.

01401
Hierarchical Topology Optimization of Structures with Local Constraints

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This work discusses new extensions on the problem of hierarchical topology optimization of structures and its applicability. Assuming that the structure is made of a locally periodic material, and based on continuum topology optimization models, hierarchical topology optimization has the purpose to simultaneously optimize the lay-out of the structure and its material microstructure i.e. its characteristic unit cell. Here the problem is formulated as a structural compliance minimization (stiffness maximization) problem, subjected not only to a global volume upper bound constraint, but also to local material constraints that will guarantee appropriate features for fabrication or other requirements for specific applications. The inclusion of (local) material microstructure constraints is critical if one seeks the identification of practical materials for instance in the design of bone substitutes (bone grafts). To demonstrate the model and its applicability several examples will be presented and discussed.

01406
Buckling optimization of composite stiffened panels: some important issues

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The purpose of this presentation is twofold. On one hand attention will be focused on how to properly represent the buckling behaviour of composite stiffened panels (local/global, linear/nonlinear). On the other hand approximations suitable to optimization will be discussed. The Sequential Convex Programming approach (CONLIN, MMA, ...) is adopted but the conclusions are also valid for other approaches (SLP, SQP, ...). In particular results obtained with the most recent versions of SCP will be heavily employed: Globally Convergent Method of Moving Asymptotes (GCMMA) with sub-iterations. The various concepts and issues discussed here are supported through an illustrative example. However they are still valid for real life problems addressed by SAMTECH: design optimization of AIRBUS wings, fuselages or even the full plane. In our illustrative example the optimisation problem consists of minimizing the weight of a thin walled composite stiffened panel subjected to compression and shear, while satisfying some stability requirements, e.g. buckling and collapse loads must be larger than a prescribed value. We consider the optimization of a composite fuselage panel made of seven so-called super-stringers, i.e. a stringer riveted to a skin panel. The Figure below shows the whole panel and

gives an idea of its location in a real aircraft. The considered stringers have a trapezoidal profile (Omega stringers). The panel and the associated stringers are made of composite layers, each of them defined by an orientation angle and a thickness. While the fibre angle is restricted to take four discrete values (0º, -45º, 45º and 90º), the thickness may vary continuously between some prescribed bounds. Constraints are formulated in the form of buckling and collapse reserve factors: the buckling reserve factors results from a linear finite-element analysis, and the collapse reserve factor is computed by a nonlinear finite element simulation. The first buckling load is of course of interest when designing a structure to withstand instability and theoretically this single value corresponds to the constraint. However, due to mode-switching, there is no guarantee that the first buckling load always corresponds to the same buckling mode. As a consequence the related sensitivities are not necessarily relevant for the subsequent steps and may cause erratic convergence. This undesirable behaviour is often (and erroneously) referred to as "non-differentiable". We propose some ideas about the real nature of the problem. It is also shown that using a large set of restrictions allows to avoid oscillations and to speed up convergence of the optimisation process. Turning to the optimization strategy, several approximation schemes are experimented in our study. The selection of a suitable optimisation method will be discussed in details, with emphasis on the most recent SCP approach, GCMMA (Globally Convergent Method of Moving Asymptotes) with sub-iterations. All these numerical experiments were carried out using the SAMCEF system: ASEF, STABI, MECANO and BOSS-QUATTRO.

01416
Optimisation of yield surfaces for Magnesium

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In many industrial applications, models using empirical or physical laws are used for design or simulation. These models often involve some unknown parameters. The unknown parameters of a model have to be determined prior to solving the problem. Generally this identification is obtained by solving an optimisation problem using the observed (measured) data from the real problem. The parameters of the material model on the microscale can be determined by the identification procedure. The identification of model parameters of a plastic potential which accounts for anisotropy and unlike yielding in tension and compression, can be realised with the help of the isocontours of plastic equivalent strains, generated by the crystal plasticity based RVE calculations, has been introduced in the present work. The parameter identification is obtained by a combination of a genetic algorithm and a gradient method. In a first step, the genetic algorithm, suitable application for the large dimensional search-spaces about which a little is known, yields a solution close to the global minimum. After that the optimisation procedure switches to the more ecient Newton's method. The Newton's method has been used to fit a hardening function among the solution obtained from genetic algorithm. Newton's method may fail if the Jacobian matrices are singular or indefinite. Trust-region has been used to avoid such problem. The optimisation procedure is able to deliver satisfying results to predict both the isocontours of plastic equivalent strain values and the strain ratio values.

01418
Nonmonotone trust-region method for the weighted orthogonal Procrustes problem

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This work addresses a nonmonotone trust-region method for the weighted orthogonal Procrustes problem (WOPP). This problem has attracted attention of several researchers worldwide thanks to its diversity of applications, as for example, factor analysis, rigid body movements, structural and systems identification,

multivariate data analysis and others. In short, the WOPP consists on rotating and scaling a known set of data, arranged along the columns of a rectangular matrix, in order to best fit another set (a target matrix) in the least-square sense. From the mathematical point of view, one minimises a matrix-dependent quadratic function subject to a Stiefel manifold, which can be seen as the set of rectangular matrices with orthogonal columns. Based on the equivalence between trust-region technique and Levenberg-Marquardt approach, we incorporate a regularisation term on the objective function instead of using trust-region explicitly, thus our method circumvents computational difficulties which might arise from the intersection between the feasible set (Stiefel manifold) and the trust-region constraint. Under certain assumptions we prove global convergence to stationary points for a general nonlinear programming problem. Some numerical results are carried out on small and medium size problems in order to exhibit the algorithm performance. Although the tests feature several local minima, the experiments have shown that our nonmonotone scheme had success to reach the global minimum in all of them.

01432
Model Generation and Mathematical Modelling

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Mathematical modelling has two issues: first, to create a model of a dynamic system using expert knowledge and second, to discover a model using the measured data. We observe the model-driven and the data-driven approaches to the model creation problem and propose the new combined one. It gathers strong sides of classical approaches: the result model could be explained by experts and it fits measured data well. The new technique is illustrated by the model of pressure in combusting camera of diesel engine.

01437
A new algorithm based on feasible directions and cutting planes for nonsmooth convex inequality constrained optimization problems

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We propose a new algorithm for nonsmooth convex constrained optimization problems (NCCOP), which combines the feasible directions algorithm (FDIPA) suggested by Herskovits [1], with some basic ideas of the cutting plane and bundle methods [2]. We define an equivalent constrained nonlinear problem (ECNP). To solve (ECNP), a sequence of auxiliary linear problems (ALP) is constructed by substitution of the (ECNP) constraints by cutting-planes. At each iteration, the feasible descent direction of the FDIPA is obtained for the (ALP). This is done solving two systems of linear equations with the same coefficient matrix. For this search direction, the algorithm computes a step-length. The step-length is defined as the product of a fixed positive factor times the value of the longest step that can be done without leaving the feasible region defined by the cutting planes. When the search direction does not intersect any of the cutting planes, the step-length is set equal to a prescribed positive value. The search direction and the step-length define a trial point. If it is feasible for the (ECNP), it is denoted

"serious step" and defines the next iterate. If it is not feasible, the step is denoted "null step". In any case, a new cutting plane for the trial point is added to the (ALP). The Algorithm continues generating serious steps until a convergence criterion is satisfied. One of the main advantages of the proposed algorithm is that it is very easy to implement. Furthermore, it does not require the solution of a quadratic problem at each iteration, and does not use a merit function or filter techniques for monitoring the progress to the solution. Numerical results for a set of well known benchmark problems are reported. These results show that the proposed algorithm is robust and efficient.

01443
The adaptive block relaxation method for ill-conditioned problems in nonlinear elasticity

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At present for numerical solution of boundary-value problems in nonlinear elasticity the finite element approximation (FEA) is widely used. As is well-known, standard methods, such as the method of elastic solutions (the quasi-Newtonian procedure) and method of variable elastic parameters (the Richardson procedure of simple iterations), are very sensitive to condition number of appropriate resolving systems of algebraic equations. After the standard Lagrange continuous piecewise linear spatial FEA of the variational problem in nonlinear elasticity we receive the appropriate finite dimensional essentially nonlinear problem. The initial continual stationary problem is approximated by the problem of mathematical programming. It is demonstrated that for some finite elasticity models describing elastomers in water or oil the appropriate finite dimensional problem can be ill-conditioned. The main cause of this phenomenon consists of the following: the global stiffness matrix can have rows with essentially different factors. As a result, this finite dimensional problem needs special preconditioned numerical methods. The original decomposition method of adaptive block relaxation (ABR) is proposed for numerical solution of ill-conditioned FEA models of nonlinear elasticity. The ABR method takes into account essentially nonlinear deformation of material and practically disregards the condition number of the global stiffness matrix. Its main idea consists of iterative improvement of zones with "proportional" deformation by special decomposition of domain (variables) and separate calculation in these zones (on these variables) on every iteration step. Zones of essential nonlinear deformations, as usual don't known a priori, therefore, they are corrected adaptively on every iteration step. The global convergence theorem for the ABR method is proved. Numerical results show that to find the deformed configuration, this method has qualitative advantages over standard techniques.

01444
Comparison Between Two Cad-Based Aerodynamic Shape Optimization Approaches Using Adjoint Methods For Fast Gradient Computation

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Aerodynamic shape design of an aircraft using gradient-based optimization techniques has become nowadays a reliable application. Finite differences approaches to evaluate the gradients

of the cost function with respect to the design parameters have been successfully used in the last decades, but they are now being replaced by the adjoint methods. As a key advantage, the adjoint approach makes the gradient computation independent from the number of the design variables and therefore provides an important reduction of the required computation time within the optimization process. In this work, a shape optimization framework has been developed and integrated into the DLR TAU code, used by the AIRBUS industry, which solves the compressible 3D Reynolds-Averaged Navier Stokes equations with a finite volume formulation on unstructured grids. Key aspects of this optimization framework are the use of the adjoint methodology, both continuous and discrete approaches, and the use of a Computer Aided Design (CAD) based parameterization, relying on NURBS or Free Form Deformation to handle complex configurations and ensures curvature and continuity of the geometric representation. Two different approaches for optimization have been considered for comparison purposes: - Approach A. Use of the Discrete Adjoint methodology and a volume formulation for gradient computation. Within this approach, Free Form deformation is used and the design variables are the lattice box points. - Approach B. Use of the Continuous Adjoint methodology and a surface formulation for gradient computation. The parameterization is provided with a surface NURBS definition where the design variables are directly the spatial coordinates and weights of the NURBS control points. The rest of the steps in the optimization process are kept the same for both approaches, in order to make a proper comparison. The objective function considered is the minimization of the drag coefficient maintaining the lift into a range of 10% from the original. The optimization algorithm employed is a simple descent method in which small steps are taken in the gradient direction. The design optimization framework has been applied first to a transonic inviscid RAE2822 profile at M=0.729, AoA=2.31°, defined by a NURBS curve with 14 control points. The design variables, coordinates and weights of the control points, can move freely during the optimization process, except those situated on the leading and tailing edge in order to maintain the chord line and angle of attack. The reduction of the drag coefficient is around 60% with both approaches, but there are noticeable differences in terms of computational cost and number of iterations required to obtain the optimized profile. Final considerations about the main advantages of each approach will be also discussed.

01455
Lift and Project Cuts for Robust Optimization

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Real world mixed integer linear programming (MILP) models often contain numeric and hence uncertain data. We are interested in solutions to such problems which remain feasible under change of the problem data. This question is addressed by Robust MILP. We consider a notion of robustness where the coefficients of the constraint matrix are perturbed row-wise, where the perturbations are described by a polyhedrally encoded set. In this talk we are interested in the worst case strategy, i.e. solutions should be feasible under all possible perturbations. While MILP problems are routinely solved by Branch & Cut codes, little theory for our type of Robust MILP problems is available: usually one reformulates the robust problem as a regular MILP problem in a higher dimensional space. We present a generalization of the Lift & Project method, that directly handles robust problems, and show how the cut generation problems of our method and of a MILP reformulation of the robust problem are related. Computational results will be presented on robstified versions of MIPLIB and other MILP benchmark instances. This is joint work with Utz-Uwe Haus.

01460
A steady-state NSGA-II algorithm for multi-objective optimization of Diesel combustion

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In order to comply with environmental regulations, automotive manufacturers have to develop efficient engines with low fuel consumption and low emissions. Thus, development of engine combustion systems (chamber, injector, air loop) becomes a hard task since many objectives in conflict have to be optimized and many parameters have to be defined. Evolutionary Multi-objective optimization represents an efficient tool to explore the search space and find promising engine combustion systems. In this work, a phenomenological 0D model of Diesel engine combustion is coupled with a state-of-the-art multi-objective evolutionary algorithm NSGA-II. The 0D combustion model allows to compute, from the compression to the expansion strokes, the phenomena of: Injection, mixing, combustion, and major pollutants formation thanks to a detailed kinetic scheme. Besides, it takes into account spatial heterogeneities on temperature and mixture composition inside the combustion chamber. A standard parallel version of NSGA-II based on master-slave paradigm is applied using a grid system. In this standard version, the selection process is generational: Variation operators are applied once all individuals belonging to the same generation have been evaluated. However, the computation of different solutions can have very different durations. Thus, some processors sometimes stay idle. To tackle this issue, a steady-state version of NSGA-II has been implemented: Only one individual is created per generation, and uninterrupted use of available processors in the grid system is ensured. Comparison between both approaches described above is performed.

01466
Reliability-Based Multidisciplinary Design Optimization Using Metamodeling

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This paper focuses upon the development of efficient reliability-based multidisciplinary design optimization (RBMDO) for handling high fidelity simulation models. The reliability-based optimization (RBDO) is directly formulated using a double-loop iteration process. This formulation is computationally intensive because of the two levels of optimization required. The inner optimization loop is to find the reliability and the upper loop optimization solves the RBDO problem. Solving such nested optimization problems can be computationally prohibitive, especially for large scale high fidelity MDO problems. There has been a considerable effort to reduce the computational cost associated with RBMDO. However, the computational cost still is very high for RBMDO based on high fidelity models. The interdisciplinary coupling inherent in MDO causes increased computational effort beyond that encountered in a single discipline optimization. For example, a single high fidelity structural or aerodynamic analysis of an aircraft configuration requires several CPU hours on a supercomputer. In addition, a typical aerospace design involves tens to hundreds variables and reliability constraints. These issues result in a very high overall computational cost limiting real-life application of RBMDO to complex aerospace design problems based on high fidelity simulation models. The methodology adopted in this paper is based on metamodeling, which is developed to simultaneously utilize computational models of varying levels of fidelity within a collaborative optimization (CO) framework. CO is a bi-level MDO framework, with discipline-

specific optimizations free to specify local designs, and a system level optimizer to coordinate this process while minimizing the overall design objective. In discipline level, metamodeling techniques are used in conjunction with the double-loop method to reduce the computational cost of RBMDO, while ensuring convergence to the high fidelity solution. It consists of computationally efficient simplified numerical models (low-fidelity) and expensive detailed (high-fidelity) models. The low-fidelity models are tuned using a small number of high fidelity model runs, which are then used in place of expensive high fidelity models in the RBMDO process. The low fidelity model is tuned in such a way that it approaches the same level of accuracy as a high fidelity model but at the same time remains a computational inexpensive model to be used repeatedly in the optimization process. In this process, only tuned low-fidelity models are used in the optimization process. The use of equality constraints at the system level in CO introduces numerical and computational difficulties, which hinders the use of derivative-based optimization techniques whereas more robust optimization techniques such as particle swarm optimization (PSO) are prohibitively expensive. To overcome this difficulty, the construction of metamodels at the system level is based on the moving least squares method (MLSM), trust region strategy and PSO optimization algorithms. The proposed method is demonstrated on a unmanned aerial vehicle wing test problem involving two disciplines (structure and aerodynamic). The results of the proposed method show significant improvement in computational cost for solving RBMDO based on high fidelity simulation models in comparison with standard methods.

01478
Electrical Impedance Tomography to Fluid Identification in Ducts: A Brief Review

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The electrical impedance tomography (EIT) is a method of obtaining images of internal organs, or any other driver internal volume whose images you want to use as a research subject, with a generic iterative algorithm (AGI) are reconstructed conductivities that generate the pixels of the image. This technique had its beginnings in medical applications has now spread to the various branches of engineering. However, this problem is a nonlinear and ill-conditioning which makes it particularly difficult to solve the problem of electrical impedance tomography requires a detailed knowledge for their application. The application of EIT in process engineering in ducts with fluid in its various phases is important because there is many applications in mechanical, chemical engineering. Considering the simplicity and reduced computational time of Algorithm Newton-Raphson method, this paper raises questions regarding the characteristics to be observed during application of the technique, such as the standardization of current convergence and evaluation of the image versus the method convergence.

01483
Solution of the non-linear parabolic problems using nonlinear complementarity algorithm (fda-ncp)

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Parabolic type problems involving a variational and complementarity formulation arise in mathematical models of several applications in Engineering, Economy, Biology and different branches of Physics. These kinds of problems present several analytical and numerical difficulties related, for example, to time evolution and moving boundary. In this work we implement a numerical method based on the finite difference scheme for

time evolution and nonlinear complementarity algorithm (FDA-NCP) for solving the problem at each time step. We use the implicit finite difference scheme with adaptative time step implementation which allows us to use bigger time steps and speed up the simulations. One of the advantages using the FDA-NCP is its global convergence. This method was applied to the non-linear parabolic problem which describe some simple cases of the reaction-diffusion equation that appear in the chemical reaction inside the porous medium. This equation was rewritten in the quasi-variational form. The main problem consists in tracking the moving boundary that represents the chemical reaction depth inside the porous medium.

01485
On the asymptotic order in path following interior point methods.

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Interior point methods are related to Newton's method applied to a parametric KKT system. The parameter is driven to zero thereby ensuring convergence of the approximate solutions of the parametric system. Path following variants explicitly define and follow the parametric solutions, the so called central path. In this talk, we address two generalizations of the usual interior point framework from an asymptotic analysis point of view. First, we address inexact solutions of the linear systems arising within Newton's method. Depending on the inexactness allowed, asymptotic convergence order reduces; for primal variants, this reduction is more severe than for primal-dual formulations. Second, we investigate the use of higher order path following strategies in those methods. The usual high order path following variants (Mehrotra's formulation) are reminiscent of Shamanskii's generalization of Newton's method. We propose a different approach based on a high order expansion of the so-called central path, somewhat reminiscent of Chebyshev's third order method and its generalizations. For primal variants, the use of higher order representation of the path yields spectacular improvement in the convergence order while for primal-dual formulations, the benefits are important, but not surprizing.

01492
Efficient Solution of Chance-Constrained nonlinear Dynamic Process Optimization Problems with non-Gaussian Uncertainties

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The goal of this work is to develop efficient computational strategies for the solution of stochastic nonlinear dynamic optimization problems with chance constraints in order to determine control strategies for the robust, optimal and reliable performance of complex dynamic processes in the presence of non-Gaussian random errors and input disturbances. Non-Gaussian distributed uncertain variables are present in many practical processes but have not been well investigated in the chance constrained optimization framework. Due to the nonlinear model equation, it is difficult to a priori find an explicit description for the probability distribution of the chance constrained variables. For this reason chance constraints on output variables are transformed into chance constraints with respect to the uncertain input variables by using monotony relations. In the final analysis, the problem can be

approximatively transformed into a deterministic nonlinear optimization problem. The solution of the resulting nonlinear optimization problem can be done through a gradient based nonlinear optimization algorithm. However, the numerical computation of the values and gradients of the objective function and the chance constraints requires the evaluation of a set of multidimensional integrals. To date these required intensive computational resources and extensive computational time. This work shows computation time can be decisively reduced through the use tensor-product sparse-grid integration methods for the evaluation of the multidimensional probability integrals. One of the major novelty of this work lies in the consideration of non-Gaussian distributed uncertain variables corresponding to which no custom-made sparse-grid multidimensional integration techniques are available. Furthermore, the viability and efficiency of the computational approach is demonstrated through case-studies on realistic process control problems with non-Gaussian input uncertainties.

01495
Frequent Minimally Infrequent Attribute Sets

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Associating categories with measured or observed attributes is a central challenge for discrete mathematics in engineering and life sciences. We propose a new concept to formalize this question: Given a binary matrix of objects and attributes, determine all attribute sets characterizing object sets of cardinality t_1 that do not characterize any object set of size $t_2>t_1$. We determine how many such attribute sets exist, give an output-sensitive quasi-polynomial time algorithm to determine them, and show that k-sum matrix decompositions known from matroid theory are compatible with the characterization.

01497
Critical and constructive analysis of the experimental schemes for evaluation of adhesive strength

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During experimental estimation of the fiber-matrix interfacial bond strength it is common practice to use methods, which are based on testing of micro-samples- single fibers embedded in a polymeric matrix. Among the most extensively used micromechanical methods are the methods of fiber drawing from a matrix, microextrusion of a fiber segment, tensile failure of a fiber in a sample. The value of the adhesive strength is found as the ratio of the force, under which the fiber is drawn from the matrix, to the area of the fiber-matrix contact prior to failure. Numerical evaluation of the fiber-polymer adhesion strength presents a number of difficulties. One of the problems is related to the fact that the distribution of the shear stress over the fiber-matrix interface is inhomogeneous. In this study, in the framework of the linear elasticity theory we investigate numerically the stress-strain state of the samples after the adhesion strength tests with the aim to develop the most suitable experimental schemes, which can provide a more uniform stress distribution along the interface. A distinguishing feature of the boundary-value problems reflecting the peculiarities of the proposed experimental schemes are the existence of singular

points (lines), viz., the points (lines) at the interface where different materials come into contact. According to the linear elasticity theory these points can have singularity solutions, the appearance of which should be attributed to the infinite stresses. The solution of the problems under consideration by the finite element method requires the non-standard algorithms based on the application of singular finite elements or refined finite element grids, providing an appropriate accuracy of computations in the vicinity of singular points. The results of computation and numerical simulations presented in the paper support the validity of the propose algorithm. The presence or the absence of singular solutions in the vicinity of the examined singular points and, consequently, the character of stress concentration are determined by the geometry in the vicinity of the singular points and by mechanical properties of the materials used. On the basis of this knowledge, the most constructive approach is a statement of the optimization problem dealing with a search of such geometry in the vicinity of singular points that provides the most uniform distribution of the required components of the stress tensor over the contact surface. A mathematical formulation of the optimization problem is considered. The solutions of the optimization problems obtained for different schemes of adhesive strength evaluation are analyzed to reveal the general relationships for the surfaces in the vicinity of the contact zone of different materials. From the analysis made follows the conclusion that the optimal surfaces have common features related to the structure of the solution at the vertex of composite wedge. It specifies the character of singular solutions at the interfacial points of contact of different materials. The work has been funded by the RFBR (grant No 09-08-99127) and under the state support of young Russian scientists (grant No MK528620101)

01498
An immunological aproach to solve the LSP Allocation Problem in MPLS Networks

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Multimedia applications, like video on-demand, videoconference and IP telephony, must receive special attention in computer networks. Actually, those applications have become the main concern when dealing with traffic engineering and quality of service issues. In this context, the development of new transmission and optimization mechanisms is crucial, specially for networks that act as main traffic backbones . Nowadays, different classes of multimedia applications dispute network resources along with data applications. Every application has its own differentiated requirements and the network must satisfy each one according to the application individual needs. Traffic requirements may be fully identified by means of four parameters: reliability, time delay, jitter (delay variation) and bandwidth. These four parameters establish a level of Quality of Service (QoS) for each one of the traffic flows. Techniques based on QoS, like integrated and differentiated services, allow a significant improvement, although they are all based on the conventional routing algorithm still in use on IP networks. To assure the correct packet flow through the network, one can use the Multiprotocol Label Switching (MPLS) framework. MPLS consists in routing packets based on a label, which is inserted in every packet between the corresponding link and network headers. The complexity reduction of the routing process of IP packets and the introduction of traffic engineering are two of the main motivations for using MPLS. Traffic engineering is a management technique that works to guarantee that the network resources can satisfy all the traffic needs of the applications. However, the

current resource allocation can be non- optimized and, as a consequence, the future requests may not succeed, even though there are available resources spread over the network. Thus, optimization applied to resource allocation is essential to achieve high performance and maximum utilization in a given network. Traffic engineering deals with different aims like maximization of the used bandwidth and re-routing caused by congestion or failure. MPLS can be used to implement traffic engineering, as explicit routes can be defined between sources and destinations. Since route assignment is a NP-hard problem, heuristics like genetic algorithms are generally used in order to find an acceptable solution. The present work uses the immunologic algorithms in the route finding problem for MPLS networks. Some mechanisms like local search are applied to improve the computational results. The immune algorithms are compared with a Genetic Algorithm (GA). For networks with a large number of routes, the immune approach has better results. In contrast, for networks with a small number of routes, the AG presents a more interesting approach, given its smaller execution time if compared to the implemented immunologic algorithms.

01499
Immune Algorithm Applied to the Vehicle Routing Problem With Simultaneous Pickup And Delivery

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Nowadays, the application of new technologies can increase the agriculture and industrial productivity. There are several factors that raises the transportation costs of goods, like poor condition of roads due to inadequate maintenance, security, vehicle maintenance, fuel and tool prices. Companies seek logistics solutions to optimizing the overall flow of goods and reduce their operating costs. In this context, the traditional Vehicle Routing Problem (VRP) is the most important Combinatorial Optimization problems. There are several different variants of the VRP, being the Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) one of them. This variant can be defined as: given a fleet of k vehicles with Q capacity and N consumers. There are some complications in this model: route should never exceed the vehicle capacity Q and goods need to be brought from the depot to consumers, but must be picked up of consumers and brought back to depot. The objective of this problem is to minimize the cost of the path traveled by vehicles. VRPSPD can be applied in breweries, airlines, carriers in general, among others. Since the problem is NP-hard, the algorithm is computationally viable to solve only problems of a moderate size. The Artificial Immune Systems (AIS) are computational mechanisms based on biological immune system and it aims to solve real world problems of high computational complexity. This approach has applications in many areas such as optimization, pattern recognition and analysis and data classification. This work proposes an unprecedented adaptation of an immune algorithm to VRPSPD. Opt-aiNET is an extension of the classic aiNET algorithm for optimization problems. This algorithm evolves from a population (set of candidate solutions) of size dynamically adjustable, has mechanism to exploit the search space, it is capable of performing multiple location and it has great ability to maintain optimal local solutions. Algorithms based on initial population enable greater diversification of the search space since it consists of more than one solution to match. However, with large computational cost. Tests were performed with instances of 50, 75, 100, 120, 150 and 199 consumers. Results showed that for 3 (three) instances with until 100 customers to the system implemented in this work was better than the best results in the literature for the same instances of the problem.

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01502
Application of X-FEM and Level-Set Description to Shape Optimization of Holes in Elastic Plates and Periodic Microstructures

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This paper deals with the shape optimization of holes in elastic plates and periodic microstructures. Performing shape optimization with the classical finite element method (FEM) generally suffers from mesh management issues when modifying the geometry. Moreover this method does not allow any modification of the topology thus limiting the gain in terms of objective function. To circumvent these drawbacks, several authors have proposed different fixed grid methods such as the topology optimization or more recently the extended finite element method (X-FEM) coupled with a Level Set description. Indeed the X-FEM has the advantage of being able to take into account non conforming boundaries on fixed mesh. Therefore, the evolution of the geometry of arbitrary holes or any discontinuity can be captured during the optimization process without remeshing (as required with the classical FEM approach). A geometrical description based on Level Sets allows to keep a smooth and clearly defined boundary while treating problems involving discontinuities and propagations. In this paper, the problem of shape optimization of holes in elastic plates and periodic microstructures is studied using the X-FEM and Level Set description. More precisely, our research aims at validating this approach by revisiting the analytical solutions obtained by Vigergauz. Hence, Vigdergauz has shown that an elliptic inclusion, whose orientation and eccentricity depends on an applied macroscopic uniform stress field ensures a global energy minimum under hydrostatic loads. Moreover, he has shown that this optimal shape provides a uniform stress distribution along the boundary of the inclusion (the equi-stress condition). Here, the proposed method is applied to different 2D academic test cases considering several objective functions such as compliance, bulk modulus or shear modulus for elastic plates or periodic structures. Furthermore, we present the applications of strain energy-based homogenization method with X-FEM to optimize the microstructure of large plates. The study of the shape of a hole on a plate is a classical problem when dealing with isotropic materials. Nevertheless, it is not the case for orthotropic materials. Here, our study is extended for such materials. Numerical implementations have been realized using the object oriented finite element code OOFELIE (http://www.open-engineering.com/) and the optimization environment of BOSS Quattro \\ (http://www.samcef.com/). Various applications have been succesfully carried out. The recovery of the expected results shows the potential of the method.

01516
A hybrid metaheuristic optimization algorithm based on SFLA

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In the last decades, there has been widespread interaction between researchers seeking various evolutionary computation methods to conceive more accurate and expeditious solutions.

We herein present an evolutionary algorithm based on the Shuffled Frog Leaping Algorithm (SFLA). Similar to the SFLA, our method partitions particles into different groups called memeplexes; however, the best particle in each memeplex thereafter determines its movement through the search space in each iteration of the algorithm toward the global best particle and the worst particle in each memeplex keeps track of its coordinates in the solution space by moving toward the local best particle (the best particle in the same memeplex). Not only does this method lessen computation costs and offer speedier solutions in comparison to the Particle Swarm Optimization, but it also has a distinct advantage over the SFLA in that it reduces the probability of the particle's being trapped in the local minima by directing the best local particle toward the global best particle. Our method was tested on two test functions in different circumstances and the results were subsequently compared with those of the other evolutionary methods such as the SFLA. Success rate and search time were the parameters considered to check our method efficiency.

01525

A new approach for power system load flow by trust region and filter multidimensional techniques.

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The solution of load flow in electrical power systems consists mainly in determining the state of the network, represented by a set of nonlinear equations and inequalities, which underlie the static model of the network. This paper presents a new approach to solve the problem of load flow, using a model of Gauss-Newton (GN) in the minimizing of a nonlinear least squares problem associated with the equalities and infeasible inequalities constraints. In each iteration of the algorithm, a trial step is computed by minimizing the GN model in the trust region. To control and decide whether the trial step should be accepted, it is used the filter technique as an alternative to the merit function. This technique was recently introduced to the solution of nonlinear programming problems and its main concept is that the filter accepts a trial step if it reduces either the objective function or a measure of constraint violation (infactibility), avoiding that the search for solutions returns to points already determined. In the muldimensional case, the difference is that each component of the filter represents the value only of the constraints considered in the original problem and a new vector is accepted as it reduces the infeasibility in a specific set of constraints. Preliminary numerical results on some standard IEEE systems are very encouraging and validating the robustness of the proposed method.

01531

A Particle Swarm Optimization Algorithm for Truss Optimization on Shape and Size with Dynamic Constraints

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In this paper, a structural truss mass optimization on size and shape is performed taking into account frequency constraints. It is well-known that structural optimizations on shape and size are highly non-linear dynamic optimization problems since this mass reduction conflicts with the frequency constraints especially when they are lower bounded. Besides, vibration modes may switch easily due to shape modifications. This paper intends to investigate the use of a Particle Swarm Optimization (PSO) algorithm as an optimization engine in this type of problems. This choice is based on reported well-behavior of such algorithm as global optimizer in other areas of knowledge. Another feature of the algorithm is taken into account for this choice, like the fact that it is not gradient based, but just based on simple objective functions evaluations. This is of major importance when dealing of highly non-linear dynamic optimization problems avoiding bad numerical behavior due to gradients. The algorithm is briefly revised highlighting its most important features. It is presented four examples regarding the optimization of trusses on shape and sizing with frequency constraints. The examples are widely reported and used in the related literature as benchmark examples. The results show that the algorithms performed better than other methods in most of the cases.

01549
Investigation of Influence Parameters on the Hot Rolling Process Using Finite Element Method

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Rolling process is one of the most popular processes in manufacturing industries in order to make different parts with a long rang variety of dimensions. In this procedure the internal raw material transform into desirable shape by at least two rolls. In comparison with other methods for analyzing the rolling process, the finite element method is the most practical and accurate one, so a coupled thermo elastic plastic three dimensional finite element model is considered to analyze the hot rolling process. In present research the influence of various parameters such as geometry of the slab, temperature, friction between work-rolls and slab, percentage of thickness reduction, rotational speed of work-roll have been studied on process. Outputs like temperature distribution, stress, strain and strain rate fields, roll force have been obtained through different inputs. The outputs of finite element simulation are used to investigate the effects of parameters on product integrity and mechanical properties of part.

01561
Developing a shallow-waters finite-differences numerical model to study convectively dominated flows near the boundaries

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The shallow water equations are introduced and discretized in a standard C-grid with a leapfrog, face-centred numerical scheme combined with simple Asselin-Roberts filtering as presented in Kantha and Clayson [4]. Dirichelet, radiative and closed conditions were implemented at the boundaries[2]. Simple testing were performed with a gaussian level elevation and with wind forcing. The geostrophic equilibrium of a gaussian level elevation is presented and an analytical solution of the steady-state is obtained. Results show that Dirichelet and closed boundary conditions reflect all surface waves back inside the domain and multiple linear superpositions occur, eventually leading to instability. A study on the scalar of Okubo-Weiss[1, 6, 3] is suggested as a diagnostic tool to evaluate hyperbolicity/parabolicity of convectively-dominated[5] flows near open-boundaries [2].

01568

Development of a mathematical model that complys the specifications required by quality standards of differents ethanol importing countries

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In this paper, a Non Linear Programming (NLP) model is developed to establish a volumetric quantity of ethanol that each brazilians destillaries should produce to form a share to assist the annual demand requered by the countries importers of the product. Because of the countless economical and partner-environmental problems caused by the excess of the gasoline's consumption and others pollutants and nonrenewables fuels, the exported product (ethanol) was taken as a pratic solution for such problems, because the objective is use it as a renewable fuel for automotives, mixed with the gasoline. The model aims the minimization of the global cost of annual production, considering the specifications of the quality pattern demanded by the different countries importers. To reach the properties of the final blend, was necessary convert some properties of each ethanol in volumetrics basis and consider a case of study, with similar data to the real, to evaluate the application and the great global results of the program. The global optimization solver Conopt, available in GAMS, was used to solve the problem.

4 Efficient Analysis and Reanalysis Techniques

01163
A FEM approach to optimal control problems in vehicle dynamics

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Vehicle dynamics control can be studied as an optimal control problem. The dynamics of the vehicle is given by a set of ordinary differential equations and corresponding boundary conditions whose solution represent the state variables. The controls are given by the force acting on the vehicle and the angle of this force. During the maneuver we minimize certain quantities in order to achieve a desired track. In particular, we study a double lane-change maneuver for a vehicle. The aim is to find the optimal way to maneuver a vehicle to avoid an obstacle in the road and then to retrieve its original position and travel direction. We present an adaptive finite element method for solving this optimal control problem. Necessary conditions for optimality are derived in a weak form. The resulting equations are approximated by a Petrov-Galerkin finite element method. Using the method of dual weighted residuals, we derive an a posteriori error estimate. The error estimate is used as the basis for the implementation of a multi-level adaptive algorithm.

01178
Interference and diffraction analysis of holographic gratings using the Finite-Difference Time-Domain method

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The Finite-Difference Time-Domain method (FDTD) is based on a time-marching algorithm that has proven accurate in predicting microwave scattering from complicated objects. In this work the method is applied at optical wavelengths, more concretely the method is applied to rigorously analyze holographic gratings for the near-field distribution. It is well known that diffraction gratings with feature sizes comparable to the wavelength of light must be treated electromagnetically, because the scalar diffraction theories, including Fourier and Fresnel approximations, no longer apply. The FDTD method permits to analyze the electromagnetic field distribution in function of time and space. In optical wavelenghts the simulation of wide areas implies more memory and time processing. For that reason, some add-ons are included in order to correctly calculate the far field distribution obtained from the numerical near-field values computed in the simulation region. As a consequence the total grid simulation size can be reduced improving the performance of the simulation, in terms of memory usage

and time processing. Values in the near-field region are computed due to the illumination of the grating by means of a plane wave with different angle of incidence. In addition, we compare the results obtained by the FDTD method to those obtained using the Kogelnik's theoretical expressions applied to diffraction gratings. As it will be seen in this work there is good agreement between numerical and analytical values, thus validating our FDTD implementation.

01246
Flux Relaxation as an Approach to the Stability Improvement for Explicit Finite Difference Schemes

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The constrained optimization problems where a partial differential equation (PDE) or a system of PDEs appears as an essential part of the constraints often arise in various applications. The efficient and robust solution of PDE constrained optimization problems has a strong impact in automotive and aerospace industries, chemical processing etc. The appropriate mathematical treatment of such problems requires the use of powerful algorithmic tools for PDE solution. Nowadays the computer systems with performance of above 100 Tflops have become accessible to researchers. This opens big opportunities for mathematical modelling allowing the simulation of processes as close as possible to the object under investigation. First of all it concerns industrial applications which are, as a matter of fact, multidisciplinary and possess a complicated geometry. Moreover, the industrial problems require high computational accuracy which is caused by the necessity to optimize technical processes already known. All this makes mathematical modelling using the HPC systems an important factor of scientific and technical progress. HPC systems based on the multicore processors require software being created to take into account a hybrid structure of memory: distributed among the processors and shared among the cores inside the processor. In this regard very promising are the explicit schemes, which can be easily adapted to the architecture of the multicore systems and allow to effectively employ the systems consisting of 103-104 cores within single simulation run. But the explicit schemes impose severe stability limitations on the size of the time step, especially when the parabolic equations are solved. It is well known that explicit schemes for parabolic equations have very strong stability condition. This limitation is acceptable when spatial grid is rather coarse. For fine grids which are used as a rule in HPC calculation satisfying this condition makes the needed number of time steps extremely large. Analogous condition for hyperbolic equations is not so limiting and it is more adequate from the physical point of view because small spatial details demand appropriate time resolution. So, development of explicit schemes with a rather mild stability condition is one of the most important trends. A physical approach is proposed in this paper which permits to improve the situation and achieve practically Courant like stability condition for parabolic equation. In addition, physically founded flux relaxation approach may be useful not only for parabolic equations. It permits to improve stability of explicit schemes for gas dynamics problems, even if we solve them in the frames of Euler equations, when there is no parabolicity at all. Moreover, it gives better solutions from the physical point of view. This fact opens wide perspectives for modeling real scientific and engineering problems on modern high performance computer systems by use of explicit schemes, which

are much simpler for parallel implementation than widely used now implicit ones. Most of all it concerns multicore computer systems with hybrid architecture.

01320
Towards a Blank Shape Optimization: Enhancement of Procedure and FE Solver

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Sheet metal forming is a challenging technological process widely used by automotive carmakers. The success of a forming operation is strongly dependent on a large number of parameters. Amongst them, the initial blank shape is one of the most important process parameter with direct impact on the quality of the finished part and also on its cost. However, due to the problem physical and geometrical non-linearities, namely the ones related with materials' mechanical behaviour, contact with friction and tools' geometry, there is not a simple procedure to determine, for a given final geometry, the initial optimized blank shape geometry. A method to determine the optimal blank shape for a formed part, using the deformation behaviour predicted by finite element simulations and salient features of NURBS surfaces, will be presented and discussed. In brief, by using an iterative process based of FE simulations and a cost function to evaluate and weight the scattering between the target and the current geometry of the blank, the initial guess will be iteratively corrected, according to the FE simulations, until the optimized initial blank shape geometry is achieved. The method is able to predict an optimal blank shape within a few steps. However, the time efficiency of this procedure is strongly dependent of the numerical efficiency of the FE solver. DD3IMP, an in-house static implicit FE solver, is the FE solver used in this work. Static implicit codes are well known for their robustness, reliability and accuracy of numerical results. Unfortunately, these codes are also usually known to be very time-expensive. The effectiveness of the blank shape optimization procedure relies not only on the optimization algorithm but also on the numerical efficiency of the FE solver. The aim of the present work is to show not only the improvements and effectiveness carried out on the blank shape optimization algorithm but also the enhancements introduced in the FE solver in order to speed-up the main algorithm. The results show that an important decrease of the computational efficiency of the optimization process was achieved. The main FE solver enhancements will be detailed, namely the implementation of a new solver for the linear sparse systems, the implementation of OpenMP directives to parallelize several branches of the main algorithm, in particular the ones related with the loops over the finite elements and contact, and some re-written subroutines that allow a significant local improvement of the computational efficiency. In fact, the improvements in the FE solver allow increasing the use of implicit codes for solving large scale forming problems, as well as use them in inverse analysis and iterative optimization procedures. The computational efficiency of implicit FEM codes can be improved using different strategies, from optimization according with (1) hardware, (2) operating system, (3) compiler options, to guaranteeing (4) state-of-art libraries and (5) improvement of the code algorithm. In this work, the exploitation of these different strategies is described and its applicability to a blank shape optimization procedure demonstrated.

01428
Efficient Eigensolution Reanalysis using sensitivity data

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Methods of computing eigensolution sensitivity have been known for a long time. Both exact and approximate methods are available in the literature. While eigenvalue sensitivity is used routinely in structural optimization with eigenvalue constraints, few application of eigenvector derivativeses are reported in the literature. The objective of this paper is to present an effective eigensolution reanalysis approach using first and second order eigenvector sensitivity data. In the proposed new approach, modes shapes and their derivatives are used as basis vector for eigensolution of the modified system. Comparison of numerical results with several existing eigensolution reanalysis methods shows the proposed algorithms are very effective. Additionally, a technique has been developed which provides an indication of whether the proposed method will generate acceptable results or not. This will provide guidelines for using the proposed method in structural optimization to indicate when an exact reanalysis is required. This will potentially make optimization using reanalysis techniques faster and more reliable. Detailed derivations and numerical examples will be presented in the full paper.

01429
A mixed approach SPH+Finite Element Method to solve fluid-structure interaction problems

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A mixed formulation (Smoothed Particle Hidrodynamics plus Finite Element Method) for three-dimensional fluid-structure interaction problems is developed. The solid is considered composed of a linear elastic material, which undergoes large displacements, and its motion is coupled to that of an incompressible fluid, governed by the incompressible Navier-Stokes equations. A finite element's monolitic algorithm is employed to couple the structure and fluid equations of motion, being an arbitrary Lagrangian-Eulerian formulation (ALE) used in order to take into account the large mesh motion near the structure. Additionally, an alternative approach, which adopts the SPH meshless technique, is proposed in order to circumvent the problem represented by the severe distortion of the fluid mesh near the solid. Finally, some fluid-structure interaction benchmarks are analysed to highlight the main features of the proposed technique in terms of computational cost and accuracy and to compare this hybrid approach (SPH+FEM) with the traditional one, i.e. pure FEM.

01538
Combinatorial Optimization with Fuzzy Parameters: Parallel Machine and Flow Shop Scheduling

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We consider combinatorial optimization problems with fuzzy parameters which are defined by the sets of possible values. For example, the set of possible values can be a finite set or the set of points of an interval. In the case where the sets of possible values contain only one element, the problem becomes

free of any uncertainty. Employing the concept of globally optimal solutions, we obtain sufficient conditions under which a global optimum exists for any values from the sets of possible values. We also consider approximation algorithms with good relative error on the avarage when many instances of the problem are generated. All the results are verified by computational experiments with parallel machine and flow shop scheduling problems with fuzzy processing times of the jobs.

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Sensitivity Analysis

5

01002
Modeling and Optimization Exergy loss reduction in plate heat exchangers of typical surface configurations – A review

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High maintenance costs increase total cost during the services life of heat exchanger. Therefore exergy analysis and energy saving are very important parameters in the heat exchanger design. In this review, the effects of surface geometries on heat transfer, friction factor and exergy loss were examined for two different types of heat exchangers, namely Flat plate heat exchanger and corrugated plate heat exchanger, with single pass under conditions of parallel and counter flow for laminar flow conditions. Reynolds number and Prandtl number were in the range of $50 \leq Re \leq 1000$ and $3 \leq Pr \leq 7$, respectively. The parameterization of the different configurations is considered and algorithm developed as a function of configuration parameters, viz. number of channels, number of passes for the two fluids, feed connection relative location, hot fluid location, type of flow in channels and object function defined. It was seen that the exergy loss in corrugated type heat exchanger is less than that in other types. Accordingly, pressure drop increases too. Pressure drop greatly increases the capital costs though heat transfer has larger effect on exergy loss. Because of this, a thermodynamic optimization should be made between heat transfer and pressure drop.

01073
Experimental design in constructing sensitivity and functionally oriented models for power system optimization and control

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The paper presents results of research into the use of factorial experimental design for adequate and rational constructing sensitivity models as well as functionally oriented models for the purpose of system optimization and control. The advantages provided by the application of experimental design techniques to constructing sensitivities in relation to traditional approaches, based on utilizing the system Jacobian matrices, are discussed. In particular, these advantages are associated with the feasibility to build "secants", but not "tangents". Taking into account that the experiments with mathematical models (but not with real systems) create significant difficulties in all stages of statistical evaluating the results of experiments, the paper proposes a line of attack of the problem of estimating reproducibility dispersions without performing parallel experiments in factorial space points defined by each line of the experiment matrices. The sensitivity models obtained with the use of experimental design techniques are applicable to control technologies associated with utilizing knowledge based approaches (in particular, a fuzzy logic based approach) as well as with utilizing optimization models. Taking this into consideration, the results of the paper are illustrated by their applications to the following power engineering problems: - coordinated fuzzy logic based voltage and reactive power control in power systems in regulated and deregulated environments with utilizing diverse types of sensitivity indices (the paper includes the description of fuzzy rules included in knowledge base and the corresponding control system with its functions); - power system operation, based on the application of procedures of sequential multicriteria

optimization to realize dispatch on several objectives, including objectives of an environment impact (the described procedures of sequential multicriteria optimization are based on applying the Bellman-Zadeh approach to decision making in a fuzzy environment, whose utilization conforms to the principle of guaranteed result and provides a constructive line in obtaining harmonious solutions from the Pareto set on the basis of analyzing associated maxmin problems). The paper also describes goals and procedures of constructing functionally oriented models (models with given structures) on the basis of experimental design techniques. The application of procedures is illustrated by the construction of functionally oriented equivalents to evaluate power system reaction in solving problems of optimizing network configuration (reconfiguration) in distribution systems. The lack of considering the change of power system losses may result to significant deterioration in reconfiguration efficiency. It demands to minimize total losses in distribution and power systems and serves for increasing the factual efficiency of solutions in distribution network reconfiguration. The paper results are used in monocriteria as well as in multicriteria optimization of network configuration in distribution systems. As objective functions can be considered (separately and in diverse combinations) power losses, energy losses, system average interruption frequency index, system average interruption duration index, undersupply energy, poor energy quality consumption (consumption of energy outside of permissible voltage limits), and integrated overload of network elements).

01200
Analysis Sensitivity Applied to the Maximum Loading Problem

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Voltage collapse typically occurs on power systems which are heavily loaded, weakened by transmission outages, or subjected to reactive power shortages. It is associated with reactive power deficiencies, and may result in uncontrollable system-wide voltage collapse, loss of loads, and blackout. Voltage collapse is preceded by uniformly decreasing voltage at some major buses in a heavily loaded electric power system. Contingencies, as unexpected line outages often contribute to voltage collapse blackouts. The most fundamental measurement of proximity to voltage collapse is "loading margin" defined as the maximum amount of additional load in a specific pattern of load increase that can be added to the system's operating load point (base-case) before a voltage collapse occurs. Contingencies generally reduce or even eliminate the loading margin. To maintain security against voltage collapse, it is desirable to estimate the effect of contingencies on the voltage stability margin. Action can then be taken to increase the margin so that likely contingencies do not cause blackout. The objective of this paper is to calculate power system loading margin applying the Modified Barrier Lagrangian Function (MBLF) method, a variant of the Interior Point Method, followed by the verification of how much the loading margin changes due to contingencies. This analysis is performed using sensitivity, without needing to compute or recompute several cases of solutions of maximum loading problem. The sensitivity analysis used at non linear programming applied to the determination of the margin loading provides simple and trustworthy information for the system operator decision. The sensitivity technique is based on both the information of second order and optimality conditions. Simulation results for power systems are shown to validate the effectiveness of the proposed method to solve the maximum loading problem after the occurrence of contingencies.

01255
Topology Optimization With Gradient-Guided Spectral Level Set Methodology

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The purpose of this work is to develop the tools for conducting sensitivity analyses under the framework of the spectral level set methodology, which is a level set based tool to formulate topology optimization problems. According to this methodology, the boundary of a structure corresponds to the zero level set of a function called the spectral level set function. In particular, the layout of the structure corresponds to the domain where the spectral level set function attains positive values. The function is then written as a finite Fourier series and the Fourier coefficients become the design variables of the optimization problem. That is, during the optimization procedure, the evolution of the coefficients, and hence of the function, embeds the evolution of the structural boundary. For a smooth structural boundary, the main advantage of the spectral level set methodology is to render a smaller error bound than those of classic non-adaptive spatial discretization techniques, as the number of design variables increases. Consequently, for a smooth boundary, the proposed methodology leads to a reduction of the design space dimension, which translates into a more efficient way to solve structural topology optimization problems. The application of the spectral level set methodology to topology optimization problems has already been validated in previous works. Those studies were carried on using the methodology with gradient free optimization algorithms. The present paper provides the means to bring together the spectral level set formulation and gradient guided algorithms. In particular, we calculate the derivatives of a general functional, which represents the objective and constraint functional present in the statement of a general optimization problem, with respect to the real and imaginary parts of the complex Fourier coefficients. This involves dealing with the pullback of the Dirac distribution by the spectral level set function and hence the necessity of using known facts from the theory of distributions. The resulting gradients also come in functional form. In some situations, the integrand can be quite sharp in a very narrow region in the domain of integration. In particular, the standard deviation and the magnitude of the absolute value of the integrand are of the same order of magnitude. To integrate these functionals, we consider Monte Carlo methods with a mixed strategy of importance sampling and stratified sampling. Using benchmark structural topology optimization problems, we evaluate the gradient-guided spectral level set methodology by comparison with other strategies, such as the gradient-free approach and other topology optimization formulations. The output of this work is a validated tool for topology optimization, which couples the spectral level set methodology with gradient-guided algorithms.

01410
Blade Shape Optimization using a RANS Discrete Adjoint Solver

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Recent developments in numerical tools for turbomachinery design have made practical the use of gradient-based optimization using high-fidelity computational fluid dynamic (CFD) simulations. Such has been made possible with the use of adjoint solvers, that can efficiently provide the gradients of the functions of interest with respect to the design variables required by the optimizer, at a cost almost independent of the number of variables. The derivation and implementation of the discrete adjoint solver for a legacy Reynolds Average Navier–Stokes (RANS) CFD solver are briefly explained. The adjoint-based gradients of some functions of interest, such as mass flow, pressure ratio and efficiency, with respect to shape parameters are computed and benchmarked against finite-difference approximations and excellent agreement is demonstrated. The outline of the integration of such adjoint tool in an engineering design framework is presented and discussed. The adjoint-based design framework is tested on a shape optimization problem using a set of Hicks-Henne bump functions superimposed on the baseline shape as design variables. A simple design problem is presented: a compressor rotor blade passage is setup as an unconstrained maximization problem, where the efficiency is increased by tweaking the camberline angle distribution.

01412
An exact representation of variational design sensitivity relations and improvement of classical first-order formulations

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The variation of objective functionals and PDE-constraints due to variations in the design or material configuration is termed as design sensitivity analysis. Design sensitivity relations are required within different fields, e.g. structural optimization or optimal control problems. Of interest is the change in the state and a chosen objective functional due to changes in the design variables. In the most cases, first-order sensitivity relations are considered and higher-order terms are ignored. For small perturbations in the design variables those sensitivity relations yield acceptable results. But for larger perturbations numerical accuracy of the design sensitivity cannot be guaranteed and it is of interest to study the error of the obtained sensitivity relations. This contribution is concerned with novel approaches for error estimation and the improvement of first-order design sensitivities. These approaches are based on an exact representation of the design sensitivity of the state, which is obtained by performing different Taylor expansions with integral remainders. We consider a general variational framework and present the application of the proposed approach to shape sensitivity for the model problem of nonlinear elasticity. The required higher-order variations of the weak form of equilibrium as well as the integral remainders are explicitly computed. The capability of the proposed framework is demonstrated my means of selected computational examples.

01435
On Sparse Forward Mode Automatic Differentiation with applications to Shape Optimization

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Automatic differentiation (AD) is a technique developed to differentiate computer codes exactly (up to numerical floating-point precision) and with minimal user intervention [1]. A set of independent variables is defined in the beginning of the computation. In the case of shape optimization the independent variables can be for example the geometrical design parameters. The chain rule of differentiation is then successively applied to every elementary operation throughout the computation.

In so called forward mode of automatic differentiation the derivative information is propagated forward in the execution chain. We have implemented a simple lightweight dynamic sparse forward derivative propagation technique. Dynamic means that we automatically, at run time capture the relationships between the dependent and the independent variables. By sparse we mean that the derivative information of each intermediate variable is saved in a sparse representation. This allows the computation of non-zero partial derivatives only, without the need of separate sparsity pattern detection and graph coloring phases. Our implementation is based on the operator overloading technique of C++ programming language. Thus the work of converting an original simulator into a one that computes also the geometrical sensitivities of the solution comprises mostly of replacing the variables with their AD counterparts where needed. Applicability of the implementation is demonstrated by two shape optimization examples. In the first example, existing antenna simulation software, based on EFIE integral equation formulation of time-harmonic Maxwell equations, has been differentiated with respect to the geometry using the presented technique [2]. Virtually no changes to the program structure had to be made. Computational performance of the original simulation code and an automatically differentiated version were compared, and it was found out that overhead due to our AD implementation was not excessive. In the second example, we have applied so called pseudo-solid approach to solve a shape optimization problem governed by free boundary problems of Bernoulli type [3]. This approach treats the free boundary problem as a coupled non-linear problem, which is solved using Newton iteration with an exact Jacobian. The location of the free boundary is then optimized by adjusting the shape of another boundary. To do this, the non-linear state problem is differentiated with respect to the geometry. Implementation of the solver for this optimization problem is greatly facilitated by the use of the presented AD technique.

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Industrial Applications

6

01004
Generalized power-law distribution for free vibration analysis continuous grading fiber reinforced cylindrical panels resting on two-parameter elastic foundation

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In this paper, free vibration analysis of continuous grading fiber reinforced (CGFR) cylindrical panels resting on two-parameter elastic foundation based on the three-dimensional elasticity theory are investigated using with a four-parameter power-law distribution. The CGFR panel is simply supported at the edges and it is assumed to have an arbitrary variation of matrix volume fraction in the radial direction. A generalization of the power-law distribution presented in literature is proposed. Some material profiles through the CGFR panel thickness are illustrated by varying the four parameters of power-law distribution. Symmetric and asymmetric volume fraction profiles are presented in this paper. Suitable displacement functions that identically satisfy the boundary conditions at the simply supported edges are used to reduce the equilibrium equations to a set of coupled ordinary differential equations with variable coefficients, which are solved by Generalized Differential Quadrature (GDQ) method and natural frequency is obtained. The fast rate of convergence of the method is demonstrated and to validate the results, comparisons are made with the available solutions for functionally graded isotropic shells with/without elastic foundations. The main contribution of this work is illustrating the influence of the four parameters of power-law distributions on the vibration behaviour of CGFR cylindrical panels resting on elastic foundation.

01015
Modeling and Multi-Objective Optimization of 4-Digit NACA Airfoils using Genetic Algorithms

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Increasing of lift coefficient (CL) and decreasing of drag coefficient (CD), simultaneously, are important purpose in the design of airfoils. Therefore, multi-objective optimization process is more applicable for the design of airfoils. In the present study, multi-objective optimization of 4-digit NACA airfoils is performed at three steps. At the first step, lift (CL) and drag coefficient (CD) in a set of 4-digit NACA airfoils are numerically investigated using LES that employs a RNG-based model as the subgrid-scale model. Two meta-models based on the evolved group method of data handling (GMDH) type neural networks are obtained, at the second step, for modeling of CL and CD with respect to geometrical design variables. Finally, using obtained polynomial neural networks, multi-objective genetic algorithms are used for Pareto based optimization of airfoils considering two conflicting objectives, CL and CD. It is shown that some interesting and important relationships as useful optimal design principles involved in the performance of 4-digit NACA airfoils can be discovered by Pareto based multi-objective optimization of the obtained polynomial meta-models representing their CL and CD characteristics. Such important optimal principles would not have been obtained without the use of both GMDH type neural network modeling and the Pareto optimization approach.

01025
Optimal Strategies for Treated Sewage Discharges: Economics Vs. Environmental Protection

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Fortunately the control of sewage discharges has been increased in last decades. At present, in most urban areas, a system of pipes (sewerage) collects and transports sewage to treatment plants, where it is treated before being discharged into a river, a lake or -in coastal areas- the sea. In many cases, there are several sewage treatment plants discharging into the same region (for instance, an estuary or a lake), where there also exit sensitive areas to be protected (fisheries, beaches, marine recreation zones and so on). The management of the sewage treatment system (consisting of all plants discharging into the same region) involves economical aspects, given by the treatment cost in the plants, and also environmental aspects, related to water quality in the sensitive areas. In reference [3], a unique manager for all treatment plants is assumed and, by giving priority to environmental aspects, the management of the sewage treatment system is studied as a single-objective optimal control problem of parabolic type, including pointwise state constraints. More recently, by assuming that each plant is managed by a different organization (industry, municipal government, etc.) that only takes care of its sensitive areas, the problem is formulated as a multi-objective optimal control problem, and it is studied from a cooperative [1] and a non-cooperative [2] viewpoint. In this work, we are going to study the initial problem again (a unique manager controlling all plants and taking care of all sensitive areas), but now priorities will not be given, and economical and environmental aspects will be both treated as objectives to be minimized (from the environmental viewpoint, as much objectives as sensitive areas will be considered). According to this, the problem will be formulated in the framework of multi-objective optimal control and studied from a cooperative point of view. The Pareto-optimal solutions will be characterized, a numerical method to obtain the Pareto-optimal set will be detailed, and numerical experiences in the estuary of Vigo (NW Spain) will be presented.

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01031
Reconfiguring State Health Services Logistics: Pacients Flow Optimization

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This paper presents an optimization to the flow patients for state health services offered to Parana State citizens and also analyzes a new optimized configuration for it. In Brazil, medical care is controlled by state officers, and is provided throughout a centralized planning managed by state governments in every one of Brazil's 28 states. Since geographical area is a key factor in most states, and range of services are not the same for every unit, patients demanding my have to be transported to another facility, located in the same state. A new proposition is made for state division into smaller regions, with a service level assigned for each municipality. Cities with lower levels offer just basic procedures, and patient in need of a more specialized service are sent to higher level cities. The assignment for the groups of cities must be based on size of population, health facilities, road availability and patient transportation routes should be planned for each procedure in every facility. For the regional division, a branch-and-price algorithm was used, using the column generation algorithm for each node in the branch-and-bound tree. The results obtained were considered very consistent.

01040
Proposal of a Non Destructive Test Method for Steel Bar Identification in Concrete Structure, Based on Eddy Currents Inspection

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This paper describes a methodology proposed for the development of a non destructive test (NDT) for the identification of steel bars immersed in reinforced concrete structures. The steel bars are both ferromagnetic and conducting materials and, because this, when exposed to an external high frequency electromagnetic field, they have the ability to modify the distribution of the electromagnetic field close to them, due to the presence of eddy currents induced in their bodies. The field modification can be detected in the form of induced voltage at the terminals of sensor coils placed on the concrete structure. The induced voltage will depend on the size and localization of the bar. The objective of this paper is to investigate if the correlation between the induced voltages and the bar characteristics can be used to develop a NDT technique for reinforced concrete tests. The paper will describe the development of the research activities: Initially, simulations with the use of a finite element program were done. Sets of induced voltage were obtained by considering variations in the position and size of the bar, for several designs of electromagnetic devices. The obtained results with the finite element method were used to produce the training vectors for multilayer-perceptron artificial neural networks. After the adoption of several training strategies, encouraging results were obtained. After this, hundreds of test-bodies were produced, and several electromagnetic devices constructed, in order to obtain real values for the induced voltages. The paper will present results for the numerical simulations, details of the production of the test-bodies, the construction of the electromagnetic devices and the preliminary results for the induced voltages.

01057
Shape Optimization of a Steering System Based on Fatigue Analysis

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In the process of virtual product development, shape optimization and fatigue analysis are fundamental methods. Shape optimization is often used to reduce stresses in computational strength analysis. In general, the critical region in a structural part differs in strength and fatigue analysis. Therefore, the results of the shape optimizations with respect to strength improvement compared to those for durability improvement differ as well. This contribution will describe a process of shape optimization based on fatigue analysis in an industrial setting. Essential methods of the optimization process are multi-body systems, finite element analyses, fatigue

analyses and the shape optimization itself. General and flexible interfaces have to be created in order to combine the different methods and programs. These interfaces are required for an automated optimization process. The workflow of this process with the tools Simpack, NX/Nastran, Virtual.Lab Durability and Tosca Structure will be introduced. In addition to describing the process, this study will illustrate several optimization results of redesigning the housing of a steering system. For analysis of a single static load case, maximum values of damage and stress are ascertained at the same position. In a load-time signal measured in a real vehicle, the locations of maximum damage and maximum stress are different. Results of the fatigue analysis are analysed first and then compared with the results of a static finite element analysis. Based on these two analyses, the application of the shape optimization changes the geometry of the housing according to the objective function. The resulting reduction in stresses and fatigue damage values in each strategy are then presented and evaluated. This empirical method used in the automotive industry illustrates that the process of shape optimization based on fatigue analysis is no longer an academic method useful only for limited test cases, but can also be implemented for large industrial applications.

01059
Derivative-free optimization for autofocus and astigmatism correction in electron microscopy

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Electron microscopy is a powerful research tool. Nowadays electron microscopy still requires an expert operator in order to manually obtain in-focus and astigmatism-free images. Both the defocus and the two-fold astigmatism have to be adjusted regularly during the image recording process. Possible reasons are for instance the instabilities of the electron microscope and the magnetic nature of some samples. For the next electron microscopy generations the manual operation has to be automated. One of the reasons is that for some applications the high level of repetition severely strains the required concentration. Therefore, a robust and reliable simultaneous autofocus and two-fold astigmatism correction algorithm is a necessary tool for electron microscopy automation. The problem of automated focus and astigmatism correction in electron microscopy is at least a three-parameter problem (one focus and two astigmatism parameters). The evaluation function is an image recording with a further computing of an image quality operator. The image quality operator reaches its maximum, when an image has the highest possible quality, i.e. the microscopic parameters are at optimal focus and astigmatism. Thus, the optimization goal is to maximize the image quality operator in a three-parameter space. Computations determining an image quality measure costs much less time than an image recording. Therefore, and also because repeated recordings can damage or destruct the sample, it is needed to optimize the focus and astigmatism with just few recordings. The optimization is further made difficult due to the recording's noise and the absence of analytical derivative information. Calculating (approximately) derivatives with finite differences would dramatically increase the amount of necessary image recordings, and is therefore not discussable. For electron microscopy we present an automated application for simultaneous focus and two-fold astigmatism correction based on the image quality measure and derivative-free optimization. The approach is proved to work both for simulated images and in a real-world application on a scanning transmission electron microscope. The speed and accuracy of it are comparable to those of a human operator. The Nelder-Mead simplex method and the Powell interpolation-based trust-region method are discussed and compared for a real-world application running on a scanning transmission electron microscope.

01065
Mathematical modeling for protein folding devices. Applications to high pressure processing and microfluidic mixers.

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Proteins are organic compounds made of amino acids that catalyze chemical reactions. Protein folding is a process that consist of a change in the protein structure from a folded state (the protein can perform chemical reaction) to an unfolded state (the protein becomes inactive). In this work, we center on two different devices that perform protein folding by using, respectively, concentration and temperature/pressure changes. In the first case, we study a microfluidic mixer used to mix, as fast as possible, a protein solution with a solvent. In particular, we are interested in optimizing the mixer to improve its mixing properties. To do so, we introduce a 2-D model, define the considered parameters and solve the associated optimization problem. In the second case, we focus on a particular High-Pressure-Temperature treatment device. Its objective is to unfold enzymes (a variety of proteins) inside a food sample in order to prolong its shelf life. In particular, we study a heat-transfer model that predicts the temperature evolution inside the device when the pressure profile is given. As this model is computationally expansive, we also propose and analyze a simplified version.

01067
Robust optimization of a single-stage fan using response surface

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The effect of the blade geometry deviations on the performance of a gas-turbine engine fan has been assessed. The geometry parameters having the maximum effect on aerodynamics have been determined. Based on the examination results, the task of multi-criteria robust optimization has been formulated; the said task consists in maximization of the mean adiabatic efficiency value and minimization of its root-mean-square deviation at a point on the compressor operating line. Stagger angles and airfoil thickness at ten sections along the blade height have been selected as varying geometry parameters. To reduce the computational and time costs when finding an optimal solution, a response surface plotted based on the results of 3D Navier-Stokes aerodynamic analysis is used. The optimization results demonstrate the possibility of fan aerodynamic performance increase with simultaneous reduction of the blade sensitivity to geometry deviations.

01080
Multi Objective Optimization of Concrete Mix Design in Persian Gulf With Gmdh-type Neural Networks

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One of important causes for failure of concrete structures particular in Persian Gulf region is diffusion of chloride into concrete. Prediction of concrete diffusion factor is an important issue as a key parameter in the being cycle of concrete structures. In addition concrete diffusion factor, increasing in compressive strength and reduction in initial cost is inevitable. The important conflicting objectives that have been considered in this paper are, namely diffusion factor and 28 days- compressive strength. These objective functions have been selected for two objective optimization process. Group Method of Data Handing (GMDH) algorithm is self-organizing approach by which gradually complicated models are generated based on the evaluation of their performances on asset of multi-input-single-output data pairs .The GMDH was firstly developed by Ivakhenko as a multivariate analysis method for complex system modeling and identification. In this way, GMDH was used to circumvent the difficulty of knowing prior knowledge of mathematical model of the process being considered. In other word, GMDH can be used to model complex system without having specific knowledge of the systems .The main idea of GMDH is to build an analytical function in a feed-forward network based on a quadratic node transfer function whose coefficient are obtained using regression technique. In fact, real GMDH algorithm in which model coefficient are estimated by means of the least squares method has been classified in two complete induction and incomplete induction, which represent the combinational and multilayered iterative algorithms, respectively. NSGAII algorithm is used for multi-objective optimization, this algorithm has some problem in the crowding distance subroutine, therefore a new diversity preserving algorithm, named E_elimination, is proposed to enhanced the performance of multi-objective evolutionary algorithms in optimization problems.

01081
Does Visual Discomfort Have an Influence on Muscle Pain for Visual Display Unit (Vdu) Workers?

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In three different prospective epidemiological studies, correlation between visual discomfort and average pain intensity in the neck and shoulder varied between 0.30<r<r AIMS OF THE STUDIES The aims of these studies were to investigate the correlation between visual discomfort and pain in the upper part of the body. Longitudinal epidemiological studies were performed to evaluate the aims (Aarås, A. et al. 1998; Helland, M. et al. 2008). METHODS AND PROCEDURES Questionnaires dealt with headache, visual conditions and discomfort as well as musculoskeletal pain, organizational and psychosocial factors were implemented by the participants. All questions were assessed by the participants as an average intensity for the previous six months. The same questionnaires were answered once more after lighting intervention and optometric intervention. The factors were measured on a 100 mm Visual Analog Scale (VAS). (Larsen, S. et al. 1991; Du Toit, R. et al. 2002) A detailed description of the questionnaires and procedures of measuring lighting variables as well as musculoskeletal and optometric parameters are given by Aarås et al (1998); Aarås, A. and Dainoff, M.J. (2002). Postural load and postural angles: Muscle load was measured by EMG from musculus trapezius and musculus infraspinatus (Aarås et al. 1996). Dual inclinometers were used to measure postural angles of the head, upper right arm and back (Hagen 1994). RESULTS The first prospective epidemiological study (N=150) showed that visual

discomfort had a relationship with pain intensity in the neck and shoulder (0.30< r CONCLUSION Four different prospective epidemiological studies have shown that there is a clear indication of a relationship between visual condition and visual discomfort as well as visual discomfort and pain in the neck and shoulder.

01089
Global optimization of grillage type foundations using stohastic algorithms and GRID computing

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Grillage type foundations are widely used in engineering practice [1]. Grillages consist of connecting beams and supporting piles. Aim of the present work is to optimize the pile placement scheme so that the grillage would be supported by a minimal number of piles; reactive force in each pile must not exceed a given allowable value. Since the reaction forces in piles depend on the pile positions under connecting beams, aim of the present research is to find the optimal pile distribution. Assuming that all piles have the same characteristics, the ideal pile distribution will be in case when all piles exert an equal reaction force. This optimization problem is important from the economical point of view: sometimes (especially in the case of weak grounds) very long piles are used, so saving of even several piles may give a significant reduction of construction costs. Present work consists of 3 independent parts. Firstly, the fast specialized FORTRAN software is developed for calculating of objective function, i.e. the maximum reactive force depending on the pile positions. Secondly, the suitable optimization algorithm searching for an optimal distribution of piles in the grillage is defined. Previous research [2] showed that genetic algorithms are promising for optimization of grillages, and some practical results were achieved. In this work the genetic algorithms were compared with other stochastic algorithms: modified random search and simulated annealing. Numerical experiments showed the potential of simulated annealing for our optimization problems. Third, the developed algorithms were employed for optimization of several large real life grillages that requires very long computations. Therefore, the developed software was deployed on the BalticGrid infrastructure [3]. Numerical examples show the potential of proposed technique.

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01090
An algorithm of selecting a representative load sequence for a trainer

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Variable loads affect an aircraft throughout its operation. Most common loads affecting the aircraft structure in the course of a flight are identified with the overload factor defined as a ratio of the aceleration that affects the structure to the acceleration of gravity. Variable loads lead to fatigue wear of the aircraft structure. Any cracks that occur in the structure propagate at load-spectrum dependent rate. Hence, to calculate the crack propagation rate or to carry out laboratory testing work, the load spectrum has to become well-defined. The representative load sequence (RLS) is a time-dependent course of a signal nz, which may be recognized as representative for the aircraft population under examination. The RLS has been intended to generate load history to be then used in numerical calculations and laboratory testing. Results obtained with the RLS should be representative for the whole aircraft population under examination. Taking the time for calculations or laboratory testing into consideration, the RLS has to be much shorter (fewer cycles) than the actual spectrum. What results from the above statement is that the RLS should be well-grounded, i.e. based on a great number of collected data. Generation of the RLS consists in the isolation - from the collected data – of all the information of key significance to receive correct description of the material fatigue and crack propagation. The following items of the information have to be maintained in the RLS: - the number of fatigue cycles of specific amplitude and average value, - the load sequence. For the PZL-130 Orlik, an aircraft operated by the Polish Air Force, more than 35000 flight records including the overload factor have been collected. Each flight was an accomplishment of one of about 200 exercises. The structure-affecting loads in the course of each flight can be described with five (5) numbers, each being the number of cycles nz of specific amplitude. It has been assumed that the RLS for the PZL_130 Orlik is calculated from a hundred (100) of flights selected from the total base of all recorded flights (35000). These one hundred flights (RLS) must satisfy the following conditions: - ten (10) most often performed exercises are represented in the RLS, - the number of accomplishments of each represented exercise has to correspond with the statistics of accomplished exercises for the whole period of aircraft operation, - the intensity of structure loading understood as the number of cycles nz of specific amplitude for the RLS need conform with the intensity of structure loading for the whole period of operating the aircraft. The in this way determined RLS defines the optimisation task that consists in selecting an optimal subset of one hundred (100) of vectors from the total of 35000 vectors. An objective function has been defined and a deterministic-stochastic algorithm of minimisation of the objective function – developed. The stochastic portion of the algorithm is 'responsible' for avoiding local minima in the course of the optimisation process. The developed algorithm allows the RLS to be found.

01106
On the three-dimensional bin packing using rotations.

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One of the most interesting variations of the problem of the 3-Dimensional Bin Packing problem (3BPP) is the determination of the minimum number of three-dimensional rectangular bins that are required for orthogonally allocating a given set of three-dimensional rectangular items without overlap and minimizing the occupied space: the 3BPP-min problem. This is, of course, yet another NP-Hard multi-criteria combinatorial optimization. One of the most obvious applications for this problem is the one that occurs daily in warehouses management systems, either by using manual or automatic packing. We present a new approach for the 3BPP-min problem where 90 degrees rotations are allowed in order to allow for a more compact packing. Most of the known heuristic solutions for this type of packing are based on the well-known works of Martello, Pisinger and Vigo. Boschetti has recently introduced new lower bounds specifically tailored for packing using the possibility of rotations of items that we used for designing the new heuristic algorithm. This algorithm uses both this new lower bounds and the theory of non-dominated solutions for deciding on the best packing for a 3BPP-min instance. Computational results show the effectiveness of the new approximation algorithm, that shows to be faster and achieve lower occupation of space, thus, better compaction.

01109
Modeling and Multi-Objective Optimization of Forward-Curved Blades Centrifugal Fans using CFD and Neural Network

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Increasing of head rise (HR) and decreasing of head loss (HL), simultaneously, are important purpose in the design of different types of fans. Therefore, multi-objective optimization process is more applicable for the design of such turbo machines. In the present study, multi-objective optimization of Forward-Curved (FC) blades centrifugal fans is performed at three steps. At the first step, Head rise (HR) and the Head loss (HL) in a set of FC centrifugal fan is numerically investigated using commercial software NUMECA. Two meta-models based on the evolved group method of data handling (GMDH) type neural networks are obtained, at the second step, for modeling of H and HL with respect to geometrical design variables. Finally, using obtained polynomial neural networks, multi-objective genetic algorithms are used for Pareto based optimization of FC centrifugal fans considering two conflicting objectives, H and HL. It is shown that some interesting and important relationships as useful optimal design principles involved in the performance of FC fans can be discovered by Pareto based multi-objective optimization of the obtained polynomial meta-models representing their HR and HL characteristics. Such important optimal principles would not have been obtained without the use of both GMDH type neural network modeling and the Pareto optimization approach.

01114
Modeling and Multi-Objective Optimization of Centrifugal Pumps using CFD and Neural Networks

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Increasing of efficiency and decreasing of the required NPSH, simultaneously, are important purpose in the design of centrifugal pumps. Therefore, multi-objective optimization process is more applicable for the design of such turbo machines. In the present study, multi-objective optimization of centrifugal pumps is performed at three steps. At the first step, efficiency and NPSHr in a set of centrifugal pump is numerically investigated using commercial software NUMECA. Two meta-models based on the evolved group method of data handling (GMDH) type neural networks are obtained, at the second step, for modeling of efficiency and NPSHr with respect to geometrical design variables. Finally, using obtained polynomial neural networks, multi-objective genetic algorithms are used for Pareto based optimization of centrifugal pumps

considering two conflicting objectives, efficiency and NPSHr. It is shown that some interesting and important relationships as useful optimal design principles involved in the performance of centrifugal pumps can be discovered by Pareto based multi-objective optimization of the obtained polynomial meta-models representing their efficiency and NPSHr characteristics. Such important optimal principles would not have been obtained without the use of both GMDH type neural network modeling and the Pareto optimization approach.

01115
Multi-Objective Optimization of Centrifugal Pumps using Particle Swarm Optimization Method

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In this paper, firstly, efficiency and the required Net Positive Suction Head (NPSHr) in a set of centrifugal pumps are numerically investigated using commercial software and compared with those of experimental results. Subsequently, two meta-models based on the evolved group method of data handling (GMDH) type neural networks are then obtained for modeling of efficiency and NPSHr with respect to design variables such as geometrical parameters of centrifugal pumps. Finally, using these obtained polynomial neural networks, multi-objective Particle Swarm Optimization method (PSO) is used for Pareto based optimization of pumps considering two conflicting objectives such as efficiency and NPSHr. It is shown that some interesting and important relationships as useful optimal design principles involved in the performance of centrifugal pumps can be discovered by Pareto based multi-objective optimization of the obtained polynomial meta-models representing their efficiency and NPSHr characteristics. Such important optimal principles would not have been obtained without the use of both GMDH type neural network modeling and the Pareto optimization approach.

01116
Study of an integred collector storage solar water heater

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An Integrated Collector Storage (ICS) solar water heater is studied with an emphasis on its thermal performance. The ICS system consists of one cylindrical horizontal tank properly mounted in a stationary symmetrical Compound Parabolic Concentrating (CPC) reflector trough. The main objective was the study of a simple solar system with improved thermal

performance based on the exploitation of the concentration of the solar radiation on the cylindrical storage tank surface. The numerical resolution of the governing equations was carried out using a commercial CFD code FLUENT 6.2 which is based on a finite volume method. The three-dimensional CFD model, based on the S2S radiation model, was validated, with good agreement, against experimental results from literature. In order to optimize the operating parameters of the solar water heater, we made some changes on the initial system and we studied their effects on the daily operation of the proposed ICS system, and this for a typical day of the month of May between 6h and 18h.

01117
Modeling and Multi-Objective Optimization of Cyclone Vortex Finder using CFD and Neural Networks

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In this paper, firstly, pressure drop and the collection efficiency in a set of cyclone separators are numerically investigated using CFD techniques. The Reynolds averaged Navier–Stokes equations with Reynolds Stress turbulence Model (RSM) are solved by use of the finite volume method based on the SIMPLE pressure correction algorithm in the computational domain. The Eulerian–Lagrangian computational procedure is used to predict particles tracking in the cyclones. Subsequently, two meta-models based on the evolved group method of data handling (GMDH) type neural networks are then obtained for modeling of pressure drop and efficiency with respect to design variables such as geometrical parameters of cyclone vortex finder. Finally, using obtained polynomial neural networks, multi-objective genetic algorithms (NSGA II) with a new diversity preserving mechanism is then used for Pareto based optimization of vortex finder considering two conflicting objectives such as pressure drop and efficiency. It is shown that some interesting and important relationships as useful optimal design principles involved in the performance of cyclones can be discovered by Pareto based multi-objective optimization of the obtained polynomial meta-models representing their pressure drop and efficiency characteristics.

01125
Minimizing air entrainment in the shot sleeve during injection stage of the HPDC machine

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High pressure die casting (HPDC) is an important process for manufacturing high volume and low cost components. In most of the industrial nations, about 70% of the die cast parts go to the automotive industry. Aluminum die castings are gaining importance in the production of lightweight

vehicle bodies. A mathematical model has been developed to simulate the 3D fluid flow pattern of molten metal and to predict the liquid-gas interface shape in the shot sleeve of a cold chamber die casting machine during the injection stage. The liquid wave patterns in shot sleeves and the amount of air entrapped depend mainly on the plunger velocity. At high plunger velocity, air is entrapped due to wave curling of wave in front of the plunger, and at low plunger velocity, air is entrapped by the waves reflected from the wall near the runner. In this study, a general solution is derived for the plunger velocity as a function of the plunger position that allows the engineers to precisely control the behavior of metal in the shot sleeve during the injection stage of the high pressure filling process, minimizing the risk of air entrainment.

01131
Shape Measurement Planning of Outdoor Constructions with Mathematical Programming

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A 3D scanner is a surface imaging system which is based on accurate distance measurement by electro-optical distance measurement. We can obtain surface data of objects by performing a number of independent measurements, and a 3D image emerges by merging these data. Lately, this type of device has been extending its measurement range to facilitate digitizing "existing" constructions, and used for examining and designing landscapes of towns and preserving cultural sites as well. In this research, we propose a method to make a shape measurement planning of outdoor constructions with mathematical programming. One of the most difficult problems to collect complete surface data of outdoor constructions is to avoid self and mutual occlusions. If we want to collect complete data for covering whole surfaces of the constructions, then we have to measure from multiple points usually. However, examining multiple surface visibility relative to variable multiple viewpoints is a complicated problem. Moreover, multiple measurements require plenty of time and labor, and each measurement gives a data set consisting of hundreds of millions of 3D points to be processed for further computations. So it is very important to make an effective measurement plan a priori for avoiding redundancy for both labor and computational costs. Our approach is based on a 2D diagram that would be available as a ground plan or a geological plan of the target area beforehand. To make a view plan, we propose two mathematical programming models in this research: one is to find the least number of measurements for recording all the walls of constructions, and the other is to determine measurement points to maximize scanning density. This research shows that both problems can be formulated as integer programming problems, and thus global optimal solutions can be conveniently computed by using a general-purpose solver. To solve these problems practically, our formulation requires a preliminary parameter set for representing positional information of all the constructions and the visibility of walls from the candidate points of measurement. For setting the parameter set, we will use OpenCV, an image processing library which is advantageous for 2D diagram processing. Positional information of walls is obtained from a plan by OpenCV using image processing techniques including contour retrieval, shape estimation and line segmentation. After that, we will calculate some angles which are made by walls and candidate points, compare them, and check the visibility of walls from the candidate points. We also show our approach is applicable to several modified problems. Numerical experiments show that our method is effective for large-scale problems. For example, we can obtain an optimal solution of a problem with about 2,000 candidate points and 120 walls in a few seconds.

01137
A Study of Textile & Clothing Supply Chain in Pakistan

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The expansion of textile and clothing production to Asian regions has both, increased competition and created a need for integration with the textile and clothing global supply chain. Strategies are being designed to improve competitiveness and responsiveness of the chains with increasing diversification of products. This study examines the potential of different strategies formulated by experts with focus on Pakistan´s case, developed by brain storming sessions with external experts, composed from a chain´s internal-view and based on existing strengths and weaknesses in the chain using a SWOT analysis. The aim of this previous study was to identify internal and external factors relevant to textile and clothing supply chain in Pakistan. These factors played an important role in the development of strategies which are useful for improving the competitiveness of the chain. In future it is our intention to formulate our decision structure based on external view of the chain and with more generalized criteria. This kind of structure produces the view which is usual in supply chain competitive scenarios. Here the criteria were viewed internally and the problem was formulated based on SWOT factors. Thus, using inputs from our previous work, "SWOT Analysis of Pakistan Textile Supply Chain", we evaluated the strategies developed for achieving competitiveness in textile and clothing supply chain in Pakistan and their potential effects using a process of prioritization following Saaty´s AHP. There can be innerdependencies and feedback within criteria, sub factors and alternatives which may have potential effects on the results. To study the effects of innerdependencies among factors we have used ANP and compared the results obtained by the two methods. We have suggested the implementation of developed strategies simultaneously through different entities involved with the chain, as government agencies, academic and research institutes, industrial associations and entrepreneurs themselves.

01145
Optimization of Nanocrystalline Aluminium Production Using a Objective Function

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In recent years there has been an increasing interest and research effort focused on the development of nanocrystalline materials due to important improvement of their chemical, electrical, magnetic, optic and mechanical properties. Those materials can be produced by a wide variety of processes, for example: ball milling (BM), rapid solidification, equal channel angular extrusion (ECAE) or thermal spray processing. Several of these techniques (like BM) produce powdered materials which require a subsequent consolidation for any structural application. However these techniques obtain smaller grain size and can produce special intermetallic materials. For this reason, extensive studies of the dynamics of the powder processes and their influence on microstructural changes of materials have emerged. Nevertheless, many of these efforts are focused on the understanding of the

process and on the improvement of the materials properties and they are not on the process output. In the present paper, a methodology to improve the output of powder by the BM process is proposed. This methodology has been tested with pure aluminium powder and proposes an objective function and its optimization by a simplex downhill method. After 9 iterations, the output of nanocrystalline aluminium is increased in a 35%, the powder particle size is reduced to the half and the hardness is slightly increased.

01170
Thermoelectric Parameters of Multi-Phase Systems Depending on Configuration and Concentration of Phase Inclusions

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The problem of improvement of parameters of thermoelectric materials (power factor and figure of merit) under technological as well as physical treatments is steady of great interest [1]. The thermoelectric parameters of multi-phased materials are analyzed in the frame of the model for hetero-phase systems with the variable configuration of inclusions [2]. Interpolation of formulas obtained for the main rigorously calculated limiting borders [3] tends to the certain relation between thermoelectric power, resistivity and thermal conductivity, independent both on the configuration and concentration of inclusions for two-phase system. The problem of improvement of the thermoelectric parameters of multi-phase materials is considered as a function of the parameter of configuration, and the concentration of inclusions. The real thermoelectric systems are considered in the vicinity of "insulator-metal" phase transitions [1,2]. The work is supported by RFBR grant.

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01174
Development of dynamic multiobjective optimization methodology for industrial needs

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Mathematical modeling and numerical simulations are nowadays typically tools used for research and development in industry. Often systems or processes considered change in time and thus dynamic modeling tools as well as optimization methods are needed. Then modeling is typically based on differential algebraic equations or simple relationships between system inputs and outputs, and optimization problems involve variables whose values change in time. However, traditionally optimization concentrates on minimization one objective function without violating given constraints, i.e. single objective optimization, even if there are naturally several objectives to be optimized simultaneously. For that purpose multiobjective optimization can be utilized. Then several conflicting objectives are optimized and the solutions present the best compromises between these objectives. Besides multiobjective and dynamic nature in real life optimization cases also reliability of the solution obtained and efficiency of the entire solution process are important. Hence these are also discussed here. In this paper we present an approach that can be utilized solving dynamic multiobjective optimization problems and discuss how it can be used for real life industrial problems. Thus dynamic optimization methodology is combined with multiobjective optimization in order to solve time-dependent and multi-criteria optimization problems in reliable and efficient way. We also illustrate the approach by a numerical example.

01183
Simulation and Optimization of the Operating Conditions of Production of biojet fuel

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The objective this work was investigated a new route for biojet fuel production using biodiesel made by transesterification of babassu palm oil. After, transesterification of babassu oil, the biodiesel (fatty acids methyl esters, FAME) was distilled. The production of bio jet fuel by distillation is a promising alternative to the conventional process of jet fuel production. This study investigated the major operating variables affecting conversion and product composition. A commercial process simulator was used to develop a detailed simulation of a biojet fuel production process by distillation of biodiesel. The simulated process produced biojet fuel from a biodiesel feedstock containing 90 wt.% methyl esters. Sized unit operation blocks, material and energy flows were used to conduct an economic assessment of the process. Finally, Total capital investment, total manufacturing cost, after tax rate-of-return and production cost ($/kg) were all determined for the process and the HYSYS optimizer tool was used to maximize tax rate-of-return. Our results showed that the process is economically feasible, even without government subsidy, while at the same time, the produced biojet fuel required ASTM standard for purity.

01184
Optimization of the Operating Conditions of Production Hydrogen from Glycerol Autothermal Reforming for fuel Cell Applications

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Glycerol is a waste by-product obtained during the production of biodiesel. Biodiesel is one of the alternative fuels used to meet our energy requirements and also carbon dioxide emission is much lesser when compared to regular diesel fuel. Biodiesel and glycerol are produced from the transesterification of vegetable oils and fats with alcohol in the presence of a catalyst. About 10 wt% of vegetable oil is converted into glycerol during the transesterification process. An increase in biodiesel production would decrease the world market price of glycerol. Although glycerol is used in medicines, cosmetics, and sweetening agents, world demand is limited. As such, when mass production of the biodiesel is realized, novel processes that utilize glycerol must be developed. One possibility is to use glycerol as a source of hydrogen, and, in this regard, steam reforming of glycerol

would be a suitable reaction. In the autothermal reforming of glycerol, synthesis gas that contains both carbon monoxide (CO) and hydrogen (H2) is produced. Hydrogen was expected to become an important energy carrier for sustainable energy consumption with a significantly reduced impact on the environment. Hydrogen fuel cell technologies have emerged as a promising future global energy. The technology called 'hydrogen economy' is a vision for future in with hydrogen replaced fossil fuels to reduce dependence on non-renewable energy and to cut down the environmentally harmful emissions. For this technology, hydrogen is mostly produced from hydrocarbons. Therefore, many researches have been conducted on hydrogen production from hydrocarbons to find the most economical, efficient and practical method of producing hydrogen for the fuel cell application. On this research we developed a simulation plant model using steam reforming reactor to produced hydrogen from glycerol for fuel cell application. From the simulation plant model, we made an analysis on the behaviour of the process and determined the best condition of producing hydrogen from glycerol. This case study focused on optimization of hydrogen production for fuel cell applications. In this case study, glycerol was chosen as a raw material and with autothermal reforming as a process of produce hydrogen. Using a commercial dynamic flow sheeting software, HYSYS 3.1, the process of hydrogen production was successfully simulated. In this research, fuel processor consists of an autothermal reactor, three water gas shift reactors and a preferential oxidation reactor was successfully developed. The purpose of this case study is to identify the effect of various operating parameters such as air-to-fuel (A/F) ratio and steam-to-fuel (S/F) ratio to get the optimum hydrogen production while made carbon monoxide lower than 10 ppm. From the results, an optimum A/F and S/F ratio are 5.5 and 1.5, respectively to produce 34 % of hydrogen and 10.055 ppm of CO. Under these optimum conditions, 83.6% of fuel processor efficiency was achieved.

01186
An Environmental Quality Index Related to Polluting Agents and its application in the framework of a GIS platform

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Environmental pollution represents a very relevant problem of modern engineering. In particular, nowadays plannings of urban and industrial settlements requires a careful analysis of the environmental impact of anthropic activities, therefore influencing scientific community debate. A major role in this discussion is played by the need for efficient methods of evaluation related to the quality of ambient. Actually, the most of approaches provided in literature are conceived considering well defined ambits of application and do not furnish an overall description of environmental life quality. In this paper we will discuss a different scheme, investigating the possibility of developing a general index of environmental quality which is based on taking into account different suitable kinds of polluting agents. The effective result is represented by a weighted combination of each polluting component described by means of an opportune normalized mathematical function. The idea underlying our scheme is furnishing an overall parameter which describes in a synthetic matter the health state of certain environment, enlightening stress areas and suggesting where it is necessary to intervene in order to ameliorate environmental conditions. Although, at this level, our approach represents only a toy model which requires a significant improvement, first simulations suggest interesting results. As simple examples we provide some applications of the proposed index in the context of different anthropized settings exploiting the database properties of a GIS platform. GIS tools represent a very powerful framework in the phase of data mining and of results representation and allows to easily understand environmental health conditions once experimental data have been analyzed.

01190
Optimal PID Tunning Method Applied to a Sucker Rod Pump System of Petroleum Wells

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Studies have shown that the satisfactory operation of oil wells with sucker rod pumps is due to the techniques and methods able to control the performance of the well. The Polytechnic School of Federal University of Bahia, through the Artificial Lift Lab (LEA), has nowadays a reduced model of a plant of sucker rod pump system with an artificial well of 32m of height fully instrumented, with full access and visible of the downhole well. A kind of resource of the LEA is a laboratorial support to validate existing models and to base experimentally new studies. Among some studies already executed with this sucker rod pump, there is the use of a dynamic model to control the fluid level in the annular well with PID controller (that is directly associated with oil productivity of the pump unit). However, there are in literature, several techniques for tunning PID controllers (e.g.: Ziegler-Nichols, Cohen and Coon, IMC, Integral Criteria, Pole placement). The objective of this paper is to use a optimal tunning method to PID controllers presented in Alfano Neto (2002) and to apply in the control of the fluid level in the annular well of the pump unit. This optimal tunning method is based on solution of a optimization problem through the minimization of a global objective function, that is composed by local objective functions. Thus, this method may incorporate some model uncertainties, PID control algorithims, process perturbations, manipulated variable restrictions (in this application the manipulated variable is the downhole pump outflow) and overshoot. Finally, the results with a PID controller using this optimal method were compared with other PID tunning methods available in literature.

01217
Simulation-based optimization for a parameter reconstruction problem

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In this paper, we compare trust-region methods for the solution of an unconstrained non-linear optimization problem which arises from an important industrial application in the metrology area. The optimization problem involves minimization of an objective function. For each parameter in the parameter space, the objective function is related to the difference between measured and simulated results for the parameter. We adopt trust-region methods to solve our optimization problem. Trust-region methods build a local model (quadratic polynomial) of the objective function and minimize the corresponding model within the trusted neighborhood of the current iterate(s). Two different ways of calculating the coefficients of the quadratic model are considered. In the first approach, the coefficients are approximated by finite differences. In the second approach, the objective function is interpolated at a finite amount of points yielding an implicit approximation of the coefficients of the quadratic model. We test the trust-region methods on several realistic metrology cases. The methods are primarily compared on the basis of the number of (expensive) evaluations of the objective function.

01218
Simulated Annealing Applied to Minimize the Idleness and Maximize the Contribution Margin for Generic Flexible Machining Cells

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This paper aims to propose a methodology for optimization of industrial resources of a manufacturer of parts for machining. Not only the more rational use of activities that add value to the product and the use of machine idle time, but especially by the rationalization of the production mix towards greater contribution margin as possible. The methodology provides for the hypothesis that the production of parts is daily and that is repeated with the same minimum number to be produced every day. It was used concepts of Theory of Constraints (TOC), Costing Systems, Contribution Margin, Operational Research and Machining. The TOC was used to define the production bottlenecks and therefore, detect the idle machines. For the idle machines, it was made an extra planning process to cut specific pieces, with more flexible deadlines, fixed by sale department. So, the idleness can be used more rationally, and it was possible to introduce extra profit, considering that these idle machines shall have their fixed costs anyway paid. The concepts of costing systems were used to analyze and discuss what types of costs, direct or indirect, fixed or variable, focused on machining processes. The contribution margin was supposedly negotiated by the machining front of your customers and set for each product in the production mix. Optimization techniques were used in the methodology development by means production computational simulation in order to determine which products should be produced in a work day. The machining concepts were applied to make all the calculations about this matter properly. As a final consideration, it can be said that the software is functional and responds to the possibility of financial profit maximization due to a new proposed methodology

01220
Environment of Flexible Machining - Validating an optimization procedure by real tests realized on the shop floor

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In 2008, during the EngOpt in Rio de Janeiro, the authors presented a paper proposing an appropriate model to reduce the setup of tools in an environment of flexible machining. Was understood as flexible machining, the production schedule with batches of small number of pieces of different materials and geometries from one to other batch. The proposed model was tested only by simulation data which were not from the real world of industry. Through simulation, many issues that could arise from the practice of the machining process in manufacturing environment were impossible to predict. The main question to be answered that depends on the practical application of the optimization model on the shop floor is the way in which the cutting process parameters and predict tool life should be selected from the tool manufacturer's catalog. In addition, the model predicts that the cutting edge tool life informed by a catalog for the parts to be produced in a small batch is used to estimate the life of other parts of the other batches. Besides, these and other aspects related to the difficulty of validating the

optimization method only by simulation, the model itself has undergone changes that mean an upgrade version. All these aspects were partly known, but were completely cleared after a first set of preliminary tests that were performed during the parts cutting process evolution in shop floor. Not only in aspects using catalog, but mainly because of the difficulties in finding the initial machining conditions for achieving full implementation of the model. The purposes of this work is analyze and eventually provide any need modification of the optimization model already developed by the authors in previous work and then validate the more recent one using data taken from practical application in shop floor of an industry that works behind the context of flexible machining.

01223
The model of multi-phase systems with variable configuration of inclusions and its applications.

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Effective properties of materials (thermal, magnetic, mechanical, etc.) are calculated mostly by two main approaches: in the first one local properties of system are supposed to be known functions of coordinates, and in the second one they are considered statistically as random fields [1]. In this work the approach is developed for multi-component composite materials based on interpolation formulas obtained between the rigorously calculated limiting borders [2]. The effective "current" or "voltages" in the approach contain additional factors [3, 4]. The general merit of the model is the ability to obtain algebraic formulas for complicated properties with the vectors of electrical, thermal, magnetic, etc. forces directed along the different axes [3, 4]. The examples of application of the above model are given for the analysis of multi-phase states in the vicinity of pressure-induced phase transitions. The work is supported by RFBR grant.

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01231
A Methodology for the Optimization of Bolting Sequences for Wind Generator Flanges

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In the bolted joints of wind generator flanges there is a gap between the contact surfaces of the flanges. This involves a nonlinear behaviour of the system during the tightening sequence of the joint. This phenomenom, in addition with the elastic interaction, makes it difficult to achieve a uniform bolt preload. This work presents a methodology which, based on a metamodel created for such purpose, enables the optimization of the tightening sequence; i.e. it calculates the load to be applied to each bolt in order to achieve a desired uniform preload at the end of the tightening sequence. This optimization is done with a minimum computacional cost, avoiding costly experimental measurements or nonlinear FE simulations. Besides, the methodology also takes into account that the load for any bolt must be below its yield point, and therefore calculates a two-pass sequence if necessary.

01259
Optimization of a full-scale multibody model of a wind turbine using experimental data

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Full-scale numerical models of wind turbines and their components are widely used in industries to determine dynamic loads acting on different elements of the structure or to set-up and simulate the effects of control strategies. To be able to achieve such results, representative computational models are essential. This paper illustrates the definition of a methodology to obtain an accurate and computationally light multibody model of the NREL CART-3 wind turbine using experimental modal analysis (EMA) results. Moreover, it shows the possibility of obtaining an estimate of the mechanical properties of the model if such information is not directly available. Starting from the general geometric and dynamic properties of the wind turbine, a multibody model is developed using Virtual.Lab Motion. Using this software, it's possible to separate the inertia and elastic properties of the structure using rigid bodies and flexible massless beams. Blades and tower are modeled using this approach, while the nacelle is considered as a simple rigid body, since the EMA was performed with the turbine in parked conditions. The numerical model is not an exact representation of reality and, to increase its validity, an optimization procedure is defined to update the results. This updating procedure will be driven using the optimization software OPTIMUS. A set of design variables for the numerical multibody model, such as mass and inertia properties of the bodies and directional stiffnesses of the beam force elements, is firstly defined. Natural frequencies are directly compared while normal mode matching is evaluated through the Modal Assurance Criterion (MAC). If the matching of the two models is not within the imposed limits, the design parameters are updated to new values. This phase of the work is performed using OPTIMUS' built-in optimization algorithms. The application of this methodology allows generating quickly validated and reliable multibody models. It will also allow estimating some parameters of the system if they are not directly available from direct measurement. Moreover, if compared with updating procedure of FE models, this approach does not require using model order reduction techniques.

01276
Multicriteria Optimal Design of Multibody Systems by Using Genetic Algorithms

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The design step of multibody systems requires in some specific cases an optimization process, in order to determine the set of parameters which lead to optimal kinematic or dynamic performances. The optimization task is complicated by the explicit time-dependent of the differential equations of motion, the constraints

and/or the objective functions. Usually the designer have to choose one criterium to optimize; the others are considered as technologic constraints. This method is well adapted to take into account the boundary constraints that put into practice the range of variation of some design parameters, such as stiffness and damping of shock absorbers. For constraints depending on the behaviour of the multibody system, such method means that the designer has to limit the behaviour a priori without knowing its effect on the optimal solution. This generally leads to an incomplete view of the feasible well adapted solutions. So it may be better to consider the behaviour-dependent constraints also as the objective functions, such as the displacement, the velocity and the acceleration of the bodies during the time. Such approach leads to the multicriteria optimal design. Usually the obtained set of solutions is called non dominated. It gives the designer the choice between several feasible possibilities that are not better than an another. The aim of this paper is to propose a multicriteria optimal design method adapted to general multibody systems and submitted to kinematic and/or dynamic time-dependent criteria. The optimization process is based on genetic algorithms. The paper especially describes the way for taking into account the time-dependent characteristics of the criteria. The first result refers to the well-known benchmark of the shock absorber. Comparison between the single and multicriteria solutions gives a good understanting of the advantages of the proposed approach. Illustrative examples are given in the context of the optimization of a motorcar suspension and the lateral dynamics of an urban railway vehicle.

01290
Optimal adjustment of continuous and discrete variables in the Optimal Reactive Power Flow problem

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Many engineering problems have been modeled as nonlinear programming problems containing continuous and discrete variables. The Optimal Reactive Power Flow (OPF) problem is an important problem in the area of electrical engineering. The purpose of the OPF problem is to determine the controllable variables of an electric energy transmission system: bus-voltage magnitude, bus-voltage angles and tap ratios of transformers; and to minimize transmission losses or other appropriate objective functions, satisfying a given set of physical and operating constraints of the electric energy system. Since transformer tap ratios has a discrete nature, while bus-voltage magnitudes and angles are continuous variables, the reactive-power optimization problem is modeled exactly as a nonlinear optimization problem with a mixture of discrete and continuous variables. The OPF problem is a nonlinear programming problem, non-convex, containing equality and inequality constraints, and continuous and discrete variables. In most of the techniques existing to solve OPF problems, discrete variables are treated as continuous variables and then they are rounded off to their nearest discrete steps, this method is not efficient because the discrete solution obtained can be infeasible, or it can not be an optimal solution of the problem containing discrete variables. The combinatorial-search approaches, branch-and-bound and cutting plane algorithms are generally used for solving nonlinear programming problems containing continuous and discrete variables. However, these methods are non-polynomial and consequently, they are slow and intractable for large-scale OPF problems. Therefore, it is necessary the use of an efficient method to adjust the discrete and continuous variables of the OPF problem. In this work, a function that penalizes the objective function when discrete variables assume non-discrete values is presented. By including this penalty function into the objective function, the discrete variables are treated as continuous variables. Thus, a nonlinear programming problem with only continuous variables is obtained and the solution of this problem is equivalent to the solution of the initial problem that contains discrete and continuous variables. Numeric tests using the IEEE 14, 30 and 118 buses test systems indicate that the method is efficient in the resolution of OPF problems.

01292
Inter-basin Water Transfer Evaluation in Alqueva Susbsystem

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Alqueva subsystem is the main component of Multipurpose Alqueva Project (MAP), which is designed for social and economic development of Alentejo region, in the South of Portugal. The Alentejo region is facing drought since several last years, Guadiana river will be the main water source to meet the deficits of this region through storage at the Alqueva reservoir. Alqueva reservoir pumps water to Alqueva subsystem, where it experiences the inter-basin water transfer from Guadiana to Sado basin. The study system involves the existing infrastructures and other components which are under construction. However, components, which are still in proposals, are not considered. The present study concerns with assessment of the water transfer studies in Alqueva subsystem through mathematical modeling. The study is accomplished for three different scenarios based on the existing and future infrastructure of the Alqueva subsystem. For each scenario a dynamic programming (DP) based optimization model is used to quantify the water deficits at each reservoir and the amount of water needed to be imported from Alqueva reservoir is estimated for each scenario.

01302
Revision and Optimization in Space Vector Pulse Width Modulation

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Introduction: The semiconductor technology has enabled the feasibility application of static converters for modulation signal power. Since then, numerous pulse width modulation techniques, which are more easily implemented by digital systems as well as these are suitable for more efficient converters, were proposed. The classical method of PWM compares the desired signal with the triangular wave, which is the way that sometimes it is made still nowadays according to the application. An extension to the classic PWM is known for SVPWM (Space Vector Pulse Width Modulation), this technique objectives at the use of vector spaces to determine the periods of switching. The SVPWM has become popular due to its power efficiency compared to PWM, and also to be related to transformations that make it easier to integrate in most control applications. This paper objective to review and proposals for conventional SVPWM techniques in order to reduce harmonics and better process performance, it is also proposed some extensions of the algorithm to other topologies of inverters. The topologies are studied: classic 3 legs inverter, 4 levels inverter and 4 legs inverter. Materials and methods: Classical techniques of modulation SVPWM care only with the modulation within alpha and beta space. But some harmonic problems with the phase to neutral modulation occur due to absence of compensation for component zero. This is because a vector space within the alpha-beta, which is the result of the sum of vector components of phase, requires that its three components are

symmetrical by 120 degrees. However, the combination of switching of inverters, it is impossible to obtain such a reference vector, so any possibility of switching cause an imbalance, and this must be offset by the zero sequence components within the switching cycle. It is also known that the trigonometry functions included in the conventional techniques require process, and this paper presents these techniques based on solving systems of equations instead. SVPWM for a multilevel topology based on 18 specific sub-spaces, which proposes good process speed and too accurate, was developed in this work, as well as the revision of an algorithm to 4 legs. All techniques were simulated and validated using the software SIMULINK® from MathWorks®. Results: All modulation techniques showed excellent results of modulated signals. These show a simple and effective alternative to reduce harmonics caused by conventional techniques that are applicable to real-time applications that require processing as low as possible. The proposed algorithm especially for the multilevel inverter has proven to be an easy algorithm implementation, precision and good performance. The algorithm for modulation in 4 legs proposes an unconventional way to modulate the neutral and offers numerous possibilities for applications in three-phase unbalanced systems.

01303
SIGLA – An Integrated System for Airline Management

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The aim of this paper is to present the complete process of controlling and managing the flights in an airline company. Airline planning consists of several problems that are currently solved separately: fleet assignment, rostering, crew planning, fuel control, airport taxes, etc. A system was developed to handling with all the process and provides a series of tools. Some of these tools use mathematical programming to solve the problems and this paper will describe each one. This system is being utilizing in almost all regional airlines companies in Brazil and it takes advantage of integrations between the sectors so the planning people can use information from the operational one, the crew schedule assemble the pairing according to the fleet assignment and so on. Another feature of the system is the creation of scenarios. If the solution time is reasonable, several different scenarios of the same problem may be solved and choosing the one whose solution is the best in the given situation.

01323
MILP models for multiproduct pipeline scheduling with inventory management: a comparative approach

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The oil supply chain is facing a challenging era due to use of new alternative energy sources, oil sources scarcity, and price variability which imply high impact on demand, production and profit

margins. Nevertheless, the system itself represents a complex problem to represent, optimize and, in the end, it becomes a demanding task to build effective decision support systems to help the optimization of such systems. While production has not seen recent advances, other business activities appear as promising for decision makers to conduct the business successfully. Distribution is one of the key areas for improvement since this business moves large quantities of products over large distances and between several supply and demand layers. An effective method to provide this service is by using multiproduct pipelines. However, the single problem of sequencing products to obtain an optimized pumping schedule is a hard problem. In order to have a good schedule, this problem must consider two specific issues: i) its connection to an effective inventory management at pipeline ends and ii) the consideration of the pipeline operational lag, which forbids the usage of short-term time horizons. Several authors addressed this problem over the last years, being mathematical programming the preferred implementation technique. Two major problem dimensions have been explored: i) temporal representation (continuous or discrete1,2,4) and problem topology representation (single pipeline, pipeline with branches or pipeline network and single or several input and output entities3,5). This paper addresses the scheduling of oil derivative transportation using a multiproduct pipeline, between one refinery and one distribution centre, where inventory management tasks are integrated into the problem since the demand center (distribution center) is included. A real world scenario of a Portuguese company is used to validate and compare two alternative Mixed Integer Linear Programming (MILP) models, which differ in the batch volume representation (continuous or discrete). The main purpose of these models is to provide a medium-term horizon solution for the pumping sequence considering inventory management, where the length, the sequence and the volumes of batches are computed in a single run. Model complexity is overcome using problem oriented techniques to reduce the index domain of the decision (binary) variables. The models are then compared with previously published models.

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01332
Application of the mathematical model of optimization for MIXED PROJECTS in MemoryCorp S.A.

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Inside the Investigation and the Administration of Operations, the General Theory of Nets and particularly the models of Nets of Activity, are a key tool in the processes of planning of complex projects that involve many activities. At the moment, the planning concepts and administration of projects are very used in the managerial environment as a tool for the evaluation of costs and time of execution, as well as a mechanism of control of the same ones. If the duration of each activity is known with certainty, you can use the method CPM (Critical Path Method) to determine the time required in the realization of the project. If the duration of the activities is not known with certainty, you can use the technical PERT (Program Evaluation and Review Technique) to estimate the probability of termination of the project in an estimated date. A mathematical model of optimization that analyzes mixed projects (with activities in advance of execution are know and activities in advance of execution urcertain), it will be of great help for the planning and taking of decisions. This can observe it in the sector of the construction, which is developed by projects, where each residence development an individual element with a specific objective that can contain activities in advance of known execution (installation of doors and windows) and activities with uncertain times of execution (masonry, armada and fused of badge) that which embraces the basic characteristics of the mixed projects. The development of applications in the real sector is a way to evaluate and to validate the proposed mathematical model. The next application is developed in MemoryCorp S.A., located in the city of Bogotá, in this is presented worth and the applicability of the proposed model in a real situation. In a same way, we validated the new theoretical proposal for the development and analysis of MIXED PROJECTS.

01338
Bootstrapping Neural Network Regression Model for Milling Process Optimization in Industrial Environment

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The emphasis in continuous improvement, prioritized by the organizations, has motivated the development of this intrinsic experiment applied to the manufactory process optimization, which involving the cutting parameters in shop floor and verifying advantages and disadvantages of the procedure used. Four variables had been used: Material's hardness of the parts and the cutting parameters of the milling process in high speed machine of hardened steel (cutting speed, feed per tooth and cutting depth). From the operating conditions, cutting depth and the feet per tooth are the most easily optimized: we can have values so closer to the best value, just pondering the machine power, the over metal dimension to be removed, the chip shape and quality of the final piece required for the specific target of the operation optimization. On the other hand, the cutting speed optimization is not a trivial task. Although the Maximum Efficiency Interval approach to be known as one of the most convenient way to find the optimized cutting speed, the use of the values of (x) and (K), constants in the Taylor equation, obtained from the literature or other sources from testing laboratory under ideal conditions, has making difficult the task of optimizing the cutting speed, because are different from the reality, causing distortions in the optimization process results. So, it seems that the best option is to use the Taylor equation constants from its determination in a factory floor. In this case there will be greater confidence in selecting the optimum cutting speed, because the procedure will be performed in real time with the occurrence of the process, with data obtained from the own machine-tool-part, targets of the optimization. Unfortunately, the determination of constant values from experimental procedure in factory floor has many limitations. In such cases the initial collected data set is most of the time very small, the magnitude of variable effects is ambiguous and data gathering costs are high. This work proposes an optimization procedure based on a data interpolation approach using a

Bootstrapped Neural Network to generate designed data sets in order to improve the value of statistical information and to estimate a mapping from input to output space. The bootstrap method is based on an imitation of the probabilistic process using the information provided by a given small set of random observations. The optimization procedure is aimed to minimize the cost and/or to increase the production in the milling process of forging tools currently used. The designed data set generated by Bootstrapped Neural Network will be statistically analyzed and it will be used, in one second stage, to determine the Taylor's equation coefficients in manufactory environment, allowing the determination of the Maximum Efficiency Interval.

01351
Residential Cogeneration System: A Multiobjective Optimization Design

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The Combined Heat and Power (CHP), which is known as Cogeneration, is the simultaneous production of thermal and electric energies. This methodology allows the use of energy by optimizing the primary energy conversion into useful forms of energy, distributing the energy production and minimizing energy distribution losses. The Cogeneration has been increasingly implemented in industry units of large and medium dimension. Nowadays, in Portugal and in all Europe, the small scale CHP for domestic use is still in development being a paramount solution for energy systems located in urban areas. The main objective of this paper is to design a small domestic unit of cogeneration in a pilot scale unit (Firstly, the problem was formulated as a minimization problem. The objective function was defined as the total annual cost of operation of the system, subject to physics and thermodynamics restrictions, similar to that used in the design and optimization of large industrial cogeneration systems, the CGAM problem (Silva et al, 2003). Despite difficulties in obtaining data for some of the components cost-equations, the model proved to be an invaluable guidance tool for the optimal design of the this type of energy systems (Leão et al., 2009). In this paper, the optimization of the adapted CGAM system has been formulated using a multiobjective approach. The objectives have been defined as the maximum utility demands and the minimization of the annual total cost of the operation. The true Pareto-optimal solutions are found with a multiobjective genetic algorithm that employs an efficient variable encoding scheme and some problem-specific mutation and crossover operators. The information gained from the Pareto-optimal solution set is shown for all non-dominated solutions, from which the final decision can be made considering appropriate scenarios.

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01355
Thermohydraulic Analysis of Heat Exchanger Cleaning

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Considerable research efforts have been made to diminish fouling problems in industrial plants. Fouling effects in heat exchanger comprehends energy losses which cause more fuel consumption with, consequently, more operational costs and an increase in carbon dioxide emissions. Additionally, if the hydraulic resistance increases too much due to fouling, the thermal equipment might be partially bypassed in order to keep throughput. The careful analysis of both effects can indicate an optimal schedule which can improve process profitability. Few works concerning the optimization of cleaning actions focus on the possible hydraulic problems. Hydraulic limitations can affect significantly the plant operational condition and should be considered including the presence of bypasses which avoids a throughput decrease. This paper presents an optimization analysis of cleaning schedule of critical heat exchangers in an industrial plant, exploring thermal and fluid dynamic aspects. The optimization problem is solved using a simulated annealing algorithm where the decision variables are the cleaning instants and the control valve opening fractions.

01356
Optimization Mathematical Model of the Cooling Process in Hard Candies

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In this paper a mathematical model of the transient heat transfer in the cooling of hard candies is proposed in order to determine optimal process parameters. Precisely, a mathematical model previously developed by authors of this paper has been extended to determine optimal operating policies aiming to prevent product defects. In fact, the previous model was recently used to study the influence on the main operating parameters on the cooling process efficiency by simulations. From the quality product point of view, simulation results showed that there is a strong trade-off between the main process parameters. Cooling air flow velocities, residence time in the cooling equiptment and the thermal conductivity of product influence on the number of decomised products as non-conforming. For example, high air velocities, especially at the beginning of the process, increase the product fragility for the wrapping stage. The most practical way of avoiding misshapen candies is by minimizing the difference of

temperature between the centre and the surface on candy. Therefore, a mathematical model based on the finite element method is here proposed to determine the optimal operating policies to minimize the temperature difference. gPROMS modeling tool is used to implement the proposed model. A Centered Finite Difference Method (CFDM) of the second order is applied to the spatial (radial) partial derivates. A sensitivity analysis on the radial discretization is considered. Also, detailed discussions of results are presented through several case studies.

01361
Optimization of the Fuel Efficiency of the M3165 Internal Combustion Engine in Transitory Operation

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This paper describes the methodology used to optimise the fuel conversion efficiency of the M3165 internal combustion engine in transitory operation for application in a high energetic efficiency vehicle for competing in the European Shell Eco-marathon 2010. The M3165 engine is a four-stroke spark ignition engine working according to the Miller-Atkinson cycle. Before performing experimental engine testing a computer program simulating the engine operation was used to perform a sensitivity analysis and identify the operating and design variables with more influence in the fuel efficiency of the engine. To measure the performance and fuel efficiency of the engine in transient operation a methodology was developed. The methodology used takes into account the inertia of the engine, of the transmission system and of the vehicle. Once the measurement method was established operating parameters of the engine were optimized experimentally in the range of application of the engine. These include the injection duration, ignition timing, cylinder head temperature and oil temperature. The injection duration and ignition timing were optimized for each engine rotation speed in the operating range of the engine.

01363
Study to determine the best option discharge petroleum products in the marine terminal

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Within what is the development of ports and terminals, the efficiency of their operations is vital that depend largely on the proper management of its facilities, which focus point. Not having adequate facilities management involves having underutilized positions in product discharge port, not having the necessary storage capacity and an incorrect inventory management, which leads to high operating costs. For the evaluation of such transactions are carried out numerical models that allow detailed analysis, which incorporates all the variables involved, ensuring that each is represented properly, which allows us to understand and analyze the results reflected in proper optimization and improvement of relevant operating conditions that help in making correct decisions. The methodology in the application software used for studies in the Terminal, needs to run a series of activities such as; - Specify the system under study covering the boundary conditions and decision variables and criteria used to meet the goal. - Collect and analyze data. - Generate simulation model, verified and validated. - Identify scenarios for further sensitivity analysis and comparison. - Presentation of results, suggestions and conclusions. The simulation model of port operation PROMODEL was applied in the maritime terminal, in order to reduce delays in payments by buoys busy missing in the storage quota and bad weather, that occur when the tanker arriving at the terminal must wait or stop the discharge, resulting in times of stay not covered that is reflected in the increase in payments. The objective was to reduce costs by payment delays by identifying the best option discharge of petroleum products, evaluating two alternatives for operation, (1) the construction of a

dock and (2) installing more buoys. The model represents the current state of unloading, storing and shipping of oil products, was used as statistical and historical reported subsequently reviewed the results of the base model for the proceeds from proposed scenarios. The main changes were made on the allocation of tanks for storage products, thereby optimizing its operations, reducing costs by avoiding payment delays and expense of an investment by building a new facility. Reductions were achieved: the utilization rates of the tanks up to 86.37% and consequently delays in a 18.49% compared to 100% making the current situation of the terminal.

01372
Integer Programming Methods for Throughput Optimization In Underground Mining

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A large underground mine needs to process a variety of ores through a system of ore passes, ore bins and hoisting skips. An integer programming method presented that has been used to optimize the flow of material through this system. This model permits the evaluation of proposed mining schedules and allows an analysis of the performance of a given mine design.

01379
Optimum Blade Design for a Novel Wind Turbine

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Traditionally, blades for wind turbines can be seen as beams clamped at one end with a central spar connected by a shear web or a spar box providing the required bending stiffness for maintaining its aerodynamic performance. For a novel wind turbine type the blades are supported at both ends and they have a different shape and loading. The objective of this paper is to find an optimal design for these new types of blades. Based on a given cross-section and three load-cases from separately performed CFD simulations several design approaches are tested employing different combinations of composite materials and shear web topologies. A full size optimization yielding the optimum ply thicknesses for all the defined patches is performed for each design approach. Here, the objective is to minimize the overall mass while displacement, failure and buckling constraints are met. The choice of the best design is based on weight, cost and manufacturing complexity. A ply stacking optimization including manufacturing constraints of the chosen design finalizes the design task.

01394
Coordination of plant wide production planning and scheduling systems

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Introduction: In this presentation, we discuss the requirements of industrial solutions to plant-wide planning and scheduling problems and investigate different plant-wide optimization

approaches. Based on these studies, we present a coordination method for melt shop and the hot rolling mill in a steel plant that overcomes the drawbacks of centralized and decentralized optimization. In today's processing and manufacturing industry, often optimization-based decision support and automation functions are used for advanced production management. Often the operation of sub-systems of a plant is optimized locally in a decentralized manner, but an overall optimization of the plant is missing on the operational level. Since even small scheduling problems for local single production stages are NP-hard, it is unrealistic to build large centralized optimization models that account for all production stages in a plant. Industrial Requirement and Application: Our work is motivated by an industrial example of currently uncoordinated distributed scheduling systems of a melt shop and a hot rolling mill in the metals industry. The production constraints in the melt shop mainly result from metallurgical rules, whereas in the hot rolling mill the production constraints mainly arise from physical restrictions and the quest for small changes in product changeovers. Because of the complex and different production constraints in these two processes, we have developed scheduling algorithms separately for both plants with different optimization objectives for each of them. Both scheduling problems are large, complex and highly constrained. Therefore, we decompose the problems into smaller optimization problems, which are solved by formulating them as mixed integer linear programs (MILP) and put together again using integer programming. Coordination Method The general coordination method is based on the idea to take up the two uncoordinated local solutions, evaluate them according to plant-wide objective criteria. The evaluation information will be used by the coordinator to tune the parameters of the distributed schedulers, such that they are coordinated iteratively. The coordination iteration will be terminated when the coordination objective exceeds a certain value or the maximum iteration number is reached. Computational Experiments We tested on real-world data the three different optimization approaches (centralized, decentralized and our coordination model) for distributed production planning and scheduling systems and compared the objective value, which is the overall production make span, and the computational effort, which is the CPU time to find the best objective value. Thereby, we show that our coordination approach dominates the other two approaches with respect to solution quality and computational effort. Future research: • expand the two stage approach to a multi-stage approach including the cold rolling mill, • generalize the approach to coordinate any locally distributed scheduling systems.

01399

Research on design and optimization of the turbine blade shroud

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As a key part of the turbine blade the shroud will take direct effect on the structural intensity vibration reliability and life-span of the engine According to the normal rules of the shroud design and experience provided by some experts this article advises a shroud which is fit for a kind of turbine blade. Based on previous work some research on shroud optimization have been done. An example proves that the procedure provided by this article about shroud optimization is available and it supplies an effective method to design and optimize the similar complicated models.

01404
Hybrid Optimization of Well Placement of Water flooding Project in an Iranian Oil Field

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The determination of optimal well locations is a challenging problem in oil production since it depends on geological and fluid properties as well as on economic parameters. Determining the optimal location of wells with the aid of an automated search method can significantly increase a project's net present value (NPV) as modeled in a reservoir simulator. This work addresses the efficient solution of this problem by using advanced techniques for coupling two important components of autonomic optimization: Dynamic model using Eclipse simulator software (E100), a hybrid optimization technique based on the genetic algorithm (GA) and polytope algorithm. In this study optimal placement of up to four water injection wells was studied for one of south west Iranian heavy oil field. Injection rate was also optimized. The net present value of the water flooding project was used as the objective function. Profits and costs during the time period of the project were taken into consideration.

01421
Reprogramming maintenance service orders with prioritization of delay time and equipment criticity in a pasta production plant

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Over the years, the maintenance management has faced problems of different kinds. Some of the most common problems are related to the programming of maintenance activities from service orders (SO), particularly those ones that aim to re-program tasks not executed on the dates originally scheduled. This article presents two linear programming models that seek to reschedule maintenance SO in a pasta factory in the state of Paraíba, Brazil. The models were built on the existing models and adapted in order to comply with technical and organizational maintenance department of the company; such as the limit of hours available to perform maintenance services, the technical ability to perform a particular service and the criticity of the equipment linked to the SO, among others.

01448
A New Metaheuristic Algorithm for the Resource Constrained Multi- Project Scheduling Problem

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This paper describes new metaheuristic algorithm for the resource constrained multi- project scheduling problem(RCMPSP). New algorithm is named vibration damping optimization

(VDO). Project scheduling problem consists of assigning start time to project activities under existing constraints, in the way of achieving predetermined objective. The objective function considered is minimization of the makespan. Due to NP-hardness of this problem, vibration damping optimization metaheuristic is used to obtain acceptable and near optimal solutions in reasonable time. All effective parameters were set after design of experiments done on test instances. Proposed algorithm is compared to simulated annealing method (SA). It can be seen that VDO has better performance than SA.

01449
Multicriterion GIS

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This work shows the best strategy for the radication of the integral center of processing residues for the metropolitan area in Rosario's city. This could be obtain through the Multicriterion evaluation, which can be defined as a set of techniques to help in the processes of take decisions. The criteria are one of the main elements of the Multicriterion Evaluation, in which the right choice will depend largely of the success or failure of the developed evaluation. It is based in the development and application of two mathemathics models of support to the decision based on the ELECTRE method and the Analytical Hierarchy Process known as method AHP. The ELECTRE method compares alternatives by pairs among all the alternatives, so that it eliminates a subset of them and chooses the one that assembles the majority of the criteria. The method of Analytical Hierarchy Process is stratified in three levels or hierarchies. The first one is the purpose of the problem, the second one to the criteria and the third one to the alternatives or possible choices. Some criteria of exclusion considered are Accessibility and Connectivity, Distance to known ways, Topography, Quality of the soil and Surface. The integration of the SIG with the EMC techniques is an important tool in the processes of planning, forecast and control of the usages of the soil through an suitable distribution of the land activities and study of the environment.

01459
The effects of a free-repair warranty on the periodic replacement policy in discrete-time process

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Consider a repairable product that should be operating at the time over an indefinitely long operation cycle n (n=1, 2, 3 …); under the discrete-time periodic replacement policy, a product is preventively replaced at pre-specified operation cycles N (N=1, 2, 3, …). When the product fails, a minimal repair is performed at the time of failure and the failure rate is not disturbed by each repair. The cost models from the customer's perspective are developed for both warranted, and non-warranted products. The corresponding optimal replacement period N^* is derived such that the long-run expected cost rate is minimized. Under the assumption of the discrete time increasing failure rate, the existence and uniqueness of the optimal replacement period are shown, and the impacts of a free-repair warranty on the optimal periodic replacement policies are investigated analytically. We show that the optimal N^* for a warranted product should be adjusted toward the end of the warranty period.

01468
A CP-based Approach for Scheduling in Semiconductor Manufacturing

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Semiconductor manufacturing involves many batch/semicontinuous physic and chemical operations. The wafer fabrication, which is the main stage in semiconductor manufacturing facilities, is a procedure composed of several repeated sequential steps to produce complete electric circuits. At the beginning of the production process, the wafer is covered with a thin uniform layer of SiO2. Next, selected portions of the wafer are marked in order to form a circuit configuration. This step is called photolithography or photomasking. The etching process is used immediately after the photolithography to etch the unwanted material from the wafer. Since this operation is not selective, the circuit configuration must be traced over the wafer. It is important to note that etching is a key step in the wafer fabrication process that involves transfers of wafer lots between baths and severe constraints on bath times. In semiconductor manufacturing facilities, the wet-etching process is carried out by one or more highly automated stations. Thus, these units are responsible for removing the unnecessary film of SiO2 formed on the surface of the wafer, in a series of chemical and deionizing baths. The scheduling problem of automated wet-etch stations (AWSs) has been tackled in several works. However, the reported approaches still have weaknesses. The proposals have presented non-exact and non-optimal algorithms (e.g. heuristic algorithm based on tabu search) with severe assumptions in order to make the problem tractable, such as considering transfer times jointly with processing times. Therefore, the objective of this work is to overcome some of these limitations. This contribution addresses the resource-constrained flowshop scheduling problem of automated wet-etch stations in wafer fabrication of semiconductor manufacturing facilities by means of a Constraint Programming (CP) methodology. CP is an emergent technique for modeling and solving satisfaction and optimization problems. This methodology has being successfully applied in many domains. Several works have shown the CP usefulness and competitiveness in the scheduling problems. The proposed approach, that consists of both a model and a search strategy, handles different features found in the complex automated wet-etching process, such as material handling and mixed interstages storage policies constraints. Due to the high combinatorial complexity of the problem, an efficient domain specific search strategy is also presented to improve the computational performance of the formulation. The applicability of the proposed integrated CP methodology (model + search strategy) is successfully tested with examples with different number of jobs and stages.

01472
A Generic Decision Model of Refueling Policies: Case Study in a Brazilian Motor Carrier

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Fuel optimizers are decision models that are increasingly recognized as effective fuel management tools by truckload carriers. Using the latest price data of every truck stop, these models calculate the optimal fueling schedule for each route that indicates: (i) which truck stop(s) to use, and (ii) how much fuel to buy at the chosen truck stop(s) to minimize the refueling cost. However the acquisition of this kind of software by small or medium companies of

motor carriers in Brazil is not feasible due to high impact on fixed cost. Therefore, this study developed a generic model for fuel optimization based on linear programming using electronic spreadsheets. The model was presented using a case study as a reference and, in this case, the model provided a decrease of 2.3% in total fuel cost.

01506
Numerical Model of Tube Freeform Bending by Three-Roll-Push-Bending

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The paper will give a brief introduction into three-roll-push-bending process. This is a new and innovative tube bending process that allows for freeform bending. The process can be classified as kinematic free form process, where the resulting tube geometry mainly depends on the feeding rate and the position of the rolls within the bending plan. Experiments showed that the process is very sensible to numerous influences including tube properties e.g. wall thickness, diameter and material as well machine properties like rigidity and process parameters including feed rate and choice of roll positions. Currently the process design is based on experiences and empirical procedures requiring substantial numbers of experiments leading to notable downtime of the machine. From these experiments characteristic lines are defined and used for process design. In order to overcome the downtime several numerical models of the process were developed. The latest developed model shall be presented in this paper. In order to overcome some imperfections of the earlier models and based on the experience gathered with them, special emphasis was put on the machine's rigidity. To model the rigidity and the behavior during manufacture connectors elements were introduced to the model, building the connection between the rolls and machine's body. Vibration theory is used to represent the effect occurring during the process. The most general case degree vibrating motion was used in the model. The vibrating motion is subject to viscous damping which was modeled by a dashpot and spring element. In initial setup that will be described in the paper the springs were defined from experimental data that was gathered from the machine. As necessary measurements could not be carried out during manufacture the values do not precisely match reality during production. Thus the model and especially the springs had to be adjusted to make computation results meet experimental work. To do so, testing points resembling extreme values in terms of the forces affecting the rolls were defined and experiments were carried out. The numerical model was adjusted to minimize the difference between computation and experiment in the resulting characteristic. The quality criterion used is the radius of the bent tube on the extrados. The paper will close with a comparison of the real world experimental results with computational results from the initial and adjusted model, where the sample points are chosen to represent the entire feasible range of roll positions.

01510
Shape optimization of supersonic ejectors with several primary nozzles

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The article deals with shape optimization of supersonic ejectors. The work is motivated by the need of design of an ejector for propulsion of an experimental supersonic wind tunnel. To intensify the mixing

processes and to improve the ejector performance, several primary nozzles placed around the mixing chamber wall are applied. Thus, the secondary stream enters the ejector through the free center of the mixing chamber and is sucked into spaces between the primary nozzles. CFD software Fluent was used to compute the flow in the ejector. Dynamic mesh method controlled by user defined functions was applied to find optimal shapes of the three-dimensional geometry. A developed method allows simultaneous optimization of all parts of the ejector, while the only invariant dimension is the throat area of the primary stream. The optimization method is based on step-by-step shift of chosen control points on the ejector wall. This method, which was originally developed to optimize subsonic ejectors, had to be improved for optimization of supersonic ejectors. The optimal shapes of the ejector for chosen boundary condition, i. e. stagnation pressure of the primary and secondary streams and the backpressure, are the results of optimizations. Declination of the primary nozzles towards the ejector axis is another result, which prevents reversal flow in the centre of the mixing chamber. The optimal number of primary nozzles is also found to ensure fast mixing with low pressure losses. The analyses of flow in the optimized ejectors are presented. Acknowledgement This project was realized with financial support of Czech Science Foundation, grant no: P101/10/1709 „Nozzles and Diffusers in Ejectors".

01511
Engineering Optimization through the qualified use of CMMS and Predictive Software

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Aiming to reach both Engineering and Maintenance Optimization the complex Managerial tasks of an Enterprise ceased of being predictably analyzed solely through linear algorithms requiring multidisciplinary approaches. Through properly placed in process sensing tools the key issue of Entreprise Maintenance becomes mainly a Proactive one, a relevant model being the optimization through the qualified use of CMMS software. CMMS (Computerized Maintenance Management System) packages may be used by any organization that must perform maintenance on equipment, assets and property. A CMMS focused on machine optimization provides a flexible application for plant personnel. Enterprise applications can restrict a focused optimization of specific equipment. If the enterprise application is focused on cost reduction and complete asset management, it might miss the very techniques that reduce cost. Corrective and preventive maintenance scheduling must be flexible as designed for machines by a CMMS system. Predictive Maintenance (PdM) is an algorithm based on the analysis of the history of failures. Report the impending failure of equipment by analyzing values that exceed or trend toward an alarm limit. The predictive software can set alarm limits statistically or by a group of machines. So, modeling the Maintenance Management activity becomes a compact and focused system without the influence of enterprise restrictions, as the operating Davison CMMS software proves.

01513
Reduced Order Modelling for Reliability Optimisation of Advanced Micro-Systems

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An area of recent advances in electronics packaging have been associated with the development of miniaturised integrated multi-functional modules based on 3D stacking of several silicon chips

(Integrated Circuits, ICs). Among these new technologies, System-in-Package (SiP) has gained a lot of interest. System-in-Package was developed to provide fully functional electronic systems and sub-systems that integrate several functionally different devices, e.g. optical, MEMS, sensors and other components, into a single package. Key advantages range from reduction in package complexity and size to lower cost and design effort. However, there are still many technology challenges. In particular, the board level reliability is of a great concern because of a number of issues associated with the large die sizes in SiP modules, lead-free assembly, interfacial de-lamination and the utilisation of new materials. Understanding the performance, reliability and robustness of these electronic modules is a key factor for the future development and success of the technology. This paper discusses the Design for Reliability of advanced systems in package based on computational approach that integrates methods for reduced order modelling, numerical risk analysis and optimisation. The methodology is demonstrated for the design of a SiP structure. The main focus in this study is on the techniques for reduced order modelling and the development of the associated models for fast design evaluation and analysis. The discussion is on methods for approximate polynomial response surface modelling and interpolation techniques using Kriging, Neural Nets and radial base functions. A comparative study on the performance and predictive power of the different models is presented. The reduced order modelling approach uses prediction data for thermo-mechanical behaviour of the SiP design obtained through non-linear transient finite element simulations, in particular the fatigue life-time of the lead-free solder interconnects and the warpage of the package. The finite element analysis of the package is briefly presented. The models above play important role in the analysis of the effect of design uncertainties on reliability and robustness of the advanced electronic modules. To aid this assessment, different methods for estimating the variation of reliability related metrics of the electronic package are researched and tested. Sample based methods such as full scale Monte Carlo and Latin Hypercube, and analytical approximate methods such as First Order Second Moment (FOSM) are investigated and their accuracy is compared. The optimisation modelling addresses the probabilistic nature of the reliably problem of the SiP structure under investigation. Optimisation tasks with design uncertainty are formulated and solved using modified Particle Swarm Optimisation algorithms. The probabilistic optimisation deals with two different performance metrics of the design, the thermo-mechanical fatigue reliability of the board level interconnects and the thermally induced warpage of the package. The objective in this analysis is to ensure that the design has the required reliability, as per user specification, and meets a number of additional requirements.

01515
Multidisciplinary Design Optimization Space Launch Vehicle Using Particle Swarm Optimization

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This paper concerned with the development of an efficient multidisciplinary optimization method (MDO) for the conceptual design of space launch vehicle (SLV). The main objective is to reduce the computational time for evaluation of various design alternatives during the conceptual design phase of a SLV. Over the past several years there has been significant progress in the application of MDO to solving such complex design problems. The design of SLV carrying payload to low earth orbit (LEO) is complex, multidisciplinary and multiobjective task that require making difficult compromises to achieve a balanced design among competing objectives including; minimum weight, cost, reliability, performance and operability. In addition the design optimization of SLV systems can be multi-modal, non-convex with multiple local minima, large number of design variables and constraints, and hence it

is time consuming or difficult to rapidly evaluate various design optimization during conceptual design of a SLV system. Collaborative optimization (CO) is one of main MDO approaches, which divides the whole optimization problem into two levels namely: discipline and system level optimization problem. The key limitation of CO is high computational cost (a feature common to all MDO approaches) and the system level convergence difficulties that specifically associated with CO. The implications of these issues are that derivative-based optimization techniques due to numerical noise cannot be used for the system level optimization whereas more robust optimization techniques such as genetic algorithms (GA), particle swarm optimization (PSO) and simulated annealing algorithms (SA) are computationally prohibitively expensive to be used within CO. To address these issues, the methodology adopted in this paper is based on PSO at the system level of CO involving disciplines of structures, aerodynamics, propulsion and trajectory analysis, Semi-analytical models for the disciplines are used in this work, which provides rapid evaluation of the disciplines within the CO framework. In order to overcome stochastic optimization such as GA, PSO and SA barrier at the system level in CO a two-level high quality response surfaces are introduced. The first level involves the construction of global response surface, which is used for global search at the system level. The second level of the construction of response surface is based on moving trust region for rapid local searches. Moving least squares method is used in the construction of both levels of response surface model building process. Results obtained for the conceptual multidisciplinary optimization of SLV test problem involving; structures, aerodynamics, propulsion and trajectory disciplines within the CO framework show a significant improvement in computational cost and system level convergence using PSO. In addition, the performance of PSO is compared with SA and GA on the test problem within the proposed framework.

01532
Network reliability optimization in the context of disaster preparedness strategies

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Robust optimization and stochastic programming are the two main methodologies which have been developed with the objective of incorporating – into the modeling and solution procedures – the uncertainties present in a diverse set of practical applications. A common hypothesis concerning both approaches is that the realization of the uncertain parameters is independent of the decision variables. This conjecture is valid in a variety of problems – such as portfolio optimization, scheduling of hydrothermal electricity production, communications network planning under demand uncertainty, etc. – and, not surprisingly, the vast majority of the work in these areas deals with problems in which this hypothesis is satisfied and the uncertainty is said to be exogenous. There are, however, some interesting problems in which the probability of occurrence of random events depends on the decisions taken (i.e., when the uncertainty is said to be endogenous) but the literature on such cases is very limited. Our work aims at contributing to fill this gap by studying a problem in the area of humanitarian logistics and disaster preparedness. Earthquakes, hurricanes and floods have recently proven their catastrophic potential and concerns over global warming and climate change worsen the perspective in years to come. In face of that, regions that are prone to the occurrence of natural disasters must take preventive measures in order to mitigate potential damages to vital infrastructure, and devise emergency plans so that they are able to provide care for those affected by such events. It has been pointed out that more casualties actually happen due to the isolation to which many residents are forcefully put to rather than by the event itself – which has also been the experience reported by humanitarian organizations in the aftermath of the recent earthquake in Haiti. It is thus clear that it is very important to assess the vulnerability of the transportation network and to take steps aimed at guaranteeing that it will be possible to either evacuate people to safe locations or to provide them with basic resources in a post-disaster period. The problem we study essentially refers to that of determining the optimal set of investments on the reinforcement of the links of a transportation network which are subject to random failures – the decision to reinforce a link increases the probability that it will be available afterwards. We propose (i) a re-formulation scheme which overcomes the non-linearities that arise in the original formulation presented in the literature, (ii) a cut generation algorithm that significantly decreases computational times and (iii) the incorporation of sampling techniques that allows us to solve large instances of the problem by using sample approximations even though the final probability distribution of the random variables is not known. Computational studies based on real instances of the problem are presented, along with future research directions and extensions of the proposed approach to problems in different contexts.

01536
Design of Combined Heat and Power Plant using MINLP model

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This paper presents a Mixed Integer Nonlinear Programming (MINLP) mathematical model to simultaneously optimize the configuration of a Combined Cycle Power Plant (CCPP), the geometric design and operating conditions as well. The whole process is modelled by considering detailed energy, mass and momentum balances. Physical and chemical properties of air, oil, flue gases, overall radiant exchange factor, convection coefficient, overall heat transfer coefficients are computed using nonlinear correlations. On the other hand, discrete decisions (integer variables) are employed to model the tube number, diameters and widths of tubes in each equipment section as well as the number of fins per unit length of tube among others. Continuous variables are related to the pressures, temperatures and flow-rates of gases and working fluid streams. GAMS (General Algebraic Modelling System GAMS) is used to implement and to solve the mathematical model. Once the proposed MINLP model was successfully validated with literature, it was solved considering different objective functions. The obtained results are presented and discussed in detail.

01539
Thermal Optimization of a Protruding Heater in Laminar Channel

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The heat transfer from a single heater mounted on the lower wall of a horizontal parallel plates channel was investigated under conditions of laminar airflow, with the purpose to optimize the heater height protruding into the flow region. The lower channel wall was conductive, its upper surface was in contact with the airflow and its lower surface, as well as the channel upper surface, was adiabatic. Thus, in addition to direct convection to the airflow, the heater cooling also occurs by

conduction through its interface with the channel wall. The conjugate forced convection-conduction heat transfer analysis was performed for a two-dimensional configuration, with a fixed channel height and the heater block upstream edge centered in the lower channel wall. The heater length was equal to the spacing of the channel walls and it was considered either flush mounted to the channel wall or with a protruding height into the channel. The convective heat transfer area and flow velocity around the heater increase with its protruding height, while the flow pressure drop along the channel also increases due to the partial blockage of the channel. The lower channel wall was considered with a fixed thickness, but its thermal conductivity was investigated in the range from 0 to 80 times that of the air, while the heater thermal conductivity was considered equal to 500 that of the air. The heater had a uniform volumetric heat generation rate and the airflow velocity and temperature at the channel entrance were uniform. The channel flow Reynolds number ranged in the laminar regime from 630 to 1890. The results were obtained from numerical simulations of the flow and heat transfer, employing the Control Volumes Method with the SIMPLE algorithm to obtain the flow field. The convective heat transfer from the protruding heater was evaluated numerically, considering its interface with the airflow, which included the top and the lateral surfaces. The pressure drop through the channel was included in the thermal optimization of the protruding heater height by means of an overall thermal conductance. The results indicated that for a specified Reynolds number and channel wall thermal conductivity, the convective contribution to the heater cooling increased with the protruding height while the conductive contribution decreased. This indicated that there is a heater height with a maximum overall thermal conductance. As the Reynolds number increased, the optimal conductance was obtained for shorter heaters, mainly due to the increased pressure drop and pumping power associated to larger flow rates. From the results obtained, the optimum operating conditions and heater height were identified and presented in dimensionless form within the investigated range of the pertinent variables.

01542
Predictive Control in a Heat Recuperator for an Industrial Cogeneration Plant

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This work uses techniques of optimization and MPC (Model Predictive Control) applied to a heat regenerator in a cogeneration plant. This plant generates cold by the use of an absorption chiller and generates power through a gas turbine using natural gas. The heat regenerator is the link between those two systems and its performance depends on the adopted control strategy for the entire system. The results of the numerical simulation are compared with experimental results and their parameters adjusted according to the results of the MPC.

01545
Engineering Self-Assembly through Modeling Nanostructures

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Self-assembly is acknowledged of being the main course toward engineering functional nanoscale systems. Self-assembly of nanostructured materials is scalable to industrial levels of production since it does not require control at the nanoscale. Nanostructures and nanostructured systems formed by

self-assembly include quantum dot arrays, NEMS and MEMS, nanoporous adsorbents and catalytic materials , nanocrystals, and biomimetic materials, metamaterials, etc. The role that mathematics and computer play on modeling nanostructures is to apply mathematical and computational tools developed in other contexts to the understanding, control, design, and optimization of nanostructured materials and functional systems based on nanoscale structures. Also the time-dependent properties of nanostructures (e.g.: electron, spin, and molecule transport) and the time-dependent processes used to produce nanostructures and nanostructured materials (e.g.: nucleation and growth, directed self assembly, and vapor deposition methods) should be properly described and modeled, each of these steps being essential to the manufacturability of systems composed of nanoscale objects. A main impediment to progress in theory, modeling, and simulation in nanoscience arises because theoretical efforts in separate disciplines are converging on this intrinsically multidisciplinary field. Much of the current mode of theoretical study in nanoscience follows the traditional separation of the practice of experiment from the practice of theory and simulation, both separate from the underpinning applied mathematics and computer science. Applied mathematics areas that are directly relevant to the challenges of theory, modeling, and simulation in nanoscience are bridging time and length scales, use fast algorithms, and aim to optimization and predictability. The necessity of traditional finite element elastic/plastic codes for stress/strain description at the macroscale exist, since ultimately nanostructured materials must connect with the macroscopic world, although, more rigorous and effective methods for characterizing and solving stochastic differential equations are required. By its very nature, nanoscience involves multiple length and time scales as well as the combination of types of materials and molecules that have been traditionally studied in separate subdisciplines. For example, the relatively recent discovery by nonequilibrium molecular dynamics, confirmed by nonlinear response theory, of violations of the second law of thermodynamics for nanoscale systems indicates the importance of new theoretical developments focused on nanoscale systems. For theory, modeling, and simulation, this means that fundamental methods that were developed in separate contexts will have to be combined and new ones invented. This create the necessity of a paradigm shift mainly on education and training, that definitely would produce the envisaged engineering optimization through the proper multidisciplinary approach from the earliest stage of drafting algorithms.

01547
Minimizing the Connection Cost in a Real GSM Network

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Wise resource allocation is necessary to increase the quality of service, the system capacity, the network performance, and also decrease the power consumption and connection cost. This paper investigates the located global system for mobile (GSM) network in a region of Tehran province in Iran as a case of study. It then proposes a novel approach to minimize the connection cost among different parts and components of the GSM network while considering our network practical constraints. The approach of this paper can also be used for other network planning problems such as universal mobile telecommunication system (UMTS) in the third generation of mobile systems. In order to find an optimal solution for the total network connections cost, we use a mathematical programming based on mixed integer programming to minimize the connection cost. At the end, simulation and practical results show that our proposed algorithm decreases the connection cost and improves the service quality of the GSM network.

01550
Mixed-Flow Grain Dryers Finite Time Functioning Optimization

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Grains production in Brazil almost triples during the last decade, increasing from 50 to 150 million tons/year. According to the Brazilian National Confederation of Industry, the Brazilian industry pre-processes annually more than 50% of the harvest, before setting it up for sale on international market. In terms of potential of consumption, the grains harvest drying represents approximately 104 TJ/year of thermal energy to be commercialized by the Brazilian energy market. This dramatically increased the need for more efficient drying plants and more productive drying technologies. To optimize the grain drying plants we firstly addressed the problem of determining the best strategy for drying gas delivering to the drying chamber, such that to maximize the utilization of the drying gas moisture removal and carrying capability. Results shed some light on sizing drying chambers for given conditions when the drying gas moisture carrying capability almost double while the drying gas mass flow rate decreases six times. Numerical values of thermal efficiency calculated indicate a potential improvement of the grain drying process from 14.28% for constant drying air delivering up to 27.53% when the best variable drying air delivering strategy is employed. Secondly, we investigate two different strategies for energy recovering in continuous mixed-flow grain dryers. To increase the energy efficiency of the whole drying plant, when the wet drying air leaves the drying chamber, some of its internal energy is recovered in the heat exchanger by the atmospheric air inflow. The process inside the heat exchanger allows to gradually increases the atmospheric airflow temperature before it enters the heater. To avoid that already dried grains naturally pick up moisture from the atmosphere during the storage, the second strategy ensures their cooling down in the cooling chamber before leaving the dryer. Some of the grains internal energy, removed by the atmospheric air during the grains cooling down, is now used for preheating the atmospheric airflow before it enters the heat exchanger. Numerical results obtained for the soybean drying process yield energy efficiencies of 2.8 - 3.5 MJ/ (kg of vaporized water), while the heater consumption of methane varies from 4.7 to 5.8 Nm3/ (ton of dried soybean).

Topology Optimization in Aeronautics and Aerospace Engineering

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01249
New developments in material parameterization for optimal fibers orientations in composite structures

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In this paper, a new parameterization of the mechanical properties is proposed for the optimal selection of plies orientations in structures made of fibers reinforced composite materials [1]. Recent parameterization schemes from multi-phase topology optimization (i.e. Discrete Material Optimization – DMO, [2]) are compared to the novel approach in the selection of conventional laminates including only 0, -45, 45 and 90° plies. In the new parameterization the material stiffness is computed as a weighted sum of the candidate material properties, and the weights are based on the classical shape functions used in the finite elements method. When the 4 candidate orientations are considered, each vertex of the reference quadrangle then represents a candidate ply. In this case, compared to DMO, this method requires less design variables, since the 4 pseudo-densities representing the presence or the absence of a given candidate ply in DMO are now replaced in the weights by two design variables, which are the 2 natural coordinates of the reference quadrangular element sufficient to identify each of the 4 vertices. The selection of a suitable shape function is discussed in the case of 3 candidate laminates (0°, 90° and ±45°), where 3 nodes representations obtained with the shape functions of either a triangular membrane element or a second order bar element can be used to identify the 3 materials. Numerical applications with in-plane loadings are proposed and solved in order to demonstrate that the new approach is an interesting alternative to DMO, able to select the optimal orientations and to combine the material distribution and optimal orientation problems.

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01254
Recent extensions of the Prager-Rozvany (1977) optimal layout theory

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In this paper the optimal layout theory (Prager and Rozvany 1977) is employed to investigate symmetry and non-uniqueness in topology optimization. Symmetry may save much CPU time in computing discretized optimal topologies and often simplifies the derivation of exact analytical solutions. The above concepts are discussed in the context of 2D trusses and grillages, but can be readily extended to other structures and design constraints, including 3D problems and numerical solutions. The treatment of the subject is pitched at the background of engineering researchers, and principles of mechanics are given preference to those of pure mathematics. The author hopes to provide some new insights into some fundamental properties of exact optimal topologies. Combining elements of the optimal layout theory (Prager and Rozvany 1977) with those of linear programming, it is concluded that

for the considered problem class the optimal topology is in general symmetric if the loads, domain boundaries and supports are symmetric. However, in some special cases the number of optimal solutions having the same minimal volume (cost) may be infinite, and some of these may be non-symmetric. The deeper reasons for this are explained in the light of the above layout theory. All fundamental hypotheses and propositions presented in this paper are supported by extensive and unequivocal 'empirical' evidence. This is based on all of the known exact (analytically derived) optimal topologies in the literature for both trusses and grillages by a number of authors. Moreover, they are all demonstrated herein on illustrative examples, which are mostly rather simple, so that the underlying concepts are not obscured by computational complexities. Optimal trusses play an important role in basic research on topology optimization. Trusses are often used for testing new methods and illustrating general properties of optimal topologies. As a recent example we may mention Stolpe's (2010) challenging educational article, which has inspired some of the research reported in this text. Trusses may also be employed as benchmarks for perforated plates with in-plane stress and 3D structures (for a quantitative method see e. g. Rozvany et al. 2006). This is because the optimal topology of these structures tends at low volume fractions to that of trusses (Rozvany, Olhoff and Bendsoe 1987, Bendsoe and Haber 1993, for a review see Allaire's (2002) book, pp. 336-342). A similar link between the optimal topology of thin perforated plates in bending and that of grillages was shown by Rozvany, Olhoff and Bendsoe (1987), and in greater detail by Lewinski and Telega (2001). The theory of exact optimal grillage (beam system) topologies is fully developed (e. g. Rozvany and Hill 1976, Prager and Rozvany 1977b, Sigmund et al. 1993), and also highly suitable for investigating general characteristics of optimal topologies. The 'propositions' in this paper will also be extended to structures with a finite number of elements in the ground structure. Problem classes for which there exist only non-symmetric optimal topologies will also be discussed, and some controversial issues in the early literature resolved.

01285
Lamb-wave Damage Detection in an Aircraft Panel with Topology Optimization of Sensor Layout

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Structural Health Monitoring (SHM) technology has become increasingly important as an approach to reduce the maintenance costs and increase the availability of aircraft structures. One of the critical structural failures in aircraft skin panels is the emanation of cracks at the riveted holes. Acoustic waves such as Lamb waves show promising results in detection of such micro-cracks and discontinuities in the material. However, random location of such defects would lead to an increase in the amount of sensors that are needed to detect these discontinuities thereby increasing the cost. The objective of this paper is to arrive at a topology optimization of the piezoelectric sensors, their location, number and form, used for the generation of Lamb waves to detect micro-defects of a constant size that occur at random locations on the Al 2024 aircraft panel. The fundamental problem in structural topology optimization is the determination of an optimal layout of material within a prescribed domain. In our particular case, we are considering piezoelectric material distributed over a thin aluminum plate. The topological approach admits the structure is a set whose topology can be changed during the optimization process. Consequently, breakages and merges of the set may occur, and holes may appear or disappear during the search for an optimal structure. Also, in some problems, it might be interesting to allow the structure to divide or to coalesce. The main challenge of the proposed approach concerns the characteristic propagation of the Lamb wave for a continuous layout of piezoelectric sensors, which would have to be determined at every iteration of the optimization process. The obtained results would throw light over an approach for optimizing the sensors in terms of location, number and topology which could be further extended to large scale aircraft panels.

Recent Developments in Derivative-Free Methods for Engineering Optimization

8

01018
Bioinspired Methods in Process Integration for Design Optimization

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In this paper we would like to describe the spread of biologically inspired methods for solving real-world optimization problems in engineering where simple utility functions are usually not able to synthesize complex phenomenon. Nowadays computer technologies have been challenging the environment of engineering design by enabling software tools such as PIDO (Process Integration for Design Optimization) and MDO (Multidisciplinary Design Optimization) systems. This is due to the advances in processor speeds, run-time reduction strategies, parallel computation, powerful disciplinary analysis and simulation programs. The advantages of using a PIDO and bioinspired methods may be summarized as follows: reduction in design time, systematic, logical design procedure not biased by intuition or experience. In the first section we make a general introduction of all the tools that are necessary for solving engineering problems (e.g. optimizers, metamodels, data analysis) and where bioinspired methods applied. Then, we focus on a multivariate analysis tool named self-organizing maps (SOM). In the last section, a list of application domains and success stories is presented.

01038
Imperialist Competitive Algorithm for truss structures with discrete variables

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Although the goal of optimization is to reduce the costs of a structure construction, but it is clear the considering of economical conditions and engineering criterions. This study is a new method called Imperialist Competitive Algorithm (ICA) which is employed to optimization of several truss structures with discrete variables, and compared with the Heuristic Particle Swarm Optimization (HPSO) and other methods. The results show that the ICA is the robust algorithm for finding the global optimum and has the fastest convergence rate among these methods. Also by the solved examples, it is shown that this method is quite proper even for constrained problems. Furthermore, the proposed ICA can be effectively used to solve optimization problems for structures with discrete variables.

01096
Inverse Robot Kinematics with Genetic Algorithms

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The inverse kinematic of a robot manipulator is a problem that the analytical is not usually possible. In last year many researchers are studying numerical methods in order to try o solve this problem. This work deals with obtaining the inverse kinematics of a robot manipulator using genetic algorithms (GA). To do that, a experimental setup was assembled, composed by a robotic didactic kit. The robotic manipulator was assembled

to have movements only in the x-y plane and has two revolute joints. Its direct kinematics was obtained using Denavit-Hartenberg parameter. The main idea is to write the inverse kinematics problems as an optimization problem and solve it using the GA theory. The direct kinematics of the robot was used to compare the real trajectory with the one obtaining by the GA. Preliminaries results show that the algorithm implemented is quite good and the converges to the solution very fast.

01242
Direct-Multisearch for Multiobjective Optimization

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In practical applications of optimization it is common to have several conflicting objective functions to optimize. Frequently, these functions are subject to noise or can be of black-box type, preventing the use of derivative-based techniques. We propose a novel multiobjective derivative-free methodology which does not aggregate any of the objective functions. Our framework is inspired by the search/poll paradigm of direct-search methods of directional type and uses the concept of Pareto dominance to maintain a list of nondominated points (from which the new iterates or poll centers are chosen). The aim of our method is to generate as many points in the Pareto frontier as possible from the polling procedure itself, while keeping the whole framework general enough to accommodate other disseminating strategies, in particular when using the (here also) optional search step. We prove under the common assumptions used in direct search for single optimization that at least one limit point of the sequence of iterates lies in the Pareto frontier. Computational results are reported on a test set of multiobjective problems, which show that our methodology has an impressive capability of generating the whole Pareto frontier even without using a search step.

01284
A genetic algorithm for topology optimization of dome structures

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Domes are structures largely used in arenas, exhibition pavilions, theatres, terminals, hangars, convention centers, gymnasiums, etc. The structural configuration of those structures allows for a completely free inner space without any interior column. There are several possible geometries for the domes depending frequently on the desired architectonic effect and the inventive ability of the architect. A preliminary engineering analysis usually comprises a few conventional configurations, pre-defined by the architect, and the engineer only chooses the sizes of the bars to satisfy the applicable codes, considering economic aspects. In this paper a genetic algorithm is proposed to solve the weight minimization problem of dome structures composed of standard modules considering configuration, shape, and sizing design variables. We consider domes assembled from standard modules composed by 10

members which are grouped into seven distinct profiles. The set of design variables includes: (i) sizing design variables (cross-sectional areas of the bars); (ii) a shape design variable corresponding to the height of the dome and (iii) shape design variables corresponding to the inner diameter of the dome at certain heights. Further, cardinality constraints are introduced to define alternative member groupings of the standard modules. This type of evolution of the whole structural configuration is an attractive feature because it allows the designer to automate the search for the dome global configuration, finding the best number of standard modules simultaneously with the shape and sizing design variables for these modules. As a result, a much larger space of possible solutions is searched, potentially leading to counter-intuitive or non-traditional solutions. Several experiments are performed using a 120-bar dome as test-bed. The adaptive penalty method (APM) is applied to enforce all the mechanical constraints considered in the structural optimization problems discussed in this paper.

01339

Multi-objective optimization of tube hydroforming process by genetic algorithms

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Tube hydroforming process (THP) is one of the most important manufacturing processes that allow to manufacture a large panel of complex and simple tubular parts. The main advantages of the process compared with conventional stamping and assembly processes: offer improved formability to the material, significant reductions in weight, lower springback, and a best thickness repartition in the tube that avoid the occurrence of such plastic instability like wrinkling and bursting. The process parameters mainly loading paths are the important factors that influence the quality of the final product. The aim of this work is to optimize the internal fluid pressure path, axial displacement of the punch and the counterpunch force applied to form the T-part. Three objectives functions can be defined to reach the goal: (1) minimize thickness deviation, (2) maximize branch height, and (3) obtain the final desired shape. To construct these functions a central composite design (CCD) was used. To solve the problem a multiobjective strategy is used based on genetic algorithms. In multi-objective problems there is no unique optimal solution that can satisfy all the criteria simultaneously but a whole set of potential solutions referred to as the Pareto optimal front. As an example chosen to prove the efficiency of our approach, the target part is a T-shape. This work shows the robustness of the multiobjective strategy to solve this kind of problems and to obtain satisfactory results. Key Words: Tube hydroforming process / Multi-objective optimization / Design of Experiment / Genetic algorithms / Pareto solutions.

01342

A multi-objective optimization approach in a job-shop scheduling rules simulation

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Since the arising of the Toyota production system, known as lean production, manufacturing companies around the world have been working out to improve their production processes, reducing

inventory levels and eliminating waste. These companies are often faced with conflicting priorities: in order to achieve low unit cost it is necessary to produce a high volume of low mix products, which can lead to increase lead times and the costs of maintaining large inventory. Moreover, the current demand in manufacturing environment is a high mix and low volume of products. The Toyota production system is supported by the concept of Just-in-Time, called pull production systems which, in contrast to the traditional push systems, allow the production of a product only at time it is needed and only in the exact amount that it will be used. On the other hand, in the push production systems the release of new orders is controlled by a central planning that considers demand forecasts, such that the accomplishment of a previous operation is authorized without waiting for a request from the next operation in subsequent work station. There are also other production systems that are aimed to ensure the release of a new order to the shop floor just after the finishing of an open order, keeping constant the work-in-process. In this context, the fact is all manufacturing environments can benefit from a good production schedule. Proper scheduling leads to increased efficiency and capacity utilization, reduced lead times and consequently increased profitability of an organization. However, to attain maximum benefit, different environments require different approaches. The scheduling rules could be very simple, such as select the task that is due the soonest (Earliest Due Date), or select the task that requires the least amount of time to complete (Shortest Processing Time), but these rules could also be very complex (which is usually the case in the real world) such as a combination of or exceptions to the simple rules. These combinations and exceptions make planning and scheduling a difficult task. To deal with this difficulty multi-objective optimization techniques seem to be the most suitable approach. This paper proposes the combination of a multi-objective technique with an Arena simulation model for the optimization of some performance measure in job shop environment. This optimization will consider minimizing the lead time, the number of tardy jobs and the total tardiness. In the simulation model the main scheduling rules in flow shop and general job shop have been considered, with randomly generated routes and operation times. The multi-objective optimization approach is based on the integration of the Genetic Algorithm with an Arena simulation model through the Visual Basic for Application language.

01391
Bilevel Derivative-Free Optimization and its Application to Robust Optimization

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We address bilevel programming problems when the derivatives of both the upper and the lower level objective functions are unavailable. The core algorithms used for both levels are trust-region interpolation-based methods, using minimum Frobenius norm quadratic models when the number of points is smaller than the number of basis components. We take advantage of the problem structure to derive conditions (as far as is possible closely related to the global convergence theory of the underlying trust-region methods) under which the lower level can be solved inexactly and sample points can be reused for model building. In addition, we indicate numerically how effective these expedients can be. A number of other issues are also discussed, from the extension to linearly constrained problems to the use of surrogate models for the lower level response. One important application of our work appears in the robust optimization of simulation-based functions. The robust counterpart of an optimization problem without derivatives falls in the category of the bilevel problems under consideration here. We provide numerical illustrations of the application of our algorithmic framework to such robust optimization examples.

01415
A New Hybrid Evolutionary Algorithm Based on ICA and GA: Recursive-ICA-GA

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In this paper a new method is proposed to combine ICA (Imperial Competitive Algorithm) and GA (Genetic Algorithm) which improves the convergence speed and accuracy of the optimization results. The presented algorithm named R-ICA-GA (Recursive-ICA-GA) is based on consecutive runs of ICA and GA. It is proved in this paper that a fast decrease occurs while the proposed algorithm switches from ICA to GA. The main goal of the algorithm which is presented is to use this fast decrease to perform a faster optimization technique. Moreover, the simple combination of ICA and GA which is named ICA-GA is presented in this study. These two combination schemes of ICA and GA are discussed and used to be compared with other conventional algorithms. Finally, three fitness functions are used for comparing the suggested algorithms. The obtained results illustrate that the proposed algorithms are at least 32% faster in optimization processes and the variance of their convergence speeds is smaller compared to the ICA and GA.

01434
Stochastic optimization of electromechanical coupling in ferroelectric materials

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Polycrystalline ferroelectrics differs significantly from single crystals because of the presence of variously oriented grains or crystallites [1]. The orientation of ferroelectric crystals plays a critical role in the anisotropy of their piezoelectric properties [2]. The set of combination of variables, known as solution space, which dictates the orientation distribution of grains is unlimited. Thus, simulated annealing combined with homogenization is employed for the identification of the optimal granular configuration of the ferroelectric ceramic microstructure with optimum electromechanical coupling suitable for applications such as transducers and actuators. The effective macroscopic electromechanical coupling k are calculated at every iteration using the mathematical homogenization method. The configuration of crystallites at each step is chosen by the optimization algorithm. The single crystal ferroelectrics are also investigated in an effort to compare the performance characteristics with that of polycrystals. A configuration constraining the orientation distribution of the c-axis (polar axis) of the crystallites is identified. This grain configuration would optimize the figures of merit such as k of the ferroelectric material.

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01469
A trust-region subspace method for derivative-free bound-constrained optimization

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Several trust-region based algorithms have been proposed, in the last decade, to minimize a function, in the case where its derivatives are not available or are computationally prohibitive. Such a problem occurs for instance in shape optimization for aeronautics when three dimensional partial differential equations are involved in the computation of the cost to be minimized. The algorithms we are interested in, typically minimize a polynomial interpolation model inside a trust region, and if the ratio of the achieved function decrease over the model decrease is large enough, the step is accepted and the trust region is expanded. The reason for this ratio to be too small, is either that the trust region radius is too large, or that the geometry of the set of points used for the interpolation, as measured by the poisedness of the set, is not satisfactory. In any case a geometry improving step is performed by these algorithms, that costs additional objective function evaluations. A new variant of derivative free algorithm has been proposed in Scheinberg and Toint (2009) as an attempt to reduce as much as possible the recourse to geometry improving steps, while maintaining a mechanism to take geometry into account. This algorithm implements an implicit poisedness control by making use of a self-correction mechanism combining the trust-region mechanism with the polynomial interpolation setting. We extended the algorithm to handle bounds and propose applying a subspace method where the step is limited to the current set of active variables. Considering a subspace method in model-based optimization enables to save a substantial amount of costly function evaluations as the maintained interpolation sets are much smaller, and make it possible to maintain geometry on the faces that are explore along the iterations. After reducing the dimension of the problem to the number of free variables, the minimization is pursued in the resulting subspace by a recursive call of the algorithm. To enhance the robustness of the code with respect to round-off errors, shifting and scaling techniques are performed to keep the condition number of the linear systems as low as possible. In our approach, we use variable size interpolating models of degree $1\e d\le 2$. The initial model is linear but the interpolation set is consequently augmented during the calculation. This enables the algorithm to converge with a model degree $d When the iterates seem to indicate that several bounds can be considered as active, nearly active points are projected on the free space variable. To save function evaluations, function values corresponding to these projected point are not recomputed, giving rise to point with approximate functions value that we call "dummy" points. We show how to algorithmically deal with those points to maintain a good convergence behaviour and demonstrate the efficiency of our approach on problems from the CUTEr library.

01473
An adaptive surrogate-assisted differential evolution algorithm for constrained structural optimization problems

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Differential Evolution (DE) is a simple and efficient stochastic, population-based, heuristic for global optimization over continuous spaces. In this paper a previously developed DE that dynamically selects the mutation operator (among several commonly used variants) according to its previous performance is adopted as the search engine for structural engineering optimization problems. However, as with other evolutionary algorithms, there is a great computational cost associated with the large number of fitness function evaluations usually required in order to achieve a good solution. To improve performance when a fixed budget is considered we propose the use of a similarity-based approximate model to be used as an inexpensive surrogate for the computationally intensive simulation required for objective function and constraint checking evaluations. The resulting surrogate-assisted differential evolution algorithm with dynamic selection of mutation variants is then applied to constrained structural optimization problems in order to assess the applicability and relative performance of the proposed procedure.

01476
Least squares parameter fitting without derivatives

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Computationally expensive numerical simulations can now be found in all engineering disciplines. These simulations often depend on a set of parameters, which are determined by fitting the simulation output to data. The resulting optimization problem is challenging because the derivatives of the simulation output with respect to the parameters are unavailable and the expensive simulation must be run for potentially many different parameter values. In this talk we will relate our experiences developing a solver for least squares problems without derivatives. POUNDerS (Practical Optimization Using No Derivatives, for Squares) exploits the structure in these problems by forming a quadratic interpolation model for each residual. The aggregate of these models is then minimized in a trust region framework, with an emphasis placed on using as many previously-obtained function values as possible. We have found this approach to be highly successful in practice and will demonstrate its application on several computationally challenging problems in nuclear physics.

01504
Comparison of Derivative Free Methods for Design Optimization of Industrial Devices

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Numerical simulation tools for solving partial differential equations have greatly improved in computational efficiency and flexibility in the past decade. As a result, today it requires relatively little effort to simulate complex industrial devices with high fidelity. This makes it possible to connect the simulation to optimization algorithms and thus support the engineering and design process for such devices. Choosing an appropriate optimizer however is not easy, since the

corresponding optimization problems typically have the following features which make them hard to solve: (a) a function evaluation (i.e. running a simulation) is computationally expensive, (b) numerical inaccuracies give rise to noisy functions even in cases where the response of the physical system is smooth, and even jumps in the functions are frequent, (c) typically more than one property of the design matters, which makes the problems multi objective. In this work, we study two concrete design optimization problems: (1) Optimization of a shielding device for eddy currents where shunts have to be placed, and (2) optimization of a high-voltage insulator design. The former problem is defined on a discrete search space, while the latter is on a compact subset of a Euclidean space. On these problems, we will compare the performance of various optimization algorithms that are appropriate to cope with the features (a)-(c) above to a higher or lesser degree, including classical derivative free algorithms, local response surface based derivative free algorithms, and meta-heuristics, in particular genetic algorithms. For those algorithms which are not intrinsically multi objective, we will discuss how to use them to solve multi objective cases. Moreover, we will briefly discuss the extended setup where the optimization algorithm can select the fidelity level of the simulation, resulting in function evaluations of a higher or lower accuracy and computational costs. This adds an additional degree of freedom to trade-off speed vs. accuracy.

01512
Solving the Job Shop Problem with a random keys genetic algorithm with instance parameters

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In this work is presented a genetic algorithm for the Job Shop Scheduling Problem (JSSP). The genetic algorithm is based in random keys chromosome that is very easy to implement and allows using conventional genetic operators for combinatorial optimization problems. JSSP is a classic combinatorial optimization problem and is also a NP-hard problem. In the JSSP each job is formed by a set of operations that has to be processed in a set of machines. Each job has a technological definition that determines a specific order to process the job's operations, and it is also necessary to guarantee that there is no overlap, in time, in the processing of operations in the same machine; and that there is no overlap, in time, in the processing of operations of the same job. The objective of the JSSP is to conclude the processing of all jobs as soon as possible, this is, to minimize the makespan. The JSSP represents several real situations of planning and for that it is a very important problem. Recently, the load operations in a warehouse were modeled by a JSSP with recirculation. The use of exact algorithms for the Job Shop is still limited to instances of small size. The alternative to solve the Real-World Job Shop Scheduling Problem is the use of heuristic procedures. Genetic Algorithms is a well known heuristic technique and largely used on the engineering field of solving optimization problems. This genetic algorithm includes specific knowledge of the problem to improve its efficiency. It is used a constructive algorithm based in Giffler-Thompson's algorithm to generate active plans. The constructive algorithm reads the chromosome and decides which operation is scheduled next. The first population generation is based on the instances parameters. This option increases the effectiveness of the genetic algorithm. The genetic algorithm is tested by using some benchmark problems and is presented computational results.

01534
Hybrid Optimization of Evolutionary and Approximate Gradient Search for Expensive Functions

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Optimization of expensive functions is more feasible with algorithms that require fewer evaluations of the objective function. In that spirit, this paper proposes a hybrid evolution strategy. As in (Eng. Opt., (39) 2007, 87-104), the proposed algorithm combines an evolution strategy (ES) with a gradient search technique. The proposed algorithm differs in that it uses a local radial basis function approximation to the objective function to compute approximate first and second derivatives to the objective function surface. The derivative information is used to propagate a gradient individual alongside the evolving population. The gradient individual is included for possible selection each generation. Tests on a small suite of standard test functions and a hydrologic application show that this hybrid approach can greatly accelerate the covariance matrix adaptation evolution strategy (CMAES). This hybrid approach is flexible and requires little modification of an existing evolution strategy; thus, it does not seem to alter negatively affect convergence when an objective function does not have sufficient smoothness for derivatives to yield useful descent information.

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Surrogate-and Knowledge-Based Optimization Procedures for Computationally Expensive Engineering Design Problems

01008
Multi-Fidelity High-Lift Aerodynamic Optimization of Single-Element Airfoils

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The primary purpose of a high-lift system is to increase allowable aircraft weight (or decrease aircraft´s wing area) for a given takeoff and landing performance. Therefore, high-lift systems have a major effect on the sizing and economics of most transport aircraft. Traditionally, high-lift systems have been designed using wind tunnel testing, which is both lengthy and expensive. However, recent advances in aerodynamic design have allowed incorporation of computational tools as an integral part of the high-lift design process. Specifically, the combination of high-fidelity computational fluid dynamics (CFD) analysis with gradient-based optimization techniques have made the design process more effective, as well as removing difficulties in the decision making process, which are traditionally done by a designer. High-fidelity CFD simulation is reliable but computationally far too expensive to be used in a direct, simulation-based design optimization, especially when using traditional, gradient-based techniques. There is a need to develop methodologies that would allow rapid design optimization with limited number of CPU-intensive objective function evaluations. Surrogate based optimization (SBO) techniques currently used in aerospace engineering are either exploiting functional surrogate models (that require substantial computational effort to be set up), or adopt approaches such as classical space mapping (which does not guarantee sufficient alignment between the low- and high-fidelity models and requires enforced first-order consistency that required sensitivity data from the high-fidelity model). In either case, the overall computational cost of the optimization process is still high. A computationally efficient design optimization methodology for transonic airfoils has been introduced recently that uses a computationally cheap, physics-based low-fidelity model to construct a surrogate of an accurate, but CPU-intensive, high-fidelity model. The low-fidelity model is corrected by aligning its airfoil surface pressure distribution with the corresponding distribution of the high-fidelity model. The alignment is carried out using a shape-preserving response prediction (SPRP) technique and ensures good generalization capability of the surrogate model with respect to both objectives and constraints (lift and wave drag). This design methodology, however, only accounts for inviscid flow effects. In this work we extend our methodology to account for viscous flow effects, which are important at high-lift conditions. In particular, both inviscid and viscous effects are handled by separate SPRP-like mappings which are subsequently combined with low-fidelity model to construct a surrogate. To demonstrate the computational efficiency of the methodology, several examples of single-element airfoil design at high-lift conditions are provided.

01009
Computationally efficient simulation-driven design optimization of microwave structures

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Due to increasing complexity of microwave structures, their analytical models can only be used-in many cases-to yield initial designs that need to be further tuned to meet given performance specifications and growing demands for accuracy. On the other hand, for some emerging classes

of circuits such as ultrawideband (UWB) antennas or substrate integrated circuits there are no systematic design procedures available that would result in designs satisfying prescribed specifications. Therefore, electromagnetic-simulation-based design optimization becomes increasingly important. However, a serious bottleneck of simulation-driven optimizations is their high computational cost. It makes straightforward approaches employing electromagnetic (EM) solver directly in an optimization loop impractical. Computationally efficient simulation-driven designs can be realized using surrogate-based optimization (SBO), where the optimization burden is shifted to a surrogate model, computationally cheap representation of the structure being optimized (referred to as the fine model). The successful SBO approaches used in the microwave area are space mapping (SM) and various forms of tuning, as well as and tuning SM. Unfortunately, their implementation is not always straightforward: substantial modification of the optimized structure may be required (tuning), or additional mapping and more or less complicated interaction between auxiliary models is necessary (SM). Also, space mapping performance heavily depends on the surrogate model selection. On the other hand, tuning might not be directly applicable for radiating structures (antennas), whereas space mapping normally requires fast coarse model (e.g., physically-based circuit models). Such models might not be available for many important structures including broadband antennas or substrate-intergrated circuits. Here, a simple yet computationally efficient design optimization methodology is introduced based on sequential optimization of coarse-discretization EM models. The optimal design of the current model is used as an initial design for the finer-discretization one. The final design is then refined using a polynomial-based approximation model of the coarse-discretization EM data. The unavoidable misalignment between the polynomial and the fine model is corrected using space mapping. Our technique is straightforward to implement, it does not require a circuit-equivalent coarse model or any modification of the structure being optimized. It is also computationally efficient because the optimization burden is shifted to the coarse-discretization models. The proposed approach is demonstrated through the design of various microwave devices including UWB antenna, microstrip bandpass filter and a coplanar-waveguide-to-microstrip transition.

01062
Surrogate-based Optimization of Biogeochemical Transport Models

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Understanding the oceanic CO2 uptake is of central importance for projections of climate change and oceanic ecosystems. Simulating ocean circulation and biogeochemistry has become a key tool for understanding the ocean carbon cycle and its variability. The underlying models are governed by coupled systems of parabolic partial differential equations for ocean circulation and transport of biogeochemical tracers. The coupling relations between the tracers are more or less empirical, i.e. it is not very clear how the coupling terms look like mathematically, and, moreover, how many tracers have to be taken into account. Many model parameters are used which are chosen such that the model results remain feasible and that given measurement data is matched by the model output. To a substantial degree the resulting problems belong to mathematical disciplines of Optimization, Optimal Control and Inverse Problems. The overall aim is to minimize a least-squares type cost functional, measuring the misfit between the model output and given data. The optimization variables are the unknown parameters in the nonlinear coupling terms in the tracer transport equations. This optimization process requires a lot of expensive function evaluations and corresponding derivation information. Hence a big issues is to reduce the overall optimization cost, which in particular becomes important for computationally much more expensive 3-dimensional models. Here the idea of surrogate-based optimization could provide an essential contribution. Besides the accurate high-fidelity model in focus various approximation schemes will be analyzed to create a computationally cheap but still reasonably accurate surrogate. A coarsening in the temporal resolution of the numerical model as well as a Fourier-type functional approximation of a one-dimensional biogeochemical model have been analyzed so far. According to the nonlinear equation subproblem within the Space Mapping (SM) framework we investigated the so-called SJN method, a global Quasi-Newton method for Systems of Nonlinear Equations (cf. [Kosmol, 1993]). Results show that local solutions can occur leading to termination of the method and that ill-conditioning of the system might destroy the convergence. To overcome this problem, much effort is currently put into the development of a modified Quasi-Newton method and corresponding convergence results according to [Deuflhard, 2004]. Here the merrit function within the well-known damped Newton method is replaced and a modification for both ill-conditioned and singular Jacobian is derived from a comparism with steepest descent methods. Involved algorithms are tested for the steady-state solution of a simple box-model of the North-Atlantic Ocean and afterwards extended to the real SM problem. Hereby secant approximations to the Jacobian of the surrogate such as the Broyden rank-one update and alternatively Automatic Differentiations are used. Furthermore we consider corresponding methods to overcome badly scaled problems. Reduction in the spatial resolution, linearization of the model equations and decoupling of the PDE's are some of the further possible concepts for creating a low-fidelity physical model. Last but not least the development of appropriate validation techniques for the surrogates is indispensable.

01083

An Integrated Systems Approach for Formulating Engineering Optimization Problems

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Previous vast researches on optimization have been mainly focused on optimization theory and optimization techniques and scarcely paid interests on the process of problem formulation and interpretations of its results. In other words, there exist many studies on how to understand the problem generally and generically and/or how to solve the problem while few on how to formulate the problem and/or how to utilize the results for supporting the decision making based on it. In order to play a key role as a really useful tool more than staying at the level of concept and just a guideline, the studies on optimization must turn its attention differently, make great efforts from the above aspects and validate its effect in real-world applications. In this paper, therefore, we focused on a novel attempt that aims at formulating the optimization problem systematically as well as reasonably. Such efforts can be viewed as a task for establishing optimization engineering that is a new paradigm of optimization study. Now, looking at the current state of science around the optimization, we will notice that element technologies on computer science have exhibited a significant progress both from hard ware and software, and are developing still now over 50 years. However, in many cases, technologies belonging to the soft side are used independently and individually within the respective specific field. If we use these appropriately in a collaborative and/or integrated manner by virtue of systems engineering, we can cope with ill-defined and ill-posed circumstances that will appear often before formulating the optimization problem. By making systematic use of element technologies for recognitions and conception together with optimization methods, we will give a new methodology and a concrete procedure to formulate the optimization problem. It is a smart idea to choose decision variables, constraints and objective functions of the problem under consideration in terms of Mind Map and TRIZ as tools for brainstorming, QFD (Quality Function Deployment), Kano method and IP (Integer programming) as those for qualitative and quantitative classification and calculation, and IDEF0 (Integrated Definition method) and Mind Map as tools for mutual understanding of the plotted plan and for schematic instruction. Through a case study taken from a mechanical engineering process, we will show the proposed approach is just relevant to share the substantial information among members of the team and formulate the optimization problem in a tangible manner. It should be emphasized that as a further step of this study, thus formulated multi-objective optimization problem was solved and has been shown the preferentially optimal solution obtained there is promising to improve the real operating conditions greatly. This is a first attempt to focus our concern on how to formulate the optimization problem systematically and comprehensively toward real-world applications. This is also an introduction to the optimization engineering and an effort to seek collaboration to the concept of SSME (Service Science, Management and Engineering) in the future.

01091
Fast forced response prediction using surrogate models

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This paper presents first results of the project "Analysis of in-service damages", whose objective is the development of fast assessment methods for the influence of damaged high pressure turbine nozzle guide vanes onto the low engine order excitation of the downstream rotor blade. To quantify the forcing, the modal forces for the rotor eigen-modes of interest are obtained by solving the unsteady Navier-Stokes equations (URANS) for a full assembly of a stator and rotor ring [1, 2]. These computations are very demanding, requiring approximately two weeks on 40 cores on an HPC cluster per calculation, which is too high to be routinely employed for the assessment of in-service damage patterns. In order to develop a fast assessment technique, surrogate modeling techniques have been investigated to replace the time-consuming URANS calculations: After giving a short overview on the problem of forced response prediction and low en-gine order excitation, this contribution will concentrate on the development of the fast assessment method, namely (i) the parameterization of the damages, (ii) the process to automatically perform a large number of forced response calculations as well as the DoE technique employed to select the sampling points, and (iii) the chosen surrogate modeling technique [3,4,5]. Finally we will show numerical results to assess the accuracy and dem-onstrate the applicability of the surrogate model developed in this project.

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01107
Tailored metamodels for fuzzy reliability based optimization tasks

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An appropriate structural design process enforces the consideration of uncertainty within structural parameters in order to ensure an intended reliability and robustness during the lifetime. Therefore, various reliability based, robustness based and even reliability based robust optimization schemes are on hand. Most approaches fail to

represent real available information appropriately by using just stochastic methods for uncertainty modeling. Especially in the presence of imprecision, vagueness and incompleteness, which is covered by the collective term epistemic uncertainty, superior uncertainty models like the generalized uncertainty model fuzzy randomness should be favored. The introduction of fuzzy random quantities in the design process requires the formulation of an fuzzy reliability based optimization procedure. As a matter of fact, an improvement of accuracy of simulation results is always linked to an increase of numerical expense. Even a reliability based optimization procedure loses applicability when it is adopted for ambitious industry-relevant problems. Hence, the introduction of metamodels is inevitable. Among others, the application of neural networks as metamodel is appropriate especially for highly nonlinear and noisy response surfaces. Since a fuzzy reliability based optimization task merges together fuzzy, stochastic, fuzzy stochastic structural parameters and design variables, the dimensionality of the problems increases and the applicability of metamodels meets its limits. This becomes obvious in an insufficient approximation quality and sometimes the metamodel even fails to map the global trend appropriately. To keep the fuzzy reliability based optimization procedure applicable for industry-relevant problems tailored metamodels may be formulated. One measure is to introduce metamodels on different levels of the simulation scheme. Thereby, the dimensionality and characteristic of the response surface varies on respective levels. On account of this fact, multiple metamodels may be combined within the fuzzy reliability based optimization task. Another measure utilizes the fact, that for reliability analysis and optimization tasks it is dispensable to approximate the response surface in a global manner. Thus, a patchwork like approximation scheme may be applied, which concentrates just on regions of interest. In result, the approximation quality is increased while the requirements on the metamodels are reduced. In this approach concepts of tailored metamodels for fuzzy reliability based optimization are introduced. First of all, the fuzzy reliability based optimization task is presented with additional comments about the numerical realization.Then, the general approach of neural network based metamodels is introduced and reasonable modifications are elaborated to tailor metamodels to the fuzzy reliability based optimization task. Therefore, the patchwork approach and principle ideas thereof are elucidated in detail. From the variety of solution statements, an appropriate approach for industry relevant applications is highlighted and demonstrated by means of an example.

01194
Improving the accuracy of large-dimension response surface models: application to the vibration behaviour of a car body

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Multidisciplinary optimization is essential for vehicle design in order to reach minimal weight with respect to structural performance requirements in crashworthiness, noise or vibration. Because finite element computations are time consuming and lead-time of vehicle project design is very short, the use of response surface models is very advantageous, provided that they are accurate enough. Taken from a non-linear vibration problem with 29 independent design parameters, this paper first suggests a methodology to reduce the number of parameters by using a screening method combined with a Nastran sensitivities analysis. The identification of the influent non-linear parameters will use less experiment than a classical screening method. Then it discusses the accuracy of various response surface models used to predict the first global natural frequency of a car body. The accuracy of a method based on an Optimal Latin Hypercube design and a Radial Basis Functions is presented first and its robustness is discussed taking into account the random generation of the design. Then different attempts are presented in order to improve the accuracy of the approximation model through more suitable design of experiments like the Nearly Orthogonal Latin Hypercube design. This paper ends with a comparison of these methods in terms of accuracy and efficiency.

01227
Design of Experiments - A- D- I- S-optimality

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A metamodel approximates an original model with a model that is more efficient and yields information about the response. Response surfaces and Kriging approximations are such metamodels. A metamodel is based on evaluations of the original function at some design points, where the choice of design points is crucial. The design points constitute the design of experiments (DoE). There are many methodologies of how to chose the DoE. In this work A-, D-, I- and S-optimal DoEs are generated and evaluated. The optimal DoEs are obtained by solving the following mathematical optimization problems: - A-otimality. Minimize the average variance of the model coefficient estimates. - D-otimality. Minimize the generalized variance of the model coefficient estimates. - I-otimality. Minimize the average of the expected variance (taken as an integral) over the region of prediction. - S-otimality. Maximize the geometric mean of the distances between nearest neighbors of the design points. The optimization problems are solved by a hybrid method which consists of a genetic algorithm and sequential linear programming. The different optimality criteria are evaluated for a number of test cases in order to show the characteristics of each criteria. Regular as well as non-regular design spaces are considered. Furthermore, Kriging approximations of the well known Rosenbrock's banana function are generated to evaluate the accuracy of a resulting metamodel based on the different DoEs. Results from the test cases show that D-optimal DoEs tend to place more design points close to the boundary of the design space compared to A- and I-optimality. It is also shown that A- D- and I-optimal DoEs often include duplicate design points which is not beneficial for a deterministic response, but might be beneficial for non-deterministic responses. Concerning S-optimal DoEs the design points are evenly distributed over the entire design space and no duplicates occur. Furthermore, the S-optimal DoE generates the best fitted Kriging approximation of the Rosenbrock's banana function.

01250
Optimisation of Supersonic Projectiles using Adaptive Sampling of the Pareto Front

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This paper describes the implementation and demonstrates the application of an optimisation framework for supersonic projectiles. A surrogate model is constructed using Kriging from initial sample data produced by two aero-predictive codes (CART3D and MISL3). A multi-objective evolutionary algorithm (NSGA-II) was used to determine the Pareto front. By applying an adaptive sampling algorithm, the surrogate model was refined in the region of optimal designs. Analysis of the results showed that the point of maximum lateral acceleration intersects all of the two-dimensional Pareto fronts. This design consists of a small tail and large canard with maximum deflection. Although the time-to-target and roll moment variation objectives would appear unrelated, the analysis showed that they both drive the design in the same direction; towards a small tail and small canard aileron deflection. Static stability was the main driver for an increase in tail size. Overall, there were no significant discontinuities in the Pareto fronts and it was established that for this configuration of projectile, below 10g lateral acceleration there was little possible improvement to any of the other objectives.

01260
Approximate models for loads transfer in MDO of turbine blade

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Turbine blade design is a typical multidisciplinary design optimization (MDO), involving aero-dynamics, thermal analysis and structural design and so on. Due to the difference on grid nodes in flow field analysis and structural analysis, load transfer is often inevitable in MDO of turbine blades. Temperature distribution is a key factor for the strength and life of turbine blades, therefore temperature load transfer impacts on the result accuracy of MDO of turbine blades. In this paper, three approximation models, including polynomial model, kriging model and RBF (radial basis function) model, are used to interpolate between two types of node in the load transfer. The results show that the accuracy of kriging model and RBF model are very close and are higher than that of polynomial model for the load transfer of turbine blade. However, the efficiency of kriging model is decreased rapidly when the data samples to fit kriging model from the flow field get more and more. In addition, the accuracy of kriging model is not as them of the RBF model and polynomial model as been improved, and even is dropped when the distances between the samples are very small. Finally the optimization for a turbine solid-blade is accomplished by using RBF model to transfer temperature load between flow field analysis and structural analysis.

01308
The effect of more appropriate correlation function choices when creating Kriging surfaces for mathematical optimization

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In engineering optimization Kriging literature, the type of Spatial Correlation Function (e.g. Gaussian, Exponential, Matérn) is usually decided a priori, and the shape of the function varied to obtain the optimum Kriging surface. This process can be formidable, partly because of the tendency of the correlation matrix to become ill-conditioned. In most of the literature on Kriging applied to engineering optimization very little attention is given to the selection of the correlation function. However, it is not only important for the accuracy of the Kriging model, but also influence the condition of the correlation matrix, the inverse of which has to be calculated. In this paper we investigate the benefit of examining the data to guide the selection of the correlation function, specifically the influence of a more appropriate SCF on the accuracy of the Kriging fit, and on the search for the optimum parameters.

01321

Metamodeling for Global Optimization using Radial Basis Functions with Cross-Validation Adjustment of the Shape Parameter

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This paper discusses a numerical investigation on a technique for choosing optimal shape parameters of radial basis functions in the context of metamodeling for global optimization. In previous works it was observed that the shape parameter in the inverse multiquadrics and others radial basis function exerted a strong effect on the convergence rate of the optimization process. The paper focus is in the implementation of a leave-one-out cross-validation scheme for optimizing the shape parameter as suggested by Rippa. It is based on the minimization of a suitable cost function that ideally has the same behavior as the error function approximation. In each iterative step the shape parameter that minimizes this cost function is chosen for constructing a global metamodel using the costly function data already available. A Controlled Random Search Algorithm (CRSA) is employed for optimizing both the metamodel approximations and the corresponding shape parameters. The main objective is to investigate the effect of the shape parameter optimization on the convergence rate. Comparative numerical results are presented for both the benchmark Dixon-Szegö functions and real world functions related to engineering design.

01385

Design Optimization Using Approximations Based on High- and Low-Fidelity Models

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The convergence characteristics of an optimization technique based on approximation concepts strongly depends on the quality of the approximations. In many cases the original complex model (also called high fidelity model), used for the structural response analysis, can be replaced by a simplified one (a low fidelity model). For example, the analysis can be done using a coarser finite element mesh, using a reduced number of the natural modes of the model in dynamic analysis, etc. Usually such a model inherits the most general features of the original one and the response analysis with this model is computationally much less expensive than with the original model. Thus, a simplified (low fidelity) numerical model provides a good basis for high quality approximations. The idea to endow the approximation function with some properties of the original implicit function to improve the quality of the approximation stems from the empirical model-building theory wherein it was shown that a so-called mechanistic model, i.e. the one that is built upon some knowledge about the system under investigation, provides better approximations than purely empirical ones. Thus, the approximation F=F(f(x),a) is defined in terms of the function f(x) representing the structural response obtained using the simplified model (x is the vector of the design variables) and the vector of the tuning parameters a. The vector of the tuning parameters is used here (in least-squares fitting) to reduce the discrepancy between the structural response obtained using the low- and high-fidelity models. Depending on the way of introduction and the number of the tuning parameters in the simplified expression, the following three types of the approximations have been suggested: Linear or multiplicative function of two tuning parameters. a=[a0,a1]: F(x,a)=a0+a1*f The tuning parameters are introduced in an explicit correction function which also depends on the design variables. Again, using the linear

and multiplicative models as the correction function, the following approximations can be built. To fit the simplified model into the data obtained with the complex model, some of the parameters of the simplified model other than the design variables can be considered as the tuning parameters. The choice of the tuning parameters should then be based on physical grounds. The applicability of the above-mentioned approximations is demonstrated on a number of problems: test optimization problems with analytical solution, an optimization of the dynamic behavior of a four-bar crank-shaft mechanism and a real life optimization problem of railway track design. In the letter problem the elastic properties of a track structure in turnout have been varied with the aim of reduction of the dynamic forces between wheel and rail. Effectiveness of these three types of the approximations has been investigated as well. The results of the optimization problems using the presented approximations and analysis of the approximation effectiveness are presented in the paper.

01494
Noisy Expected Improvement and On-line Computation Time Allocation for the Optimization of Simulators with Tunable Fidelity

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The use of surrogate models for facilitating optimization and statistical analysis of computationally expensive simulations has become commonplace. In particular, the kriging-based EGO algorithm and its underlying EI criterion have been recognized as efficient tools for the optimization of deterministic computer experiments. However, in mainly frameworks, such as Monte-Carlo or partially converged simulation, the simulator response departs from the actual function by an error term (noise), which prevents from using the EI criterion and the original EGO. Besides, the amplitude of this error term (or fidelity) can often be tuned by the user. For instance, if the response is obtained using Monte-Carlo simulations, the accuracy is inversely proportional to the square root of the number of MC samples. In this context, optimization strategies must address two main issues: 1) dealing with the noise in the response, which can hinder optimization convergence, and 2) making a trade-off between the fidelity of the response and the allocated computation time at evaluated points. Some heuristics have been proposed to modify EI for the case of homogeneous noisy observations, as well as for multi-fidelity simulators with a few levels of fidelity. Here we propose a quantile-based criterion which is a natural probabilistic extension of EI, enabling a rigorous treatment of continuous fidelities. The proposed variant of EI not only depends on the noise variances of past observations, but also on the fidelity of the new candidate observation. Hence, defining any sequential optimization strategy based on such a criterion allows to choose both an input space point and a fidelity level at each iteration. Here, we study a procedure that takes advantage of this additional degree of freedom. We assume that the evolution of the response is available on-line. Once an input space point has been selected, computation time is invested on it until a stopping criterion is met. One of the advantages of such procedure is that it prevents from allocating too much time to poor designs, and allows spending more credit on the best ones. Another remarkable property of this algorithm is that, unlike EGO, it takes into account the limited computational budget. Indeed, the algorithm is more exploratory when there is much budget left, and favours a more local search when running out of computational credit. The proposed quantile-based EI criterion is derived in the framework of Gaussian Processes, and compared to the classical EI and existing variants. The online allocation optimization algorithm is then tested on analytical test functions, showing a substantial improvement over constant allocation strategies. Finally, an original application in nuclear criticality safety is implemented in the Promethee workbench and applied to the Monte Carlo criticality simulator MORET5.

01507
Multi-objective optimization using surrogate functions

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Technical processes and products typically depend on many parameters which control, for instance, geometry, material and/or process parameters. The user would like to adjust these parameters easily in order to analyze product or process properties and to obtain the best design of the product or the optimal control of the production process considered. Quite often, the parameter-dependent criteria to be optimized can only be evaluated by means of resource-expensive simulations or physical experiments. Response surfaces approximating the parameter-criteria dependencies can then be used as a basis for the optimization. This task is typically solved by means of multi-objective optimization, which formulates the problem as a mapping from the space of design variables to the space of target criteria and tries to find an optimal manifold (the so-called Pareto front) in these multi-dimensional spaces. The Pareto front is a surface possessing trade-off property: none of the criteria can be improved without a simultaneous deterioration of at least one other criterion. In this sense the points on the Pareto front are better than the points outside, but they are equally optimal among each other. The problem of finding the optima of a set of vectors is reflected in the literature of a variety of application areas at least since the 1970s. It can be implemented efficiently as an exhaustive search using recursion and divide and conquer strategies. We discuss advantages and disadvantages of the approach when applying it to inexpensive evaluations of RBF-based surrogate models, and suggest an additional local optimization algorithm to cope with the specific problem of a biased distribution in objective space. If only a very small portion of the parameter space is constituted by Pareto optimal designs, a finite set of parameter evaluations cannot describe the Pareto front sufficiently well in objective space. If we additionally assume, though, that there are no local Pareto fronts near the global Pareto front, designs on the front can be found by a local algorithm starting from the result of a previous exhaustive search. As an answer we suggest a novel algorithm that produces a trajectory towards the Pareto front starting from an initial design. The trajectory is the result of the iterative solution of a linear program combined with a trust region method. Each step maximizes the minimum improvement among all objectives. We shortly discuss the proposed algorithms and their possible combinations and finally give results from empirical verification.

01518
Design optimization of multibody model of rail vehicle supported by Response Surface Method

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The process of designing a new vehicle stands for a number of analyses of different types which have to be completed. On one hand a vehicle should satisfy all requirements concerning material strength to prevent from failure resulting from fatigue etc. On the other hand it should be as light as possible to reduce power

consumption. Moreover, designed vehicle has to guarantee the stability of motion and high quality of contact cooperation between rail and wheel. Apart from already mentioned purely technical aspects of the design, responsible for both fast and save travel, there should be also of engineer's concern the quality of travelling assessed from passenger's point of view. In the paper the task of design optimization of a rail vehicle is described. The coefficient of travel comfort is considered to be optimized. As an object of analysis the multibody model of a five-wagon tram is used. It is parameterized to allow variations in masses of structural elements as well as stiffness coefficients of suspension systems. The acceleration measured in selected localizations is used to calculate the coefficient of travel comfort. The task of design optimization may require many configurations of a model to be simulated. It happens especially in a case when relationships between input, i.e. design, and output, i.e. being optimized, parameters are non-monotonic and therefore fast gradient-based methods cannot be effectively applied. The application of Response Surface Method may be a solution to define variation of optimized entities by the introduction of metamodels. Approximating techniques also allow for the sensitivity analysis and help to search for the most influential design parameters which should be taken into account in the optimization as well as to find the least influential ones which, in turn, can be neglected. In the work the results of a limited number of numerical analyses performed for multibody model have been used to elaborate metamodels describing the comfort index. Large number of metamodels with different regressors have been considered to represent optimized parameter. Genetic algorithms have been applied to choose the best approximation. Finally, elaborated metamodels have been used to conduct the optimization task, again with the application of genetic algorithms. Obtained design, which characterizes improved coefficient of travel comfort, has been verified with the outcomes of multibody analyses. In the paper there have been also presented and compared the results of uncertainty analyses performed for both evaluated metamodels and multibody model of the tram. The work was supported by the Polish Grant no. NN 509353934 The elaboration of optimization method of design of rail vehicles with introduced uncertainties.

01533
Review of Efficient Surrogate Infill Sampling Criteria with Constraint Handling

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This paper discusses the benefits of different infill sampling criteria used in surrogate-model-based constrained global optimization. Here surrogate models are used to approximate both the objective and constraint functions with the assumption that these are computationally expensive to compute. The construction of these surrogates (also known as meta models or response surface models) involves the selection of a limited number of designs, evaluated using the original expensive functions. Conventionally this involves two stages. First the surrogate is built using an initial sampling plan; the second stage uses infill sampling criteria to select further designs that offer model improvement. This paper provides a comparison of three different infill criteria previously used in constrained global optimization problems. Particular attention is paid to the need to balance the needs of wide ranging exploration and focussed exploitation during global optimization if good results are to be achieved.

Continuous Optimization

10

01024
A procedure improving interior point algorithm for the convex optimization

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In this paper we propose a new shape of algorithm to solve a convex programming by interior point methods of central trajectory type. This method consists in remaining in a certain vicinity of the central trajectory by using Newton iterations. We present in this paper a procedure of initialization for this kind of the problems which is a dificulty major of this type of the methods and a numerical study of the methods of central trajectory by introducing the parameter of weight to take into account the problem of initialization and to more improve the numerical behavior of the interior methods of points. The technique of resolution used appears very significant from the efectiveness point of view and algorithmic simplicity as well as theoretical complexity is much reduced compared to the methods of resolutions recently used.

01092
Numerical Simulation Of Contact Problems Under Large 3D Elastoplastic Deformation

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In this work news simulations using optimization procedures of 3D contact problems with friction in solid mechanics are presented. The bodies in contact undergo finite deformation within an elastoplastic range. A brick element based on a compressible elastoplastic material is applied in the numerical examples. The augmented Lagrangian method is used to solve the contact problems. For the contact formulation within the finite element method, the matrix formulation for a node-to-surface element consisting of a master surface with four nodes and a contacting node is derived. Here, the discretised contact surfaces are not smooth, i.e. there is no continuity of the normal vector between the adjacent surfaces. At the edge between the surfaces the normal is not uniquely defined. That needs a special algorithmic treatment. When one slave node is sliding from one surface to the adjacent one, the node-to-surface contact formulation is not sufficient to solve the contact problems. Then, for the special cases the node-to-edge and node-to-node contact formulations are employed, see Bandeira et al. (2005). The purpose of this paper is to present numerical examples using the formulation of contact mechanics and the elastoplasticity algorithm for large 3D deformation, considering the possible sliding of slave node from one surface to the adjacent one. The formulation is derived based on exact linearization. Several numerical examples for contact problems in elastoplastic range are presented.

01141
A Tricriterion Load Sharing Approach for a Multidimensional Erlang-C System

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The dimensioning of a telecommunication network is a highly complex problem which implies the extensive use of decompositions of the associated large-scale optimization problems. This is further complicated by the stochastic nature of the teletraffic flows to be carried by the arcs of the network. All these requirements lead to a very significant number of interrelated optimization problems and sub-problems which may be approached with different formulations. In this talk we examine the general issue of optimal selection of a routing algorithm in the context of network synthesis, where the performance is to be optimized for a given stationary input. The network is seen as a multidimensional Erlang-C system, since each alternative path is modeled as a M/M/n delay service group. The problem is focused on the optimal load-sharing (of a certain offered traffic assumed as Poissonian in nature), between alternative paths in the network. In practice three main objectives are present in this formulation. Firstly an efficiency criterion requires the total number of waiting calls in the system, to be minimized. On the other hand, a criterion of uniformity in the grade of service measured by the mean waiting time, entails that the absolute difference between the mean waiting times experienced by the calls in the different service groups must be as small as possible (ideally it should be zero). A third criteria is very popular in queueing systems synthesis: the minimization of the proportion of calls which must wait more than a specified limit time. The optimization problem may be seen as a tricriterion convex separable continuous problem. Some mathematical results characterizing the set of the nondominated solutions of the tricriteria formulation, are present. An algorithm for traveling on that set is presented based on the resolution of monocriteria convex problems using Newton-Raphson method, is proposed. Some numerical and graphical results are also presented. Finally, possible advantages of the tricriterion formulation of the problem and its implications on transmission system optimization models, are discussed.

01144
Fractional Multiobjective Variational Problems

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The Fractional Calculus (FC) is one of the most interdisciplinary fields of mathematics, with many applications in physics and engineering. The history of FC goes back more than three centuries, when in 1695 the derivative of order $\alpha=1/2$ was described by Leibniz. Since then, many different forms of fractional operators were introduced: the Grunwald-Letnikov, Riemann-Liouville, Riesz, and Caputo fractional derivatives, and the more recent notions of Klimek, Cresson, and Jumarie. FC is nowadays the realm of physicists and mathematicians, who investigate the usefulness of such non-integer order derivatives and integrals in different areas of physics and mathematics. It is a successful tool for describing complex quantum field dynamical systems, dissipation, and long-range phenomena that cannot be well illustrated using ordinary differential and integral operators. Applications of FC are found in classical and quantum mechanics, field theories, variational calculus, and optimal control. The Fractional Calculus of Variations (FCV) started in 1996 with the work of Riewe. Riewe formulated the problem of the calculus of variations with fractional derivatives and obtained the respective Euler-Lagrange equations, combining both conservative and nonconservative cases. Nowadays the FCV is a subject under strong research. Different definitions for fractional derivatives and integrals are used, depending on the purpose under study. Investigations cover problems depending on Riemann-Liouville fractional derivatives, the Caputo fractional derivative, the symmetric fractional derivative, the Jumarie fractional derivative, and

others. Although the literature of FCV is already vast, much remains to be done. Knowing the importance and relevance of multiobjective problems of the calculus of variations in physics and engineering, it is at a first view surprising that a multiobjective FCV is a completely open research area. The main aim of the present work is to introduce a multiobjective FCV. For that we make use of the Caputo fractional derivative, extending such notions to the fractional derivative operator (α,β) which is a convex sum of the left Caputo fractional derivative of order α and the right Caputo fractional derivative of order β. The fractional variational problems under our consideration are formulated in terms of the fractional derivative operator (α,β). We discuss the fundamental concepts of a variational calculus such as the Euler--Lagrange equations for the basic, Lagrange and isoperimetric problems. Next, we consider fractional multiobjective variational problems. To the best of the authors knowledge, no study has been done in this field before. The main results of the paper provide methods for identifying Pareto optimal solutions. We show that the necessary and sufficient conditions for Pareto optimality are obtained converting the fractional multiobjective variational problem into a single or a family of single fractional variational problems with an auxiliary scalar integral functional, possibly depending on some parameters. We end with the section of applications and future perspectives.

01169
Assessment of a hybrid multi-objective pattern search filter method

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A hybrid multi-objective evolutionary algorithm (MOEA) for solving nonlinear multi-objective optimization problems that relies on a pattern search filter method is proposed. The aim is to reduce the computational time involved in solving expensive multi-objective problems by improving a subset of Pareto points. The proposed pattern search filter method relies on two components. Each entry in the filter aims to measure feasibility and optimality. The feasibility and optimality come directly from each single-objective nonlinear program problem that is associated to the multi-objective problem. Experiments carried out with a set of nonlinear multi-objective problems show that our pattern search filter approach is effective in reaching improved Pareto points. A comparison with other techniques known in the literature is presented.

01177
An SQP Interior Point algorithm for solving large scale nonlinear optimization problems

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We propose a numerical algorithm for solving large scale smooth nonlinear programming problems. The algorithm is based on an SQP method where the quadratic subproblem is solved by a primal-dual interior point method. A feature of the algorithm is, that the quadratic subproblem is not necessarily solved exactly. We prove convergence for a wide range of variations reaching from an ordinary SQP mode, where the quadratic subproblem is solved exactly to an interior point method for nonlinear programming, where only one iteration is applied to each quadratic subproblem. To be able to solve large problems we can either use a limited memory BFGS update to approximate the Hessian of the Lagrangian or use the exact and possibly sparse Hessian. Numerical results are included for some elliptic control problems by Maurer and Mittelmann with over 5 million variables and 2.5 million constraints. We plan to add the results of some real world problems, too. This work is funded by EADS.

01193
A non-classical class of variational problems

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We study a new non-classical class of variational problems that is motivated by some recent research on the non-linear revenue problem in the field of economics. This class of problem can be set up as a maximising problem in the Calculus of Variations (CoV) or Optimal Control. However, the state value at the final fixed time, y(T), is a priori unknown and the integrand is a function of the unknown y(T). This is a non-standard CoV problem. We solve an example in this problem class using symbolic algebra software.

01195
Hybridization of a Genetic Algorithm with a Pattern Search Augmented Lagrangian Method

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Genetic algorithms as most population based algorithms are good at identifying promising areas of the search space (exploration), but less good at fine-tuning the approximation to the minimum (exploitation). Conversely, local search algorithms like pattern search are good at improving the accuracy of that approximation. Thus, a promising idea is combining local and global optimization techniques. We propose a new hybrid genetic algorithm based on a local pattern search that relies on an augmented Lagrangian function for constraint-handling. In this study, we test different hybridization schemes concerning population-handling, as well as local search refinements for a better point. We use performance profiles as proposed by Dolan and Moré in 2002 and a benchmark set of global problems to evaluate the effect of the proposed hybrid algorithms. Population size effect on the algorithm is also assessed.

01197
Application of a maintenance model for optimizing tamping on ballasted tracks: the influence of model constraints

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When performing track maintenance, tamping is the measure usually adopted to correct the longitudinal profile, which is the geometrical parameter that most influences vehicles and tracks dynamics in the

vertical direction. That is why several documents define limits for track quality, taking into account both safety and comfort aspects. This paper presents an application of a developed model for scheduling tamping on ballasted tracks that takes into account the evolution over time of the track degradation, the track's layout, the dependency of track quality recovery on track quality at the moment of maintenance operations and also the track quality limits that depend on train speed. All these aspects are considered in a mathematical programming through suitable constraints, which can be formulated as a mixed 0-1 nonlinear problem. In the present work, the influence of track layout and track quality recovery in scheduling tamping is analysed.

01198
A Deterministic-Stochastic Method for Non-convex MINLP Problems

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A mixed-integer programming problem is one where some of the variables must have only integer values. Although some real practical problems can be solved with mixed-integer linear methods, there are problems occurring in the engineering area that are modelled as mixed-integer nonlinear programming (MINLP) problems. When they contain non-convex functions then they are the most difficult of all since they combine all the difficulties arising from the two sub-classes: mixed-integer linear programming and non-convex nonlinear programming (NLP). Efficient deterministic methods for solving MINLP are clever combinations of Branch-and Bound (B&B) and Outer-Approximations classes. When solving non-convex NLP relaxation problems that arise in the nodes of a tree in a B&B algorithm, using local search methods, only convergence to local optimal solutions is guaranteed. Pruning criteria cannot be used to avoid an exhaustive search in the solution space. To address this issue, we propose the use of a simulated annealing algorithm to guarantee convergence, at least with probability one, to a global optimum of the non-convex NLP relaxation problem. We present some preliminary tests with our algorithm.

01226
A Feasible Sequential Convex Programming Method

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In many real world optimization problems, model functions can only be evaluated on a special subset F of the feasible region which is described by additional nonlinear constraints. To ensure feasibility with respect to this subset, it is required that all iterates of an optimization algorithm retain strictly feasible while all the other constraints may be violated during the iteration process. We propose a modification of a sequential convex programming (SCP) method which ensures that the solutions of all subproblems stay in the subset F. The general idea of SCP is to generate a sequence of strictly convex and separable subproblems, where an augmented Lagrangian merit function is applied to perform a line search and to guarantee convergence from arbitrary starting points. In our proposed modification, the resulting

subproblems are expanded by additional constraints, describing F, to guarantee feasibility with respect to this subset in each iteration step. The algorithm is introduced and some numerical examples from Free Material Optimization are presented.

01271
Embedding a Competitive Ranking Method in the Artificial Fish Swarm Algorithm for Global Optimization

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Nonlinear programming problems are known to be difficult to solve, especially those that involve a multimodal objective function and/or non-convex and at the same time disjointed solution space. Heuristic methods that do not require derivative calculations have been used to solve this type of constrained problems. The most used constraint-handling technique has been the penalty method. This method converts the constrained optimization problem to a sequence of unconstrained problems by adding, to the objective function, terms that penalize constraint violation. The selection of the appropriate penalty parameter value is the main difficulty with this type of method. To address this issue, we use a global competitive ranking method. This method is embedded in a stochastic population based technique known as the artificial fish swarm (AFS) algorithm. The AFS search for better points is mainly based on four simulated movements: chasing, swarming, searching, and random. For each point, the movement that gives the best position is chosen. To assess the quality of each point in the population, the competitive ranking method is used to rank the points with respect to objective function and constraint violation independently. When points have equal constraint violations then the objective function values are used to define their relative fitness. The AFS algorithm also relies on a very simple and random local search to refine the search towards the global optimal solution in the solution space. A benchmarking set of global problems is used to assess this AFS algorithm performance.

01280
Comparative Study of Penalty Simulated Annealing Methods for Multi-local Programming

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In a multiglobal optimization problem we aim to find all the global solutions of a constrained nonlinear programming problem where the objective function is multimodal. This class of global optimization problems is very important and frequently encountered in engineering applications, such as, process synthesis, design and control in chemical engineering. The most common method for solving this type of problems uses a local search method to refine a set of approximations, which are obtained by comparing objective function values at points of a predefined mesh. This type of method can be very expensive numerically. On the other hand, the success of local search methods depends on the starting point being at the neighbourhood of a solution. Stochastic methods are appropriate alternatives to find global solutions, in which convergence to a global solution can be guaranteed, with probability one. This is the case of the simulated annealing (SA) method. To compute the multiple solutions, a function stretching technique that transforms the objective function at each step is herein combined with SA to

be able to force, step by step, convergence to each one of the required global solutions. The constraints of the problem are dealt with a penalty technique. This technique transforms the constrained problem into a sequence of unconstrained problems by penalizing the objective function when constraints are violated. Numerical experiments are shown with three penalty functions. This is a joint work with Edite M.G.P. Fernandes.

01282
The influence of control parameter costs in a dynamic epidemic model

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Dengue is a disease predominantly found in tropical and sub-tropical climates, mostly in urban and semi-urban areas. According to the World Health Organization, the incidence of dengue has drastically grown in recent decades and about two fifths of the world's population are now at risk. Humans are contaminated through mosquitoes, mainly by the aedes aegypt, but only the female mosquitoes acquire dengue from an infected human. People not only provide the mosquitoes with blood meals but also nutrients needed to reproduce through water-holding containers in and around the home. The dynamic model presents a set of nonlinear ordinary differential equations and an objective function in order to minimize government investment in fighting the disease. Total investment consist in costs to break the reproduction cycle of the mosquitoes, such as the application of insecticide, in the educational campaigns and also in costs related with human health issues. The goal of this paper is to use optimal control approach to evaluate the effectiveness of the controls. Tuning the parameters of associated costs, different results are reported. Depending on relative weight of the controls, numerical results show that different strategies to fight the disease could be used. Consequently, it is shown that government investment is influenced by the manipulation of these parameters. A numerical package for dynamic optimization with real data taken from the recent outbreak of dengue disease in Cape Verde in 2009 was used.

01357
Muscle Control Model for Postural Stabilization Based on State-Dependent Riccati Equation

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The biomechanic model of a human musculoskeletal system and the simulation of behavior in movement can be applyed in several areas, such as sports, engineering and medicine. The purpose of this work is obtain a dynamic and control model that represents a musculoskeletal system of a human posture. The description of kinematic and dynamic links movements is based on Newton-Euler and Euler-Lagrange formulation. The resulting movements are produced by sets of force actuators muscle-tendinideous.

These dynamic models are non-linear with multiples input and output and many degrees of freedom. This results in many difficulties in the determination of parameters like forces and moments. In this paper, it was used a control based on state dependent Riccati equation theory. A geometric model for simulations is obtained with Matlab/Simulink software. This model allows simulations of postural control.

01367
The Ellipsoid Covering problem: an Continuous Approach

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This paper presents an application of Signomial Geometric Programming to solve the problem of configuration a machine for Gamma Rays. This type of machine is used to treat tumors. The treatment consists in to bombard a tumor shaped like an ellipsoid with portions of radiation similar to spheres with pre-defined radii, some care must be taken during treatment to minimize the amount of radiation and to attain the lowest numbers of healthy cells possible. To achieve this goal we must bear in mind the following strategy: apply enough radiation in all parts of the tumor and attain the lowest number of healthy cells. To solve this problem we have to write it as a Discrete Signomial Geometric Programming problem. At first, we solve a continuous relaxation of this problem using a technique known as condensation method jointly with a primal dual interior point method, at second place we use one of Branch and Bound method to determine the discrete solution of the problem. Computational results are presented using some examples from the literature.

01375
A Global Optimization Stochastic Algorithm for Head Motion Stabilization during Quadruped Robot Locomotion

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Visually-guided locomotion is important for autonomous robotics. However, there are several difficulties, for instance, the robot locomotion induces head shaking that constraints stable image acquisition and the possibility to rely on that information to act accordingly. In this work, we propose a combined approach based on a controller architecture that is able to generate locomotion for a quadruped robot and a genetic algorithm to generate head movement stabilization. The movement controllers are biologically inspired in the concept of Central Pattern Generators (CPGs) that are modelled based on nonlinear dynamical systems, coupled Hopf oscillators. This approach allows to explicitly specify parameters such as amplitude,

offset and frequency of movement and to smoothly modulate the generated oscillations according to changes in these parameters. Thus, in order to achieve the desired head movement, opposed to the one induced by locomotion, it is necessary to appropriately tune the CPG parameters. Since this is a non-linear and non-convex optimization problem, the tuning of CPG parameters is achieved by using a global optimization method. The genetic algorithm searches for the best set of parameters that generates the head movement in order to reduce the head shaking caused by locomotion. Optimization is done offline according to the head movement induced by the locomotion when no stabilization procedure was performed. In order to evaluate the resulting head movement, a fitness function based on the Euclidian norm is investigated. Moreover, a constraint handling technique based on tournament selection was implemented. Experimental results on a simulated AIBO robot demonstrate that the proposed approach generates head movement that reduces significantly the one induced by locomotion.

01376
Algorithmic strategies for the recognition of graphs with convex quadratic stability number

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A stable set of a graph is a set of mutually non-adjacent vertices. A maximum stable set is a maximum size stable set and its size is called the stability number of the graph. Graphs whose stability number is equal to the optimal value of a convex quadratic problem are called graphs with convex quadratic stability number or graphs with convex-QP stability number. A major difficulty in the recognition of graphs with convex quadratic stability number is the existence of adverse subgraphs (an adverse subgraph is a subgraph such that the smallest eigenvalue of its adjacency matrix doesn't change when any vertex is deleted nor when the neighbourhood of any vertex is deleted). It is still a challenge to find out adverse graphs without convex quadratic stability number. In this work, we present the main results about graphs with convex quadratic stability number including some conclusions about the existence of adverse subgraphs with convex-QP stability number in graphs of certain families.

01378
Continuous nonlinear optimization of crude oil operations in refinery scheduling

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Refinery scheduling is modeled as a continuous nonlinear programming problem, considering crude oil operations from tankers to crude distillation units. Yes-No decisions are modeled as complementarity constraints, without binary variables. The refinery infrastructure is modeled as a graph, with equipment as nodes and connections as arcs. Each connection can have a transfer operation flow which is mapped as a continuous variable. Recent examples from the literature, based on actual refineries, are solved.

01445
A feasible direction interior point algorithm for nonlinear semidefinite programming

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Semidefinite programming (SDP) deals with the minimization of an objective function subject to a semidefinite constraint on a symmetric matrix-valued function. When either the objective function or the constraint matrix function is nonlinear we are considering a nonlinear SDP problem. This contribution describes a feasible direction technique for this class of nonlinear problems. The algorithm performs Newton-like iteration based on the first order Karush-Kuhn-Tucker conditions. In all iterations, two linear system with the same coefficient matrix must be solved. The first linear systems generate a descent direction. In the second linear system, a precisely perturbation in the left hand side is done, and as a consequence, a feasible and descent direction is obtained. In order to hold the next point in the interior region, a linear search is performed along the feasible direction. Some numerical results are shown for nonlinear semidefinite programs coming from Free Material Optimization problems.

01446
On the ellipsoidal core for cooperative games under ellipsoidal uncertainty

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This paper deals with the ellipsoidal core for cooperative ellipsoidal games, a class of transferable utility games where the worth of each coalition is an ellipsoid instead of a real number. Ellipsoids are a suitable data structure whenever data are affected by uncertainty and there are some correlations between the items under consideration. In the real world, noise in observation and experimental design, incomplete information, vagueness in preference structures and decision making are common sources of uncertainty, besides technological and market uncertainty. It is often easy to forecast ranges of values for uncertain data. Nevertheless, the representation of data uncertainty in terms of ellipsoids is more suitable than the error intervals of single variables since ellipsoids are directly related to covariance matrices. The ellipsoidal core has been recently introduced by Weber, Branzei and Alparslan Gok to answer the important question ``How to deal with reward/cost sharing problems under interval uncertainty?". Here, we study properties of this solution concept, relate it with the interval core for cooperative games whose characteristic functions are interval-valued,and present conditions for the non-emptiness of the ellipsoidal core of a cooperative ellipsoidal game.

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Concepts for Accelerating Pareto Front Convergence

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01104
Multi-objective Analysis for Mixed-model Assembly Line Using Elite-induced PSA

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Diversified customer demands are raising importance of just-in-time and agile manufacturing much more than before. Accordingly, introduction of mixed-model assembly lines becomes popular to realize the small-lot-multi-kinds production. Since it produces various kinds of product on the same assembly line, a rational management of sequencing becomes of special importance. With this point of view, this study focuses on a sequencing problem of mixed-model assembly line that is operated under continuous and leveling production and includes a lot production line as its preceding process. Such a production configuration is very popular in many manufacturing systems, e.g., paint line and mixed-model assembly line in car industry. By taking into account such heterogeneous production lines together, reducing work-in-process (WIP) inventory between these lines becomes a major concern of the sequencing problem. Though the WIP inventory can absorb serious defects caused by various deviations occurring in actual production, it will increase the operating cost and production lead time in turn. On the other hand, to increase production efficiency is another supreme goal for many industries. Noticing these facts, we formulate the sequencing problem as a bi-objective optimization problem to prevent various line stoppages, and to reduce volume of the WIP inventory simultaneously subject to certain production conditions. It becomes extremely important to reveal certain trade-off relation or to engage in the multi-objective analysis for decision making. To work with this problem, we previously compared the performance among the several traditional methods of multi-objective analysis and a new multi-objective evolutionary approach like PSA (Pareto simulated annealing). Then, through numerical experiments, we showed the weighting method accompanied with usual simulated annealing outperformed PSA and other traditional methods. Rely on this fact, we propose a new method termed Elite-induced PSA. After revealing the advantages and disadvantages of those methods, the idea is deployed so that it can make use of the advantages of PSA and the weighting method while removing shortcomings of these methods. By applying thus developed method from the weighting method and PSA, a set of solutions can move fast at the edge of the Pareto front and spread widely thereat. In addition, it also enables us to freely control the resulting set according to the intent of decision maker. In the method, the generated elite solutions will play a major role for properly inducing solutions in the course of iteration. Here, the elite solution is a Pareto optimal solution (could be ideally) with the specific property of preference of decision maker. They are prepared easily by using the weighting method, and involved in the sub set of initial population of PSA. Finally, we will validate numerically the effectiveness of the developed method through case study.

Free Material Optimization

12

01055
Optimal orientation of anisotropic material with given Kelvin moduli in FMO problems for plates and shells

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In this work we investigate the compliance minimization problem of a transversely homogeneous plate, subjected to the in-plane and transverse loadings acting simultaneously. More precisely, we are interested in finding the optimal orientation of the proper states of a Hooke tensor (i.e. second-rank eigentensors of a fourth-rank elastic constitutive tensor) whose Kelvin moduli values are kept fixed on the middle plane of a structure. The principal feature of a case under study is that the design variables are not restricted by any isoperimetric condition. As a result of this formulation, the optimization task is reduced to an equilibrium problem of an effective hyperelastic plate with strictly convex effective potential expressed in terms of strains. Another important point to note here is that although the hyperelastic potential of the optimal structure is nonlinear, the corresponding constitutive equations are analytically and explicitly derived which leads to determining all membrane and bending components of the optimized stiffness tensor. Optimization problems of this kind, called free material optimization (FMO) or free material design design (FMD), date back to the work of M.P. Bendsoe et al. (1994), ''An analytical model to predict optimal material properties in the context of optimal structural design'', in: J. Appl. Mech. Trans. ASME, vol. 61, pp. 930-937, and still are subject to intensive research, see e.g. M. Kocvara, M. Stingl, J. Zowe (2008), ''Free material optimization: recent progress'', in: Optimization, vol. 57, pp. 79-100. Our purpose is to generalize the considerations presented in the above mentioned papers to the coupled membrane-bending loading case, hence the new formulae may be useful in obtaining solutions to FMD optimization problems of a broader class. Results of the research presented in our paper are independent of another task formulated in the framework of FMD, i.e. the optimal valuing of Kelvin moduli fields treated as design variables restricted by some isoperimetric condition. Nevertheless, it seems that our approach offers a deeper insight into the mathematical structure of the optimal stiffness tensor and enables formulating the complete FMO problem from a different point of view. Consequently, one may propose the alternative version of FMO, with new isoperimetric conditions imposed on Kelvin moduli.

01078
Asymptotic expansion homogenisation of topology optimisation unit-cells

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The multiscale and hierarchical approach to topology optimisation often uses homogenisation methods to evaluate microscale optimisation results and provide useful properties for the macroscale optimisation problem. One of these methods is the Asymptotic Expansion Homogenisation (AEH). In AEH, the geometry and material distribution are evaluated over a periodic Representative Unit-Cell (RUC). The behaviour of the RUC leads to a representative set of material properties or constitutive matrices. In this work the authors present the details of the prediction of material properties taken from the results of

the microscale topology optimisation of periodic media. Material properties and constitutive matrices are analysed over a set of RUC for thermoelasticity problems for distinct densities and under different load cases, evaluating the effective behaviour of the obtained materials in terms of elasticity, thermal conductivity and thermal expansion. Moreover, the eigendeformations of the RUC are also determined for two and three-dimensional cases using a dedicated FEA platform developed by the authors, which enables the modelling of the thermoelastic behaviour of structural components built from cellular and composite periodic materials. This platform is also capable of solving multiscale topology optimisation problems, for distinct types of finite elements and problem settings.

01120
Composite Material Design of One and Two-Dimensional Structures Using the Variational Asymptotic Method for unit Cell Homogenization

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Composite materials of one-dimensional and two-dimensional dimensions are designed using the variational asymptotic method for unit cell homogenization. The variational asymptotic method for unit cell homogenization is used to find the sensitivity of the effective properties of periodically heterogeneous materials, within a periodic base cell. The sensitivities are found by the adjoint variables method. The composite material is made of two different material phases. Designing the composite material consists of finding a distribution of material phases that minimizes a criterion defined over the macrostructure domain subjected to volume fraction constraints of the constituent phases, within a unit cell of periodic microstructures. The effective material properties of the artificially mixed materials are defined by the interpolation of the constituents. The optimization problem is solved using the method of moving asymptotes (MMA). Both the macrostructure and the microstructures are analysed using the finite element method in each iteration step. Several examples of optimal topology design of composite material are presented to demonstrate the validity of the present numerical algorithm.

01122
Finding the elastic coefficients of a damaged zone in a concrete dam using material optimization to fit measured modal parameters

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The structural safety control of large dams is based on the continuous observation of its behavior under static and dynamic actions and on the use of mathematical models for the simulation of the real dam behavior. These mathematical models should be calibrated taking into account the real behavior of the system dam-reservoir-foundation. In this paper the dynamic behavior of a cracked arch dam - Cabril dam - is studied by means an elastic 3D FE model that was calibrated using an optimization technique for the computation of the main elastic parameters that must be used for the cracked zone in order to fit the experimentally measured modal parameters (natural frequencies and modes of vibration). The Cabril dam is an interesting case study because a large number of cracks have arisen in a specific part of the dam since the beginning of its operations in 1954. These cracks have remained even after reparation works done in 1981. The free vibrations of

the dam are continuously measured by a dynamic monitoring system installed in 2008. The values of the measured natural frequencies and modes are used in our approach. Since the cracks are mainly disposed in the horizontal direction, a transversely isotropic constitutive law is chosen to model the damaged zone of the dam, having the plane of symmetry coincident with the plane of the cracks, The rest of the dam and the adjacent valley are modeled using an isotropic constitutive law. The transversely isotropic constitutive law is characterized by five independent elastic constants. For two of them, corresponding to the plane of symmetry the standard values of the concrete can be used, as done for the isotropic constitutive law of the undamaged part of the dam. The other three constants remain unknown. The goal of the present work is to find an approximation of these three values by solving an inverse problem: given the knowledge of the first natural frequencies and modes of vibrations of the dam, we will search for elastic constants such that the solutions of the corresponding eigenvalue problem are the closest to the given frequencies and modes. More precisely, the eigenvalue problem associated to the linear elasticity problem is considered with both Neumann and Dirichlet zero boundary conditions. The solutions of the eigenvalue problem (natural frequencies and modes of vibrations) depend on the five elastic constants characterizing the transversely isotropic law. We consider two parametric optimization problems in the form of least squares approximations involving the first three (physically measured) natural frequencies and modes of vibration of the dam. Steepest descent method is employed to solve this minimization problems. It makes use of the derivatives of the natural frequencies and modes of vibration with respect to the optimization parameters. This approach is typical to the field of free material optimization, where the elastic moduli are the variables to be optimized to satisfy some functional cost. The FEM is used for solving numerically the problem. The whole algorithm is implemented in C++ using the open-source library libMesh.

01199
Properties of cost functionals in free material design

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We study several properties of integral functionals arising in free material optimization as cost functions. The framework could be that of linearly elastic solids, but for simplicity of the presentation we consider scalar equations that model other physical phenomena such as heat or electrical conductivity (thus making the dependance of the cost functions less complicated - a matrix variable instead of an elastic tensor variable). The identification of adequate cost functions is essential to any optimization problem and the purpose of the talk is to establish a class of such admissible functions, covering both practical and theoretical aspects. Natural properties deriving from mechanical considerations (such as isotropy and monotonicity) are imposed. The study focuses on two main properties: subadditivity and lower semicontinuity. Subadditivity is a requirement emerging from the practical observation that by superimposing two materials (which corresponds to the sum of the material coefficients) one should obtain a material whose cost is lower than or equal to the sum of the costs of the two base materials. However, the mathematical characterization of this property is a difficult problem. The lower semicontinuity of the cost function (together with the compactness of the design space) ensures the well-posedness of the optimization problem. This latter aspect raises the question of what notion of convergence should one consider in the design space, a problem often mistreated in the literature, usually by means of introducing a topology that, despite being mathematically sound, does not reflect well the physical reality. It is known for several years that the good notion is that of H-convergence, under which we develop our analysis. The lower semicontinuity of the cost functional is related (but not equivalent) to the convexity of the integrand. A particular functional emerging from the homogenization theory, equal to the minimum amount of material needed to build a certain composite, is given special attention and its relevancy is discussed regarding subadditivity and lower semi-continuity.

01440
Micro-structure tailoring for desired material property

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Composite materials have found widespread application in structural application. High strength to weight ratio, good corrosion and fatigue resistance and the ability to tailor material properties to suit design goals have made them "the material of choice". The ability to tailor material properties has come as a boon to aerospace industry in particular. This has enabled complex and demanding structural designs like forward swept. Till now the structural tailoring has focused on orientating laminae at different angles to obtain desired material properties and coupling effects. In this work, the concept of "micromechanical tailoring" has been introduced, which enables on to obtain desired material properties at lamina level. A previous study by the authors [1] on randomness of composite structures has shown high level of randomness in material constants of composites due to variation in fiber diameter and variation in fiber location. The above study also indicated that the randomness in material properties are more dependent on positioning of fiber than on their diameter. In this work, different arrangements of fibers have been studied. Material properties have been obtained using finite element analysis for these arrangements. The results give different sets of material constants. These fiber arrangements are now varied to obtain the desired set of material constants. For this optimality study, ANSYS design optimization tool box has been used. The analysis shows that with variations in fiber location alone, the designers have a wide choice of different combinations of material properties.

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01527
Solving minimum weight problems for 2D structures with thickness and material design variables

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This contribution proposes a numerical technique to obtain lighter planar structures subject to local mechanical constraints. We consider a structured finite element mesh. For a given element, the design variables could be the thickness, the components of the elasticity matrix or both. As constraints, we take into account positive principal minors of the elasticity matrix and von Mises stress or nodal displacement. We propose an interior point procedure to solve the problem based on Newton-like iteration. The algorithm starts with an initial point at the interior of the feasible region. At each iteration, it computes a descent and feasible direction for the nonlinear problem. To maintain the next iterate inside of the feasible set, in the line search we check if all the principal minors of the elasticity matrices are positive. We use two optimization models. The first model, minimizes the sum of traces of the elasticity matrices, freezing the thickness of all elements to a constant value. The second one minimizes the volume of the structure leaving the thickness of each element as design variables. We solved numerical problems with more than two hundred thousand nonlinear constraints and design variable.

Recent Developments in Inverse Problems and Optimization with Applications in Petroleum Engineering

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01037
SPSA and Other Non-Adjoint-Based Optimization Algorithms

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Because of the lack of adjoint capability in commercial reservoir simulators, there is significant interest in the petroleum industry in developing optimization algorithms for history matching and production optimization that do not require an adjoint-gradient. We discuss such algorithms with our main focus on a new implementation of a modified simultaneous perturbation stochastic approximation (SPSA) algorithm for automatic history matching. We show this SPSA algorithm represents an approximation of the gradual deformation method but has desirable properties that gradual deformation methods do not have. The new SPSA algorithm is applied to the PUNQ-S3 reservoir model to generate a maximum a posteriori (MAP) estimate and for uncertainty quantification of reservoir performance predictions using the RML method. The results obtained are compared with those from other history matching algorithms.

01068
Using Control Cycle Switching Times as Design Variables in Optimum Waterflooding Managament

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In Oil Reservoir Engineering applications one problem of great interest is the dynamic optimization of production scheduling, considering constraints at platform´s total rate. The waterflooding optimal management problem, which is by far the most commonly used method to improve oil recovery, is studied here. The objective is to maximize the economic return of the field using as controls the rates of injector and producer wells. Usually the concession period is subdivided into a number of control cycles, whose switching times are fixed in time, and using as design variables the well rates in each cycle. In this work the times of switching control cycles are variable. This greatly increases flexibility in management which leads to a decrease in the total number of variables for the same recovery efficiency. As the numerical simulation has high computational cost it cannot be directly coupled to the optimization algorithm. In this work we use kriging data fitting approximation approach to overcome the abovementioned problem. From a proper choice of a design of experiments (DOE) scheme, followed by the evaluations of the true (high fidelity) function at the samplings, a kriging predictor is built in order to evaluate the functions at untried points during the optimization algorithm iterations. The local optimization algorithm of choice is the sequential quadratic programming (SQP). This will be embedded here in an interactive procedure, named sequential approximate optimization (SAO). A trust region based method is used to update the design variable space for each local (subproblem) optimization solution (SAO iteration). The present work compares the solutions obtained when using different strategies for the definition of design variables in the dynamic optimization of production scheduling. Constraints at platform´s total rates for different situations in which constraint on bottom hole pressure at producer wells is activated or not, are considered. Full capacity operation solutions, where both injection and production lines are operated at their limit capacities, are compared with more flexible operational constraints, where some well may be closed before the end of the concession period.

01069
Water Flooding Management Through the Combination of Global and Local Optimization Strategies

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Water flooding in reservoir Engineering is one of the most common used method to improve oil recovery after primary depletion. The management of the field can be formulated as an optimization problem in which the rates in the producers and injectors wells are to be obtained fulfilling specific constraints. For this particular problem a commonly used objective function is the Net Present Value (NPV) of the field. Each particular design will require a complete reservoir simulation which may turn the optimization task in a very time consuming process. In order to ameliorate such drawback, approximation methodologies are commonly used to build surrogate models to be used in substitution of the numerical reservoir simulations. The optimization problem described above presents multimodal characteristics which would be adequate to solve considering a global optimization strategy. As natural choices for this type of solution emerges the class of evolutionary algorithms such as genetic algorithm (GA), smarms methodologies among others. In general such algorithms, present fast convergence at initial stages of global search, but in the neighborhood of the global optimum, the search process becomes very slow. To overcome that, mathematic programming algorithms would be ideal to be combined with global strategies as they provide very fast convergence around a pre specified initial point. The resulting combination will provide a balance between a global search process and the efficiency of a local process. In this sense the combination of global and local algorithms appears as a promising strategy to solve the dynamic optimization of water flooding management problem, as a computational reduction cost can be obtained without comprising the global search properties. An optimization tool is built combining GA algorithms and the sequential approximate optimization (SAO) methodology in which the sequential quadratic programming (SQP) is the algorithm of choice. Kriging technique is considering for metamodel construction. A case study is analyzed considering the proposed strategy in which different constraints are imposed at the wells.

01113
Application of Optimization Algorithms in Perforating Procedures of Oil Wells

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The perforating process is a significant step in the construction phase of oil wells. The procedure consists in using shaped explosive charges to open a tunnel through the casing and the rock, allowing

the fluid to flow from the reservoir into the well, thus enabling the hydrocarbons production. Several factors influence in the perforating process, interfering in the productivity, such as density of shots, penetration depth, tunnel diameter, among others. Thus, optimization algorithms are useful in the design of perforating processes, intending at an optimum configuration for the perforating tunnel and consequently achieving greater productivity. Therefore, the objective of this paper is to present optimization studies to evaluate the efficiency of different algorithms and compare the optimal settings presented for each case. For this purpose, three synthesis and optimization models were used: Genetic Algorithm (GA), Artificial Immune System (AIS/CLONALG) and Particle Swarm Optimization (PSO). All of them presented satisfactory results for the problem; however the PSO showed better results in terms of number of evaluation and best fitness.

01133

Benefits and challenges of value chain optimization and dual control in the petroleum industries

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There are many incentives for exploiting mathematical optimization in the oil & gas industries, both in the design as well as the operation phase. First, nearly all “easily” producible oil has been found and is currently produced. Hence, the cost of bringing future products to the market will experience a steady increase and therefore cut profit margins. Second, more diverse, accurate and timely information is becoming available through sensors and other observation channels. Third, mathematical optimization has paid off in the downstream sector, for instance by wide deployment of real-time applications like Model Predictive Control. In this presentation we explore two optimization-based opportunities. The first is value-chain optimization of tightly coupled production systems, and the second is active use of an old, but forgotten property in stochastic systems, namely dual control. Optimal operation of complex assets may require a holistic view of the value chain. This is important if the upstream and downstream parts of the value chain are tightly interconnected. An example of this is when the gas output from a surface facility is fed back into the upstream system through gas injectors. Industrial practice typically takes a silo approach in the sense that one part of the supply chain is treated quite separate from other parts. This is evident in the upstream area where for instance a decision support application for optimally allocating well production may include well and pipeline models, but no model of the downstream system. This can be interpreted as introducing a “dividing wall” along the value chain even though systems are closely connected. We will present a new benchmark [Rahmawati et al, 2010] designed to assess the potential business value of integrated optimization, i.e. an optimization application which include the upstream and downstream parts of the value chain. Further, some results and challenges will be presented. The second part will discuss an open problem; how to utilize the dual effect of an optimization-based controller. The term dual control was introduced by Fel’dbaum in a pioneering work [Fel’dbaum, 1960] about 50 years ago. He discovered that a controller serves two purposes; it controls the system, and it excites the controlled system and thereby affects the information content in future data. Hence, the controller will, by the way the control inputs affects the system, influence future uncertainty. This is called the dual effect of a controller. This may be of particular interest for control of petroleum reservoirs since uncertainty is a major concern. Some results indicating the potential of the dual effect will be presented.

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01139
Optimization of Continuous Gas Lift Systems for Deepwater Offshore Petroleum Production

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In deepwater petroleum production, where the reservoir pressure is not suficient to guarantee the oil elevation with a viable economical returns, the need for artificial elevation technologies is mandatory. A widely applied and efficient technic is the gas lift, where the injection of gas at a certain height in the wellbore reduces the mean density of the liquid column and the static pressure difference. The amount of injected gas is a very critical operational variable, because a low value reduces significantly the oil production and a high value can increase the compression operational costs. In many cases, it is possible to verify that the oil production reaches a maximun value for a certain quantity of injected gas. In this paper, it is proposed a framework for the analysis of continuous gas lift systems using an optimization algorithm coupled to a stationary two-phase flow network model. The objective function can consider the annualized capital costs on compressor, turbine and gas pipelines, the operating costs related to fuel and the revenue from produced oil. The interaction between wells, production lines and riser are properly evaluated by a stationary two-phase flow simulator for pipe networks composed by mass balances at network elements and momentum balances at pipes using the Beggs and Brill empirical correlation. The solution of the optimization problem can estimate important information for the conceptual design phase of a petroleum production system: (i) the injected gas flow rates that guarantees maximum oil production, (ii) the injected gas flow rates for maximum profit and (iii) optimal design of gas lift system considering capital costs of compressor, turbine and gas pipelines. Case studies of single and multiple wells with different complexities describe some applications of the proposed framework. Furthermore, this paper presents a network approach for the classical Beggs and Brill correlation for two-phase flow that is capable of simulating pipe networks with convergent tree type topologies. The major motivation of this development is a lack at the open literature regarding two-phase flow sinulation in pipe networks. The major advantage of the proposed approach is the mathematical simplicity that guarantees precise results with low computation costs if compared to comercial softwares, corroborating the use of this simulator coupled to optmization algorithms.

01155
Use of Linearized Reduced-order Modeling and Pattern Search Methods for Optimization of Oil Production

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Recent work has demonstrated the applicability of pattern search methods for the optimization of oil production. When the search space is high dimensional, as it typically is for practical reservoir management problems, these algorithms will require a large number of objective function evaluations. The use of full, high-fidelity models for these function evaluations can become expensive, as practical models entail transient simulations involving two or more components and may include hundreds of thousands of grid blocks. There is therefore a significant need for accurate surrogate models that can be used in place of high-fidelity simulations. In this work we present a linearized reduced-order modeling procedure and apply it in optimizations

involving water injection in oil reservoirs. The method, referred to as trajectory piecewise linearization (TPWL), has been applied in a number of application areas but has only recently been studied within the context of reservoir management. Using states and Jacobian matrices generated during one or more training runs, TPWL constructs new solutions based on Taylor series expansions around previously simulated states and well settings. The method is very efficient because (1) the model is linearized and (2) the states and Jacobians are represented in a highly compressed form using proper orthogonal decomposition. Retraining of the TPWL model is required when the simulated states (and thus the well controls) lose accuracy. We present strategies for detecting solution inaccuracy, and accomplishing this retraining, within the context of generalized pattern search. Optimization results for well control problems (e.g., determination of O(100) optimal bottom hole pressures) demonstrate that objective function values very comparable to those computed using high-fidelity simulations can be achieved using TPWL, but with overall speedups of about two orders of magnitude. This degree of speedup may enable multiobjective optimization to be performed for practical problems.

01509
Production Optimization: Some Approaches and Challenges

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From optimal well placement to geophysical imaging problems and assimilation of seismic data there are many complex, challenging and important problems in petroleum exploration and production. Meanwhile, in the last decades there have been significant advances in general in nonlinear optimization. It is often a challenge to find the appropriate compromise between using sophisticated techniques and being able to solve realistic problems. We will attempt to address some of these issues briefly specifically in relation to the optimization of oil production under various constraints. In its most general form this determines a mixed-integer nonlinear programming problem, currently a very active research area in nonlinear optimization. We will illustrate some of these issues by way of some recent work with colleagues, including both different degrees of complexity and validation. The ultimate intent is to indicate that efficacy of the approach, using Stanford's General Purpose Research Simulator, together with the complexity of models and algorithms used make the results promising, and a firm candidate for being used in practical field cases.

01540
Kinematic Modeling of sedimentary basins in 2D using the Spectral Projected Gradient Method

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The modeling of a sedimentary basin geology is a discipline originated in the late 70's and early 80's and had its biggest evolution in the late 80's and early 90's. This discipline is currently recognized and aims to increase the chances of success in the field of oil exploration and effectively locate oil prospects. This goal is achieved through the integration into a data model for the areas of geology, geophysics and geochemistry. The geometrical reconstruction of compressive sedimentary basins starting from their formation to its current status is very important in oil exploration phase. In the structural congurations considered in this study we assume the presence of a fault on the simple case. This faults with tectonics forces are the agents that causes the structural deformations in a basin. In this study we propose a modication of the technique proposed by Divies [1] to simulate 2D geological structures deformation in a compressive sedimentary basin in order to apply the Spectral Projected Gradient method (SPG) in the minimization process. This is a deterministic low cost and low storage method based on the projection of the negative gradient that uses a spectral choice of the step length that makes the method very competitive and sometime preferable than other low cost optimization technique. The SPG method was applied to synthetics examples that simulated the initial state of a compressive sedimentary basin to obtain the deformed basin conguration.

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Inverse Problems in Heat Transfer

14

01014
The determination temperature-dependent thermal conductivity as inverse steady heat conduction problem

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The method of fundamental solutions (MFS), as one version of Trefftz method, has become increasingly popular over the last two decades. The majority of applications of this method pertain to the elliptic problems. However in recent years some different versions of the method used for parabolic heat transfer problems have appeared. This paper deals with the inverse determination of sources function in a 2D transient heat conduction problem. The 2D boundary-initial-value problem in square rectangular region with boundary is considered. An inverse analysis utilizing MFS with radial basis functions (RBF) is used to estimate the strength of the continuous heat sources. In this paper the temperature time derivative is approximates by backward difference scheme. This way in the end getting an inhomogeneous modified Helmholtz equation with the right hand side function. This inhomogeneity includes unknown sources function and temperature function known from the initial condition or from the previous time step. The solution of modified Helmholtz equation is the sum of the homogeneous solution and the particular solution. The solution of the homogeneous equations is a linear combination of fundamental solutions of the modified Helmholtz equation with the unknown coefficients. For the solution of inhomogeneous equations the right hand side function must be interpolated by RBF and polynomial with unknown coefficients. The particular solution has a form of linear combination particular solution for RBF and polynomials. Unknown coefficients are determined from collocation of boundary and additional conditions at each time step. In order to validate the discussed numerical method, some 2D numerical examples in unit square, with known exact solutions, are carried out. Simulated experimental data, needed for inverse analysis to compensate for the unknown conditions, are generated by adding random errors to the exact temperature for the interior of the plate.

01017
The determination temperature-dependent thermal conductivity as inverse steady heat conduction problem

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The paper deals with non-iterative the inverse determination of the temperature-dependent thermal conductivity in 1-D and 2-D steady-state heat conduction problem. The thermal conductivity is modeled as a polynomial function of temperature with unknown coefficients. The identification of the thermal conductivity is given by using the boundary temperature, and additional knowledge temperature in some points inside the domain and total heat flux through sample. After Kirchhoff transformation of non-linear heat transfer equation for solution of problem for heat function the method of fundamental solutions is used. The golden section search is use to found optimal place for fictitious sources boundary in frame of method of fundamental solutions. The proposed procedure is very accurate when data are taken without measurement errors. Influence of measurements errors of temperature and heat flux were investigated in this paper.

01019
Determination of the flow rate based upon a solution of an inverse coefficient problem

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This paper concerns a method designed to measure the flow rate of fluid in square – sectioned bends installed in ducts. The method of indirect measurement of the flow rate in circular-sectioned pipes, applied in the study, was developed earlier by the authors. The essence of this method is based on measurement of pressure difference in stationary flow conditions on two opposite walls of the bend angle secant. In the next phase of the measurement a comparison of the value of measured difference with the corresponding value obtained through numerical solution is carried out. The numerical value is obtained through solution of mass and momentum equations and equations describing the selected turbulence model; the examined value of volumetric (mass) flow is adjusted so as to satisfy the assumed accuracy of the condition of equality of both values being compared. In numerical computations an exact geometry of the flow space is taken into consideration along with the measured temperature and pressure of fluid on base of which its thermo-physical properties are described. In the first step of computations, two extreme values of the Reynolds number (Re) are assumed corresponding to the minimum and maximum values of volumetric flow rate being measured. In the next phase of computations, the unknown value of the volumetric flow rate is numerically determined by minimizing the expression of the difference between measured value and the corresponding calculated value . The process of minimizing of the mentioned pressure difference (measured and calculated values) is carried out by the method of secants. In other words, the principal of this method is to select such value of the Reynolds number – used as a coefficient in the partial differential equations of motion of fluid movement – for which the computed pressure difference satisfies the condition. Considering the turbulent nature of the examined flows, time averaged Navier Stokes equations (RANS) with continuity equation were used. To determine the Raynolds stress tensor components, a RSM turbulence model available in FLUENT, was used. To determine the value of measured pressure difference, which is necessary to carry out the described method, an appropriate test stand was built.

01020
Inverse problems for heat conduction equation

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One of the most important problems of cooling the gas turbine thermal blade is an execution of some planned temperature distribution and heat flux on its outer boundary. Such need leads to the Cauchy problem for the Laplace equation. In the literature many approaches to the problem are presented, e.g. fundamental solution method, fictitious sources method, iterative methods

and others. In order to solve 1D non-stationary linear and nonlinear inverse problems of that type the hyperbolic splines are applied. The obtained algorithms are illustrated with numerical results.

01021
Identification of fluid transient temperature

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Under steady-state conditions when fluid temperature is constant, there is no damping and time lag and temperature measurement can be made with high accuracy. But when fluid temperature is varying rapidly as during start-up, quite appreciable differences occur between the true temperature and the measured temperature because of the time required for the transfer of heat to the thermocouple placed inside a heavy thermometer pocket. Most books on temperature measurement concentrate on steady-state measurements of fluid temperature. Only a unit-step response of thermometers is considered to estimate the dynamic error of temperature measurement. Little attention is paid to measurements of transient fluid temperature, despite the great practical significance of the problem. When a temperature measurement is conducted under unsteady conditions, it is of great importance that the dynamic measurement errors should be taken into account. If the dynamic response of the thermometers had been modelled then the better agreement between the experimental data and model predictions would have been achieved. The measurement of the transient temperature of steam or flue gases in thermal power stations is very difficult. Massive housings and low heat transfer coefficient cause the actually measured temperature to differ significantly from the actual temperature of the fluid. Some particularly heavy thermometers may have time constants of 3 minutes or more, thus requiring about 15 minutes to settle for a single measurement. In this paper, two different techniques for determining transient fluid temperature based on the first and second order thermometer model are presented. The fluid temperature was determined using measured thermometer temperature, which is suddenly immersed into boiling water. A comparison will be made between the temperature time histories determined by using the two proposed methods. The techniques proposed in the paper can also be used, when time constants are functions of fluid velocity. Time constants for thermocouples with five different diameters were experimentally determined as a function of air velocity. The least squares method was used to estimate the time constants based on the experimental data obtained from the wind tunnel. In order to assess the accuracy of the proposed methods, the air temperature measurements using three different diameter thermocouples were conducted. Both methods of measuring the transient temperature of the fluid presented in this paper can be used for the on-line determining fluid temperature changes as a function of time. The first method in which the thermometer is modelled using the ordinary, first order differential equation is appropriate for thermometers which have very small time constants. In such cases the delay of the thermometer indication is small in reference to the changes of the temperature of the fluid. For industrial thermometers, designed to measure temperature of fluids under a high pressure there is a significant time delay of the thermometer indication in reference to the actual changes of the fluid temperature. For such thermometers the second order thermometer model, allowing for modelling the signal delay, is more appropriate.

01022
Numerical Optimization of Steam Pipeline Heating

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Power units start-ups involve heating processes of steam pipelines. Steam temperature variation rate is of great importance not only because of pipe wall thermal stresses, but also because of stresses in fittings installed on the pipeline, often very expensive. When the steam or flue gas is used as the heating medium, variation of the medium temperature is greater due to its lower density and heat capacity. For this reason, we should to take into account that steam temperature changes in flow direction during pipeline heating. A method for determining time-optimum medium temperature changes is presented. The heating of the pressure elements will be conducted in such way, that the thermal circumferential stresses at the T-pipe intersection edge at the point of the stress concentration do not exceed the allowable values. Optimum fluid temperature changes were determined with respect to the maximum thermal stress at the T-pipe, which is installed at the end of the pipeline. Temperature distributions of the fluid and pipeline (direct problem) are determined by using the explicit finite difference method. Optimum transient fluid temperature changes at the inlet of the pipeline were determined from the solution of the Volterra integral equation of the first kind. The Duhamel's integral was solved numerically using the rectangle method. Steam pipeline heating is described by energy balance equations, formulated for heating fluid and pipe wall. Heating process is analyzed on the example of the steam pipeline that connects the steam boiler and the steam turbine. The pipeline wall and the fluid region were divided into control volumes. The wall control volumes on the pipe inner surface are in contact with the volumes located at the region of heating fluid, e.g. steam. Due to axissymmetry of the problem, the analysis has been done only for a half of the pipeline. The time changes of fluid and wall temperature at the nodes are obtained from the energy balance equations formulated for all the control volumes resulting from the division of the analyzed domain. The 48 meters long pipeline with the inner diameter of 0.217m and wall thickness of 0.028m is made of 13HMF low alloy steel. The wall and fluid initial temperature is uniform. The convective heat transfer coefficient at the pipeline inner surface, for given steam velocity, is obtained from Dittus-Boelter correlation. The optimum temperature changes were determined with regard to the maximum compressive stress on the inner surface of the T-pipe. The so called influence function, i.e. the circumferential stresses caused by the stepwise increase in the fluid temperature, were determined using the Finite Element Method. During the optimum heating, the maximum circumferential stress a the T-pipe is always equal to the allowable stress. Future time steps are used to obtain a stable solution of the inverse problem. The optimum temperature changes were estimated for the T-pipe located at the end of the pipeline. The results for various steam velocities will be presented.

01047
The Maximum a Posteriori (MAP) Objective Function Applied to an Inverse Radiative Transfer Problem

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The inverse analysis of radiative transfer in participating media has numerous practical applications, including among others, non-destructive testing in industry, diagnosis and therapy in medicine, remote sensing for atmospheric aerosol particles, temperature measurement in semi-transparent materials at high temperature such as encountered in glass manufacturing, design and control of combustion systems and experiments for

the estimation of radiative properties. Implicit formulations of parameter estimation inverse problems in which an objective function is minimized have largely been employed. Although gradient based methods have been used in most cases, it has been observed an increasing interest in the use of stochastic methods for the solution of inverse radiative transfer problems. The best results are generally obtained when hybrid approaches are used. In such hybrid approaches the stochastic method is run for a small number of iterations, requiring therefore a much smaller number of function evaluations. The solution obtained with the stochastic method is then used as the initial guess for the gradient based method. In that sense, the authors successfully developed a hybrid approach where the novel Particle Collision Algorithm (PCA) is used in order to generate estimates that are then used as the initial guess for the minimization of the maximum likelihood objective function with the well known Levenberg-Marquardt (LM) method (PCA-LM hybrid approach). More sophisticated techniques for inverse problems solution, when we have a priori information, are the Bayesian approaches, where not only the experimental measurements are used in the estimation, but also the a priori available statistical information on the unknown parameters. For the case involving a priori normal distribution, it can be developed the maximum a posteriori (MAP) objective function, which can be easily minimized with the Gauss-Newton iterative procedure for obtaining single point estimates. In this work we consider the estimates obtained with several runs of the Particle Collision Algorithm (which were used as initial guesses for the Levenberg-Marquardt minimization procedure in the previous PCA-LM hybrid approach) in order to model prior normal distributions that are used for modeling the maximum a posteriori objective function. In order to compare the results obtained with the two approaches (maximum a posteriori and maximum likelihood objective functions), a relatively difficult test case is analyzed and the results show that the MAP objective function minimization yields estimates with higher precision then those obtained with the previous PCA-LM approach, where only the maximum likelihood objective function was used. In conclusion, the results show that when one has available information on the unknown parameters, such as the one provided by stochastic methods solutions, the use of the maximum a posteriori objective function instead of the classical maximum likelihood objective function can be of relevant interest.

01049
A New Procedure For Optimum Heating of Pressure Components With Complex Shape

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Two methods for determining time-optimum medium temperature changes are presented. The heating and cooling of the pressure elements will be conducted in such way, that the circumferential stresses caused by pressure and fluid temperature variations at the edge of the opening, at the point of stress concentration, do not exceed the allowable values. In the first method, the optimum fluid transient temperature is obtained from the nonlinear integral equation in which thermal stresses are calculated using the Duhamel's integral. When the fluid in the pressure vessel is the pressurized water or superheated steam, then fluid pressure is independent of temperature. In the case of water or steam-water mixture at saturation temperature, pressure is a function of saturation temperature. However, the calculated optimum temperature changes are difficult to follow in practice in the initial stage of heating. But it is possible to increase the fluid temperature stepwise to the minimum value and then heat the pressure component according to the determined optimum temperature changes. Allowing stepwise fluid temperature increase at the beginning of heating ensures that the heating time of a thick-walled component is shorter, than heating time resulting from the calculations according to EN 12952-3 European Standard or TRD 301 regulations. In the second method, at the beginning of the element heating process, medium temperature increases step-wise. To obtain the temperature step value, one must divide the allowable stresses by the maximum value of the

influence function, which defines the time changes of thermal stresses at the analyzed point when fluid temperature increases step wise by 1 K. Further medium temperature changes are determined under the assumption of a quasi-steady state. This temperature change is possible to carry out since the maximum thermal stresses caused by the unit temperature step increase occur after time from 60 to 120 seconds, when the wall thickness is about 100 mm. In order not to exceed the allowable stresses, at the beginning of the heating process, the value of a temperature step at time t = 0 can be reduced by v tmax , where tmax is the time after which the influence function reaches its maximum value. The symbol v denotes the rate of fluid temperature changes at t = 0. The total stresses during the optimum heating were also calculated using 3D FEM method in order to prove that maximum total stresses do not exceed the allowable stresses. Both methods for determining the optimum fluid temperature changes, give a possibility to decrease the duration of the boiler start up from the cold state, and consequently to decrease start up losses.

01058
Determining Thermal Contact Resistance of the Fin-To-Tube Attachment in Plate Fin-And-Tube Tube Heat Exchangers

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Externally finned tubes, or plate-and-tube elements are used in economizers of steam power boilers, air-conditioning heat exchangers, convectors for home heating, induced-draft cooling towers, and waste-heat recovery systems for gas turbines. The plate fin-and-tube heat exchangers are made by inserting the oval tubes through sheet metal strips with stamped holes and then expanding the tubes slightly to cause pressure at the tube-to-strip contacts. If the tubes are only expanded into the plates to produce "an interference fit" some contact resistance must be accounted for. The gap between the fin base and the outer tube surface may be filled with air or corrosion products. With time, heat insulating substances may accumulate in gaps, causing a decline in ability of plate fins to transfer heat. In the design of plate fin-and-tube heat exchangers, contact resistance has been included in air-side resistance as a consequence of the data reduction methods used. However, in many instances it plays a significant role and is critical if reliable performance over a wide range of operation parameters is to be predicted. However, the thermal contact resistance between fins and tubes has not been studied deeply owing to the complexity of heat transfer In this study, a new experimental-numerical technique is developed for the estimation of the thermal contact resistance of plate finned tubes. Two methods will be used to determine correlations for the heat transfer coefficient in a cross-flow plate finned heat exchanger. In the first method, the correlation for the air-side heat transfer coefficient is determined from the condition that the calculated and measured water outlet temperatures are equal. In the second method, the air-side heat transfer coefficient is determined from the CFD simulation of the flow and heat transfer in the heat exchanger. The heat transfer coefficient on the tube side is calculated using the Gnielinski correlation. The effect of contact resistance of the interference fit has been considered in this method. The air side heat transfer coefficient is determined from the condition that the air temperature differences across the heat exchanger obtained from the CFD simulation and from the analytical model of the heat exchanger are equal. In order to determine the 3D flow and heat transfer in the air and heat conduction through the fins and tubes, the problem will be studied numerically. In this paper, the air and heat flow in the tested two-row automotive radiator was simulated numerically by using the CFD program FLUENT. The three-dimensional simulations were conducted for laminar and turbulent air flows. Based on the calculated heat transfer coefficients, the dimensionless correlations for the Colburn j-factor as a function of the Reynolds number and the thermal contact resistance are found. The thermal contact resistance of the fin-to-tube attachment is estimated from the condition that the dimensionless correlations for the Colburn j-factors obtained from the first and second method are in good agreement.

01070
Fin shape optimization in tube heat exchangers by means of CFD program

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Finned tube heat exchangers are used in different thermal systems for applications where heat energy is exchanged between different media. They are used for instance in conditioning systems, radiators and heaters. Such equipment is often chosen from the sets of similar exchangers without real design work. Quick selection among the existing solutions can cause that the design does not fulfill the specification or consider the applications. One of the important issues that should be defined during the design work is the optimization of the heat efficiency taking in consideration of the cost of material. Different systems have different concerns and requirements. In this paper, the optimization of finned tube heat exchanger is presented focusing on the thermal efficiency and weight reduction by the fin/tube shape modification. With the cross-flow heat exchanger, the air streams are not heated and cooled evenly. This means that the temperatures vary along the cross section of the air stream. The heat flux depends on the temperature difference between the local plate/tube and local air temperatures. The fin and tube geometry affects the temperature changes. Numerical analyses are carried out to examine finned tube heat exchanger. Three-dimensional numerical study are performed to find heat transfer characteristics between a finned tube and the air. The heat is transferred from the tube/fins to the air that flows over the fin. Area weighted fin surface average temperature and mass flow weighted average temperature in outlet air volume are calculated and compared for different fin/tube shapes in order to optimize heat transfer between the material of the fin and air during the air flow in the cross flow heat exchanger. The solutions are obtained by means of ANSYS commercial program. The tube material is kept fixed as well as the pitch (spacing). No changes are done in temperature and pressure or flow rate. The shape of the fin and tube is modified to improve heat transfer, reduce the total mass that refer to the cost of the whole heat exchanger.

01087
Control of outlet fluid temperature in plate fin-and-tube heat exchangers

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Transverse high-fin tubular elements or plate-and-tube fin elements are found in such diverse heat exchangers as economizers of steam power boilers, air-conditioning coils, convectors for home heating, waste-heat recovery systems for gas turbines, cooling towers, air-fin coolers, car radiators and heater cores, which are used to heat the air within the car passenger compartment. In this paper, a steady-state inverse heat transfer problem which is encountered in control of fluid temperature or heat transfer rate in plate fin and tube heat exchangers was solved. The problem to be solved is of great practical importance in the operation of internal combustion engines and in heating and ventilation systems. The aim of the steady-state inverse heat transfer problem for plate fin-and-tube heat exchangers is to adjust the number of fan revolutions per minute so that the water temperature at the heat exchanger outlet is equal to a preset value. Since the outlet water temperature is a nonlinear function of the fan revolution number, a nonlinear algebraic equation was solved using the secant or interval searching method. The steady-state outlet water temperature was calculated at every search or iteration step using a numerical model of the heat exchanger. A general numerical method for mathematical modeling of cross-flow tube heat exchangers was proposed. A numerical model of the plate-fin and tube heat exchanger with two tube rows and two passes allowing for different heat transfer coefficients on each tube row was developed. To calculate the overall heat transfer coefficient , the heat transfer coefficient on the water and the air side are determined using the empirical

correlations. Extensive heat transfer measurements under steady-state conditions were conducted to find the correlations for the air and water side Nusselt numbers, which enable the calculation of heat transfer coefficients. The speed of rotation n is determined sequentially with a given time step, which is at least five times greater than the time constant of the controlled process. This condition makes it possible to use the steady-state mathematical model of the heat exchanger. An experimental test stand was built to validate the developed model based control system. The procedure developed in the paper was validated by comparing the calculated and measured values of the fan revolutions. The calculated numbers of fan revolutions compare closely with measured values. The developed method for control of the water exit temperature allows the heat exchanger to achieve the steady-state much quicker in comparison with the classic PID control. In contrast to the PID control, the model based control system using the developed procedure for determining the rotational speed of the fan for the prescribed water temperature at the outlet of the heat exchanger is always stable. The proposed control strategy can be applied in practice because the motor speed n can be changed continuously in direct as well as in alternating current motors.

01111
Computer System for On-Line Monitoring of Slagging and Fouling and Optimization of Sootblowing In Steam Boilers

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When coal is burned, a relatively small portion of the ash will cause deposition problems. Due to the differences in deposition mechanisms involved, two types of high temperature ash deposition have been defined as slagging and fouling. Sootblowers are the primary means of dealing directly with furnace wall slagging and convection pass fouling. The mathematical model of a steam boiler has been developed, showing the influence of water-wall slagging and superheater fouling on the boiler performance. With traditional methods, operators often are not able to detect the critical build-up of deposits on the specific heating surfaces of the boiler. The mathematical model can be used as a boiler slagging and fouling simulator to monitor the boiler operation when the boiler heating surfaces become covered with ash deposits. In addition, the computer-based boiler performance system, presented in reference, has been implemented to provide a quantitative assessment of cleanliness of the surfaces in the furnace and the convective pass. Measurements of temperatures, pressures, flows, and gas composition are used to perform heat transfer analysis in the boiler furnace and evaporator. First, the furnace gas exit temperature and heat absorption rate by the furnace are calculated to determine the influence of the effectiveness of the furnace walls on the heat-transfer rate to the evaporator. Then, the heat transfer in the convection pass is modeled using the Finite Volume Method (FVM). The effect of ash deposits on the superheater surfaces can be accounted for by assuming that high-temperature bonded deposits remain attached to the tube surfaces. The mathematical model of the boiler for simulation of slagged and fouled boiler heating surfaces can assist in quantifying the surface cleanliness and in training new staff about how to operate the steam boiler. With a quantitative indication of surface cleanliness, selective sootblowing can be directed at a specific problem area. Sootblower sequencing can be optimized based on actual cleaning requirements rather than on fixed time cycles which can waste blowing medium, increase cycle time and cause erosion by blowing clean tubes. The boiler monitoring system is also incorporated to provide details of changes in boiler efficiency and operating conditions following sootblowing, so that the effects of a particular sootblowing sequence can be analyzed and optimized later. This contributes to the lowering of the medium usage in the sootblowers and an increase of the water-wall lifetime. The system for monitoring the build-up of ash deposits in boiler furnaces and steam superheaters has been operating at the Skawina Power Plant in Poland since 2007. Power boiler efficiency is calculated by an indirect method. The calculated saturated steam mass flow rate is adjusted to measured steam mass flow rate to calculate the average water-wall effectiveness ψ of a combustion chamber wall in an on-line mode. Heat absorption by the furnace walls and by superheaters are also determined based on the measured data.

01319
A new approach to the retrieval of vertical temperature profiles in the atmosphere using Artificial Neural Networks

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Numerical weather forecast is based on the fact that it is possible to know the condition of atmospheric variables in the future with the knowledge of their present condition in some points of the space. So, the quality of the forecast will depend on the quality of the initial data used in the model. Vertical temperature profiles are part of the initial data used in numerical models of weather forecast. Ideally, these data are obtained by terrestrial stations, in different points of the Earth surface. In the absence of stations in all points of interest, remote sensing is an important tool, making it possible to obtain data from all the areas where it is necessary to run the weather forecast model. So, the retrieval of vertical profiles of temperature from satellite data is an important issue, widely used in the area of weather analysis. Radiances measured by satellites can be directly interpreted by the inversion of the Radiative Transfer Equation (RTE), giving the vertical profile of temperature. But it is an undetermined problem, because of the resolution and the number of spectral channels, and this solution is always unstable because of errors in the measurements (Shiguemori et al., 2006). Shiguemori (2007) proposed the use of Artificial Neural Networks (ANN) to solve this problem. Multilayer Perceptrons have been trained using data provided by the direct model, characterized by the RTE. Radiances are given as input data, an the correspondent temperature profile, in fourty atmospheric levels, is the target to the learning phase of the ANN training. As a result, profiles similar to those of experimental data have been obtained, showing a good performance of the neural network to solve this problem. Based on the work of Cintra et al. (2007), trying to simplify the architecture of the ANN, this work proposes a new methodology to solve this problem. To train the ANN, radiances and a pressure level are given as input data, and the temperature at that pressure level is the target. Test case results are presented using simulated data in order to demonstrate the feasibility of the proposed approach. CINTRA, R.; SILVA, J. da; CAMPOS VELHO, H. Retrieval of humidity profiles with radio occultation measurements using an artificial neural network. In: IPDO-2007, 2007, Miami-USA. Inverse Problems, Design and Optimization Symposium. Miami, 2007. SHIGUEMORI, E. H.; CAMPOS VELHO, H. F.; SILVA, J. S. Inferência de perfis verticais de umidade da atmosfera a partir de dados de satélites utilizando redes neurais artificiais. In: Congresso Brasileiro de Meteorologia. [S.l.: s.n.], 2006. SHIGUEMORI, E.H. Recuperação de perfis de temperatura e umidade da atmosfera a partir de dados de satélite – Abordagens por redes neurais artificiais e implementação em hardware [tese]. São José dos Campos, Instituto Nacional de Pesquisas Espaciais, 2007.

01424
Evaluation of Bayesial Filters Applied To Heat Conduction Problems

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In this paper we apply Bayesian filters technique to state estimation in a one-dimensional, transient, heat conduction problem, in order to estimate two different types of heat flow. The main objective of this paper is to

discuss and compare the performance of the several types of filters, namely: Sampling Importance Resampling Filter (SIR filter), Auxiliary Sampling Importance Resampling Filter (ASIR filter), Sequencial Monte Carlo (SMC), Combined Parameter and State Estimation in Simulation Based Filtering, and Sequential Monte Carlo without Likelihoods. The results show a good performance of these filters, which are compared in terms of the accuracy with respect to a known solution used to generate the simulated measurements, as well as with respect to the associated computational cost.

01452

Smoothed fixed grid finite element method in inverse shape identification of a pipe insulation layer made of functionally graded materials

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Abstract The inverse geometry problems in heat transfer are a class of the inverse problems in which the geometric shape of some parts of the problem domain is unknown and must be determined according to the measured temperatures in the other parts of the domain. In the present work, an inverse geometry problem is solved to determine the cross sectional shape of insulation layer of a pipe which is subjected to convective heat transfer using the measured temperatures on the accessible parts of the pipe cross section. It is assumed that the insolent is made of a functionally graded material and its thermal conductivity continuously varied in the special coordinates. Solution of inverse geometry problems is usually an iterative process and is carried out through the solutions of several forward problems. The process starts with an initial guess for the unknown geometry. The initial geometry has to be modified in each iteration to minimize the squared error between the measured and the computed temperatures. Therefore inverse geometry problems are categorized as variable domain problems. The use of traditional numerical methods which are based on boundary-fitted meshes makes some difficulties in solution of variable domain problems, since the mesh must be modified in each iteration and it is a time consuming process. In the current work, the smoothed fixed grid finite element method which is based on the non-boundary-fitted meshes is used for the solution of forward problem and shape sensitivity analysis. In this method the gradient smoothing technique is used to evaluate domain integrals numerically. The most interesting result of using gradient smoothing technique in non-boundary-fitted meshes is simplification of numerical integration over internal parts of the boundary intersecting elements. Direct differentiation method is also used in this work to obtain the shape sensitivity of the temperature field. By using non-boundary-fitted meshes the internal elements will undergo no changes during the boundary perturbation and therefore only the boundary intersecting elements will participate in the shape sensitivity analysis. To represent the unknown boundary and to manipulate the shape variations, a boundary parameterization technique using splines is adopted in this paper. In addition, to minimize the squared error between the measured and the computed temperatures a mathematical programming approach based on conjugate gradient method is used as the optimization algorithm. To show the effectiveness and the applicability of the proposed method, some numerical examples are solved and the results are compared with the exact solutions. The results show good agreement with the exact solutions. Keywords Inverse geometry problems, Smoothed fixed grid finite element method, Functionally graded materials, Non-boundary-fitted meshes, Shape sensitivity analysis

Mathematical Methods for Solving MINLP Arising from Engineering

15

01056
From infeasibility certificates towards global optimization of chromatographic processes

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In chemical industry, chromatographic processes are an essential tool to separate multicomponent mixtures. Its general idea is to separate mixtures by passing a dissolved mixture in a mobile phase through a stationary phase. As a result of the different adsorption properties of single components towards the stationary phase, the desired components are isolated. For chromatographic systems characterized by linear or Langmuir adsorption equilibria, there are reliable design rules available nowadays to decide whether a given configuration is feasible or which operating parameter should be used. For more complicated equilibrium functions such design rules are not at hand. In this talk we deal with the more realistic second-order truncations of a statistical model. Compared to Langmuir equilibrium functions they also reflect the phenomena of inflection points in their course. From a mathematical point of view, second-order equilibrium functions lead to a highly non-convex chromatographic model. In order to determine an optimal design of such non-convex processes one approaches the problem from two sides. On the one hand a feasible solution is determined. On the other hand a convex relaxation of the original model is solved in order to obtain a bound on the objective value. To derive strong bounds on the objective value we analyze several ways to relax second-order equilibrium functions. Starting with state-of-the-art relaxation schemes which are based on the relaxation of product terms, we also apply novel relaxations for bivariate quadratic terms and a lifting technique. Both the novel relaxations and the lifting technique exploit larger structures than state-of-the-art relaxation schemes. Thus, the resulting relaxations are smaller and can be solved faster. In particular, we observe that our computations heavily benefit from the relaxations constructed by the lifting technique. Applied to chromatographic aspects we investigate the shapes of feasible separation regions in terms of the internal flow-rate ratios. It turns out that the shapes valid for the equilibrium functions considered in this work are more elaborated compared to separation regions valid for common equilibrium functions. Finally, we relate our work to the field of global optimization.

01060
Periodic Filtered Approximation by Quadratic Integer Programming

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We address a problem arising in the development of pulse coders for actuation, signal synthesis and, perspectively, audio amplification. The problem is formalized as a convex quadratic integer programming problem subject to box constraints. A branch-and-bound algorithm for solving the problem is developed, which can be applied to much more general problems. It allows to solve systems of up to 100 variables in about 100 cpu seconds.

01066
Design optimization of reactive distillation columns by memetic algorithms

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The optimal design of a reactive distillation column (RDC) with respect to an economic function is a real-world problem in the chemical process engineering domain. RDCs are chemical plants that combine chemical reaction with distillation (the separation of liquid mixtures based on differences in their volatilities) within a single processing unit. The aim of the optimization procedure is to find the optimal design out of all suitable alternatives with respect to the total annualized cost. The standard approach to handle such problems is to formulate them as MINLPs and to solve them by MP methods. In previous work [1], the design of RDCs was addressed by using MINLP techniques. The solution procedure is based on a decomposition of the problem into an IP-master-problem (optimization of the number of trays and the location of the feed streams) and NLP-sub-problems (optimization of continuous variables for fixed discrete variables). The IP-master-problem was addressed by the branch and bound solver SBB. The continuous sub-problems were tackled by the multi-start algorithm OQNLP that generates starting points for the NLP solver CONOPT. An explicit restriction of the number of feeds introduces a large number of binary variables into the problem formulation that leads to a substantial increase of the computational effort needed for the solution. In [2] we proposed a memetic algorithm (MA) which is a combination of an evolutionary algorithm (EA) and the solver CONOPT for the global optimization of process designs and demonstrated it for the production of MTBE for a a priori fixed number of trays. By the use of the new method the computational effort needed for a local search of the continuous sub-problems could be reduced by 75% in comparison to the reference algorithm. The EA generates starting points for the local solver. It works on the space of the design variables. The corresponding state variables of the column designs are computed by the same solver that performs the local optimization. In [3] we successfully extended this approach to a restriction of the number of feed streams and a minimization of the number of feeds by adding a penalty term for each positive feed stream to the cost function of the MA. Only with explicit restrictions of the number of feed streams optimal results could be obtained for all model instances. In this work, the model used in [3] is extended by a variable number of trays which leads to a significant increase in the size of the search space. The global optimization of the design decisions, including continuous variables and all discrete variables, is addressed by the EA which can handle integrality constraints. The results of the new approach will be compared to the results of the commercial MINLP-techniques used in [1]. [1] S. Barkmann, G. Sand and S. Engell, CIT, 80(2008), 107–117 [2] M. Urselmann, G. Sand, S. Engell, Proc. IEEE CEC, 1721-1728, 2009 [3] M. Urselmann, S. Engell, ESCAPE 20, accepted for publication

01085
Solving Mixed-Integer Nonlinear Programs Arising in Petroleum Industry

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Mixed-integer nonlinear optimization problems are often found in petroleum industry. Model functions are determined by complex technical simulation codes and typically, the resulting mixed-integer nonlinear program is non-convex. Even more important, it is, in most cases, not possible to evaluate the objective or the constraint

functions at fractional integer variable values, an assumption often required by available solution methods. Since simulation runs are expensive, our main design criterion for developing appropriate optimization techniques is the efficiency in terms of the number of function calls. We introduce a toolbox of algorithms, that was developed over a couple of years. All solvers are based on an SQP-type approach with trust region stabilization. A quasi-Newton matrix is updated to avoid the necessity for providing second derivatives. Successively, mixed-integer quadratic programs are formulated and solved by a branch-and-cut method. Moreover, linear outer approximations are added to guarantee convergence at least for convex programs. To evaluate the performance of the proposed algorithms, we present numerical results in a comparative study. 55 test cases are obtained by two applications from petroleum industry called well relinking and gas lift. In addition 100 nonlinear and often non-convex problems found in the literature are considered.

01098
Decentralized control system design using mixed integer optimization

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Decentralized control system design comprises the selection of a suitable control structure and controller parameters. In the present paper, mixed integer optimization is used to determine the optimal control structure and the optimal controller parameters simultaneously. The process dynamics is included explicitly into the constraints using a rigorous nonlinear dynamic process model. Depending on the objective function, which is used for the evaluation of competing control systems, we propose two different formulations. These formulations lead to a mixed integer dynamic optimization (MIDO) problem. Two different solution strategies are considered to solve the resulting MIDO problem and compared with each other. The first is based on the total discretization of the underlying process dynamics using the orthogonal collocation on finite elements. Hence, the MIDO problem is transformed into a large scale mixed integer non-linear programming (MINLP) problem. The second is based on the sequential approach, in which the MIDO problem is decomposed into a series of primal problems (dynamic optimization) where the binary variables are fixed, and MILP master problems which determine a new binary configuration for the next primal problem using Generalized Benders Decomposition (GBD). The proposed methodology is applied to an inferential control of a reactive distillation column as a challenging benchmark problem for chemical process control. Results are compared with previous studies, and conclusions are drawn for future work in this field.

01360
Mixed-Integer Nonlinear Problems in Transportation Applications

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Many real-life problems contain a mixture of discrete decisions and continuous phenomena. In our talk we present two different examples from the area of transportation network design and show how they can be modeled as mixed-integer nonlinear programs. For their numerical solution we transform

them further into mixed-integer linear programs (MILPs). Hereto the nonlinear relationships have to be approximated by using only linear constraints and discrete decision variables. The MILP problem are solved with linear programming based branch-and-bound or branch-and-cut algorithms. In this way, modern numerical MILP solver are today able to handle large-scale problem instances with hundreds of thousands of variables and constraints. A further advantage, in particular in comparison to pure heuristic methods or gradient-based methods, is that these methods compute a certificate of optimality. That is, in every step an estimation towards the global optimum is given, so that the user can decide whether an intermediate solution is satisfactory or if some more time should be invested for searching a potentially better one. The one application concerns a service network design problem arising at Deutsche Bahn, one of the largest European railway companies. Their rail freight cars follow prescribed routes from origins via intermediate shunting yards to destinations. The goal in designing such routes is to reduce the number of trains and their travel distances. Various additional real-world hard constraints make the problem difficult to formulate and also to solve. The discrete decisions in this application represent the design of the service network. The nonlinearities arise from the fact that the waiting time of the cars in a shunting station decreases inversely proportional with the number of departing trains. We present different strategies how to re-formulate this nonlinear constraint as a linear one, such that numerical MILP solvers can be applied. Computational results using test- and real-world data show that this problem can be solved for instance sizes that are of practical interest. The other application deals with the optimal extension of an existing gas transportation network. The physics of natural gas in pipelines is best modeled by partial differential equation systems. On a coarser level there exist reasonable approximation formulas. However, these formulas are still nonlinear equations. Besides the pipelines, the network contains active elements which can be controlled by dispatchers, such as valves and compressor stations to decrease or increase the pressure. Some elements can be controlled in a continuous fashion, others can only be on or off, hence they are discrete. In order to increase the network's capacity, new pipelines or new active elements can be built. Since these investments are very cost intensive, the pipeline operator is interested in the most economic network extension. Each potential extension gives rise to a further discrete decision variable. Since the number of potential extensions is astronomic, we give first some ideas how to reduce the complexity, before a numerical MILP solver can be applied on linearized versions of that problem.

Optimal approaches in electrical engineering

16

01097
Transmission Expansion Planning with Re-design

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Expanding an electrical transmission network requires heavy investments that need to be carefully planned, often at a regional or national level. We study relevant theoretical and practical aspects of transmission expansion planning, set as a bilinear programming problem with mixed 0-1 variables. We show that the problem is NP-hard and that, unlike the so-called Network Design Problem, a transmission network may become more efficient after cutting-off some of its circuits. For this reason, we introduce a new model that, rather than just adding capacity to the existing network, also allows for the network to be re-designed when it is expanded. We then turn into different reformulations of the problem, that replace the bilinear constraints by using a ``big-M'' approach. We show that computing the minimal values for the ``big-M'' coefficients involves finding the shortest and longest paths between two buses. We assess our theoretical results by making a thorough computational study on real electrical networks. The comparison of various models and reformulations shows that our new model, allowing for re-design, can lead to sensible cost reductions.

01118
Dissipative processes in electrical engineering: a multi-scale approach

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In order to address the abysmal lack of efficiency of the electrical system (73% of losses, 45% of CO2 emissions worldwide…!), we propose to overcome the classical presentation of electromagnetism through a physical description of the electrical energy workflow, formulated as an optimal problem. In this framework, the laws of electromagnetism are derived from a thermodynamic viewpoint. Particularly, the so-called Maxwell-Faraday's law of induction results from an optimal path toward reversibility. Taking advantage of the quadratic property of the thermodynamic functionals along with the well-splitted scales of the current density, this approach is shown supporting a multi-scale analysis where the brute minimization condition is replaced by embedded minimizations on the various scales excited by the power electrical system. Following the previous thermodynamic viewpoint, these various scales are reviewed from deep within the material to the whole electrical system. Attention is paid on the dissipative processes and on the weakness of the modeling to properly consolidate them at the design and/or power management levels: (i) In ferromagnetic materials, the dynamic behaviour should take anomalous losses into account. Recent improvements argue for a deviated Ohm's law at the macroscopic scale while the magnetic law is kept from the static regime; (ii) At the design scale, eddy currents are at the origin of losses and signal distortion. In order to improve the finite element modelling of macroscopic eddy currents, a quadratic energy-based criterion is expressed from the numerical deviation observed on the electric power conservation. However, further calculations of the electric field within the dielectric region are expected to make the most of the criterion; (iii) At the integration level, the signal integrity issue in Electro-Magnetic Compatibility may be viewed as a competition between the electrostatic and

the magnetic couplings in dielectric regions. Galilean invariance enforcing that one regime dominates the other according to the frequency; abrupt transition is expected between the two regimes. Some parentage with the phase transition theory could be explored; (iv) At the network management level, the electromagnetic energy coupling acts as a stock to ensure the stability of the electrical system under load fluctuations. Hence the appropriate level of reliability may be faced to the investment. Finally, the interplay between energy efficient issues should be discussed within a long-term planning exercise dedicated to sustainable development.

01187
Controlled Optimization of Dielectric Problems in Electrical Engineering Design

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The paper presents an approach providing the controlled optimization of the dielectric problems when designing the electrical engineering apparatus. As one of the main problems in the dielectric design of electrical apparatus are high electrical stresses that could under certain conditions lead to the breakdown. Here we present an efficient technique for the optimal design of such components based on 3D field computation. The optimization procedure is controlled by simultaneously evaluation of the corresponding design criteria, what guaranties that the optimal design offers not only the minimal field stress but also is proven to be below the required safety margin during the operation conditions. The paper will cover advanced BEM-based simulation technique together with the used optimization approaches and design criteria evaluation. Finally, some results are presented illustrating the above procedures during the practical optimization of the real-world engineering problems.

01268
A New Equivalent Circuit Based FSS Design Method By Using Genetic Optimization Algorithm

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Frequency selective surfaces (FSS) are periodic structures which have low pass, high pass, band pass and band stop filter characteristics when interacting with electromagnetic waves. They have been widely used in broadband communications, radar systems, and antenna technology. For analyzing the electromagnetic behavior of FSS, finite element method, finite difference method or dedicated MoM methods are commonly employed. Despite their accuracy in analysis, these techniques require time consuming simulations and do not allow the designer to have a good insight into the physics behind the structures. Equivalent circuit representations are useful for quickly predicting the performance of FSS and allow performing a very simple model able to describe every kind of shape. These equivalent circuit models also provide useful physical insight into the performance of the FSS. The equivalent circuit model can also be employed in the design of the multilayered FSS. During the last years, several approaches that combine heuristic optimization methods with numerical analysis techniques have been proposed in the literature to carry out the optimization of Frequency Selective Surfaces (FSS). For a desired transmission response or a reflection response, an admittance formulation of the equivalent

circuit of a pre-defined FSS is easily derived and an equivalent circuit representation is constructed with the unknown values of circuit parameters L's, C's and R's. We can obtain the transmission and reflection parameters of this draft FSS by a full-wave simulation (by HFSS FEM solver) from its draft geometrical and physical parameters. After simulation, being known the transmission and reflection parameters the values of the inductances and capacitances of this equivalent circuit can be uniquely calculated. The inductances and capacitances can be expressed in terms of the FSS period, the dimensions of the periodic element, angle of incidence and wavelength. These are the parameters of our optimization problem. L= L(Parameters of FSS) C=C(Parameters of FSS) We have a set of non-linear equations, involving the equivalent circuit component values, the dimensions of the periodic element, incidence angle and polarization. These equations are to be solved to obtain the exact element geometry. Generic design methodology able to give a reliable method to obtain the geometric and physical parameters from the equivalent lumped circuit design. Genetic algorithms are a special class of global optimization scheme that have a wide range of applications in the design of electromagnetic systems. In this paper, FSS parameters having band stop filter characteristics are obtained by using Genetic Algorithm. The center frequency of the filter is chosen 2.4 GHz with 200 MHz bandwidth. The results show that desired characteristics are obtained successfully for the optimized FSS parameters.

01278
Structural optimization of high tension towers

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Optimal design has not been yet generalized in industrial applications since it is very difficult to define CAD tools that allow to define and to state general optimization procedures that can be applied to a wide variety of structural problems. Thus, it is necessary to propose algorithms and models to obtain the optimal design of specific problems. The definition and the analysis of these models is advisable when the benefits obtained by applying optimization techniques may be profitable. According to this idea, optimization techniques are oriented to solve great singular projects that involves a very large cost (for example, a dam, a dyke of a harbour, a long span bridge,...) or specific problems that can be used repeatedly in a large number of applications or projects (automotive and aeronautical industry, small structures in civil engineering,...). The structural optimization of electric transmission towers for large and high tension lines corresponds to the second group of optimization problems since a transmission line usually requires hundreds or even thousands of transmission towers. In this paper, the authors propose a general formulation to obtain the optimal design of latticed high tension towers. The formulation is devoted to obtain the most common objective in engineering (minimum cost) by considering the limitations imposed in actual laws and norms for this kind of structures. The system conforms to the corresponding Spanish Standard. The shape optimization problem is solved by means of an improved sequential linear programming algorithm with quadratic line search. The system performs the sensitivity analysis by means of analytical techniques. Finally, some application examples that analyse real high tension towers are solved in order to check the benefits obtained by using the optimization techniques proposed.

01328
Optimal operation and sizing of a set of cogenerations

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A cogeneration system provides electrical (or mechanical) and useful thermal energy from the same primary energy source. When comparing efficiencies between cogeneration and separate production of electricity and heat, it appears that cogeneration allows considerable savings in fuel consumption. But, beside these important environmental issues, economical viability of a cogeneration project is still challenging for operators. Economical viability relies on many factors, among which how to operate each unit. In this study, we shall focus on the heat-match mode where the operator's priority is to satisfy the local heat consumer demands. When these demands are satisfied (possibly by means of auxiliary boilers), the amount of excess electricity is exported to the grid, while the lack of electricity is bought from an electricity market. In this framework, we will consider both the question of optimal operation and optimal sizing for a set of cogenerations. First we shall consider an operator who operates over a given designed (technology, size, location) set of cogeneration units. The best operating mode minimizing the convex but non differential cost of operation for the overall set of cogeneration units is achieved through an optimization procedure. The optimum relies on the ordered sequence of marginal costs associated with the different operational modes for each unit. This merit order indicates that the optimal operation of the cogeneration power plant is achieved through an economic dispatch mode. Based on this merit order result, an optimal sizing method is addressed so as to minimize the total cost of the plants' operational strategy. The sizing problem is formulated in order to decide the nominal electrical power of the cogenerations. We can show that this formulation still leads to a convex problem.

01330
Optimization of future power systems focusing on reliability of supply

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The efficiency of future power systems is expected to improve with the integration of renewable and distributed energy sources, as they decrease the level of losses induced by the Carnot cycles. However, these energy sources also challenge reliability of supply and may induce extra-losses. Actually, there are three main kinds of losses on power systems: the losses induced by the Carnot cycles, the conveyance losses and the reliability-induced losses. Their levels depend on the network architecture: in particular in distributed systems, reliability-induced losses are expected to increase, while conveyance losses and losses induced by the Carnot cycles are expected to decrease. In this work, we introduce reliability of supply within an optimal discussion in order to assess properly the overall amount of losses on power systems. To do so, we apply variational principles – deduced from thermodynamics – to the electromagnetic field that conveys electricity from production units

to consumption loads. In this thermodynamic framework, the deviation between the mechanical power flowing through the network and the variation with time of the Helmoltz free-energy F gives an evaluation of the Joule losses PJoule, at the transmission, distribution and consumption levels. PJoule is a measure of the irreversibility experienced by the system. According to the thermodynamics, Joule losses are always positive and the lower they are, the more reversible is the evolution. This is expressed in an optimal condition – called the reversibility condition – meaning that the system always tends to minimize the Joule losses during its evolution. Ideally, a centralized power system can be described from the Helmoltz free-energy, and the reversibility condition provides the very minimum amount of Joule losses during power transaction. These are the conveyance losses. Added to the losses induced by the Carnot cycles, we find the total amount of primary energy lowered in a centralized system. Conversely, in order to explicitly take reliability into account, the description should include the inertial behavior of the electromagnetic coupling. Actually, the level of Joule losses should be assessed from another reversibility condition obtained from the Gibbs free-energy G = F - ⟦(ΦI)⟧_exc, where ⟦(ΦI)⟧_exc is the electromagnetic coupling and I_exc the excitation of the rotor. As a physical result, the latter description gives the level of both conveyance and reliability losses. These are the losses needed to operate power systems in a reliable way. Compared to the previous case, the argument of the optimum is drastically changed, which leads to new stability requirements for dynamic management of power systems. Added to the losses induced by the residual Carnot cycles, we find the total amount of primary energy lowered in a distributed system. This study enables to truly compare the overall amount of losses for centralized and distributed power systems, for a given demand and a given level of reliability. It also emphasizes the need to consider reliability requirements when designing future power systems.

01348
Power generation under post Copenhagen emission reduction pledges

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The global warming question remains on top of the energy agenda. In the past couple of years the climate change debate has been marked not only by scientific evidences reported in the IPCC assessment reports, but also politically by a number of major events: the approval of the EU climate package by the EU parliament in December 2008, the transition in US with “green” positions expressed by the new administration, and the large participation of developed as well as developing countries in the Copenhagen Climate Change Conference (COP 15), in December 2009. The international agreement at COP 15 was the final step of the two-year negotiation process set by the Bali conference in 2007. On the one hand, COP15 discussions eventually failed to reach a global agreement on greenhouse gas emissions mitigation targets. On the other hand, countries wishing to associate themselves with the Copenhagen Accord were required to formally submit to the United Nations Framework Convention on Climate Change (UNFCCC) their emission reduction pledges before the end of January 2010. The aim of this paper is to analyze the outcomes of different coordination schemes, derived from the submitted pledges, and associated to intermediate targets levels. The study relies on the ETSAP/TIAM-FR approach performing the optimization of the energy system in the long-term with explicit descriptions of the technologies used: it is based on an explicit formulation of the input-output relationships for each technology and minimises - over the chosen time horizon 2000-2050 and for a given final services demands - the total discounted cost. We assess for the period the evolution of energy consumptions (primary, electricity generation, ...) global and regional emission levels, and global and regional costs of the climate policy. We will address the ability of national energy system to curve the past trends in order to reach those targets, first relying on the actual technical structure of the energy production and consumption system. In this framework, we will assess how the energy system in general and the electricity generation in particular can evolve over time to follow different low carbon future policies? The results show a complex impact of the mitigation policies on the future electricity mix and technologies.

01388
Multi-objective study of a food-industry tri-generation system

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The use of a tri-generation system for application to the fruit conservation problem in food-industry is studied in this work. The economical and environmental benefits of the installation are analyzed by means of a multi-objective optimization procedure which takes into account the minimization of the management costs of the system and its advantage in terms of the reduction of greenhouse gas emissions. The procedure is based on a Pareto approach: exploration of the Pareto front is performed by sampling a weighted objective function combining operational costs and reduction of greenhouse gases emissions. Taken a practical case of the cooling load required by an industrial site in northern Italy, different combined heat and power installations are studied and results discussed. Primary Energy Saving (PES) and Trigeneration Primary Energy Saving (TPES) indicators are considered to compare different management strategies of the plant for each possible installation: the most common full throttle management, operational strategy for minimization of management costs and operational strategy for minimization of CO2 emissions. A further analysis is performed in order to establish the economical feasibility for the proposed different combined heat and power installation using a Simple Pay Back Time evaluation taking into account the different management strategies. General considerations about the advantages of the proposed solutions are presented.

01407
Comparison of two optimal approaches for the energy management of a thermodynamic solar micro plant

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Today, 1.6 billion people do not have access to electricity. Half of this population lives in rural area, far from any utility. Schneider Electric, through the BIP BOP* program, is currently developing innovative solution to bring electricity to these isolated sites, mainly in Africa. The idea is to build a robust, simple, maintainable, low cost and environment friendly solution. The

main components of this system are solar sensors, thermal storage, thermodynamic engine, electrical machine and inverter. One of the challenges for that kind of low power electrical generator (about 10kWe) is its ability to be well managed, with a perfect match between the demand (which can suddenly change) and the response. In this paper, we will first expose the objectives of the control laws for the system to be well managed. Then we will describe the modelling of the whole plant. We will synthesise two different controllers based on optimization techniques, the first one will be based on Hinfinite robust control; the second one will be a LQG (linear quadratic Gaussian) controller based on optimal techniques, for both control and estimation. The performance and robustness of these two controllers will be evaluated. Finally, we will use the chosen controller to optimize the size of the inertia wheel of the engine which be used a mechanical storage, nedded to fullfill energy management objectives and constraints without electrical storage.

01413
Distributed Storage for Rural Electrification by Micro-Grid

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The purpose of this paper is to study how to apply distributed storage into a photovoltaic micro-grid for rural villages with electrical network powered by renewable sources and small thermal generator. Using distributed storage with droop-mode inverters helps to reduce Joule losses and voltage drops. This allows reducing the cable's section or the power source size therefore avoiding distribution grid's upgrade. The main work will focus on optimizing the localization of these storage. The sharing of storage's capacity will also be calculated to improve network performance.

01450
Inclusion of Environmental Costs on a Long-Term Expansion Model of Hydrothermal Generation Systems

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The paper describes a methodology for the inclusion of environmental costs into the optimization process of long range power supply expansion planning. The problem is tackled through a large-scale mixed integer linear programming (MIP) model, which takes into account uncertainties related to hydrothermal generation systems as well. The environmental (external) costs, which arise from the construction and operation of power plants of several types, are computed in monetary terms and introduced in the model formulation according to the nature of their impact. Case studies based on the Brazilian system are presented and discussed. Finally, the model computes the total cost of power expansion (in financial and environmental terms), which shows to be less than the costs derived from models which do not consider environmental impacts endogenously.

01474
The effects of a 30% greenhouse gas reduction policy on the European Union electricity generation: a prospective analysis

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The latest European Union (EU) guidelines about post-Kyoto climate negotiations suggest that Member State are ready to enhance their commitment on the reduction of greenhouse gases (GHG) emissions from 20% to 30% by 2020 (compared to 1990 levels). A further decarbonization effort is likely to carry heavy consequences on the future energy mix of Europe, in particular on the power generation: this paper aims to analyze the global impact of a 30% cutting emission policy on the EU electricity production sector. The proposed methodology relies on the quantitative results of the RES2020 project, which are based on the simulation of 4 different scenarios issued from a specific MARKAL-TIMES model, involving the implementation of actual EU policies. A comparison between RES Reference scenario (taking into consideration the objectives of the Energy and Climate packages of January 2008) and RES-30 Climate scenario (implying a more ambitious reduction of GHG emissions, up to 30 %) has been developed in order to point out analogies and differences. The outlooks have been reviewed following three main axis of investigation : technologies, primary sources and geopolitical implications. As expected, the major outcome of the RES-30 scenario is the increase of the share of renewable energies in the EU electrical production. Wind energy production will keep a fundamental role in the achievement of the targets, proving itself as a mature technology as well as a flexible lever for ulterior emissions reduction. Furthermore, the hardening of environmental constraints will give a strong impulse to the deployment of all the existing technologies, in particular solar and marine renewable energies, which will have a smooth emergence in comparison to the reference scenario. Despite environmental restrictions and the anticipated increase of fuel prices, the model shows that the traditional power generation from fossil fuels will still provide an important share of the supply in the next twenty years. The remarkable aspect of the use of fossils is the tendency of substitution suffered by coal due to the raise of natural gas, which can be explained by the evident technical and economical advantages of gas in electricity production. Even if the penetration of gas in the European energy mix will depend on other essential factors, the results suggest that the GHG emissions policy can affect the European security-of-gas-supply policy in the next decades. Another delicate and controversial point of the analysis is represented by the contribution of the EU New Member Countries (NMC) in the fulfillment of the Community expectations about GHG emissions reduction. Taking into account the peculiarities of the existing production park, characterized by a strong exploitation of coal, the realization of the RES-30 policy is potentially able to induce heavy structural changes in the energy systems of this region. Despite this noticeable conversion, in both scenarios NMC will be responsible for a consistent share of European GHG emissions from electrical generation by 2020.

01475
Brushless Permanent Magnet Motor Losses Minimization with Constraints in Perspective of a Life Cycle Assessment

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Abstract: The "off the shelf", commercially available, brushless permanent magnet motor is considered for electromagnetic losses minimization in order to increase motor efficiency.

This perspective satisfies the global thinking paradigm of "Life Cycle Assessment", where we design to reduce the power consumption impact of the brushless permanent magnet motor in its industrial application. The key electromagnetic losses components are the stator winding resistive losses, the motor magnetic material iron core losses and the rotor magnet eddy current losses. These electromagnetic losses are computed through finite element dynamic computation that simulates the real life operation of the motor. As such, the power budget can be visualized to depict the impact of different loss components and can be used to develop a targeted loss reduction strategy. The motor geometry features, such as the rotor magnet shape and the stator lamination details (i.e. slot opening, tooth width) along with the motor physical properties (i. e. motor current, materials), are considered as design parameters for the optimization process fine-tuned to minimize the electromagnetic losses. Two optimization strategies and algorithms are considered for comparison. The first one is engineering oriented and some level of motor design expertise is required. This consists of performing a "Screening" to extract the most influential parameters. Then a transformation, utilizing a smaller number of of key design parameters, into a 2 steps optimization process. The utilization of this process involves more preparative design ground work, but we reduce the number of parameters and the optimization domain. The result is an economy of the evaluations of objective functions and constraints. The second strategy is "Stochastic" based and uses a Genetic Algorithm to automatically find the minimum motor electromagnetic losses for the given design parameters. Thus, it is computationally intensive because more finite elements solutions are required, but it is more "black-box" approach. During the design optimization process, there are trade-offs in terms of quantity of materials used and the use of standard or advanced materials. This results in an impact on the financial cost along with the realized reduction of the operating cost. Therefore, it is important to apply the "Life Cycle Assessment" to consider the environment cost to get the true impact of the optimum design over the motor life, rather than merely its electromagnetic performance.

01486
A Cooperative Game Theory Approach to the Allocation of Firm Energy of Hydro Plants

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A game theory approach to the problem of firm energy allocation among hydroelectric power plants is presented. A multi-plant optimization model that takes into account the synergies due to spatial and time correlations among different river basins is used to calculate the amount of firm energy that can be produced by each coalition of power plants. Operation rules based on the current state of each coalition of plants, e.g., reservoir levels and hydrologies, which use the results of the optimization model with a firm energy target for the corresponding coalitions are developed and used to simulate the operation and calculate firm energy under various synthetic stochastically generated hydrological conditions. Firm energy among plants is allocated using game theoretic solutions such as the Shapley value. Results for a four-plant Colombian hydro system are presented.

01526
Decision-helping tools for long term investment in energy storage systems

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The energy sector is characterized by very long asset life spans. Consequently, investment decisions are taken with a time horizon ranging up to several decades. Associated quantitative decision helping methods therefore face uncertainties as their major difficulty: models and optimization methods are designed to deal with them. We propose a survey of such methods in order to draw their strength and weaknesses from technical and decision maker point of views. We will focus on structural versus cyclical uncertainties and on their impact on risk and benefit functions on energy storage systems.

01529
A MIP and a Randomized Approaches for computation of the Leastcore Allocation of Firm Energy Rights

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The maximum amount of electricity a set of hydro plants can constantly produce is called firm energy. It was observed that the overall firm energy was greater than the sum of the firm energies that would be obtained separately for each hydro plant, which means that there is a "synergy" gain whenever a cooperative operation occurs. This fact leads to the question of how to allocate these benefits among the individual hydro plants. This allocation has great commercial importance in the Brazilian system, because the firm energy right of each plant defines its contracting limit, which in turn has a direct effect on the plant's revenues. On the other side, the increase of the constant energy production means that a greater demand could be continuously supplied. Therefore, the key question is to find a distribution of the benefits shares among the hydro plants which is "fair" and stable in the sense that all of them have an incentive to cooperate in the whole group of plants, a so-called core element. In other words, an allocation is fair if all participants receive more benefits by joining the "grand coalition" than by forming sub-coalitions of their own. The core of a cooperative game formalizes the concept of "fairness" in the allocation of costs and benefits. There are infinite allocations satisfying the core conditions, so this work is particularly interested in some allocation which is, in some sense, preferable to the others. This one is the leastcore element. The leastcore element is the one that maximize the smallest "advantage" that each agent (or subset of agents) has for belonging to the "grand coalition", compared to what the

same plant would receive outside the "grand coalition". The major difficulty in the calculation of the leastcore in realistic situations is the exponential increase of its constraints with the number of players. This report discusses the calculation of the leastcore of a cooperative game. In this sense, it proposes two approaches that handle the constraints growth difficulty: (i) a MIP algorithm, based on constraint generation, that computes such a leastcore element for a realistic number of players; (ii) a "randomized" procedure, in which a constraint sampling is applied to the leastcore constraints and it can be shown that the resulting randomized solution fails to satisfy only a small portion of the original constraints, provided that a sufficient number of samples is drawn. The key result is to provide an efficient and explicit bound on the volume of the original constraints that are possibly violated by the randomized solution. This volume rapidly decreases to zero as N is increased, where N is a finite set of constraints that are taken into account. The results of approach (i) can be used to check optimality of approach (ii).

01541
Selective Sampling Applied to Long-Term Generation Planning of Electric Power System

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The main goal of generation planning is to determine an optimal operation policy for the power system mix, composed of hydro and thermal generation units and transmission lines for energy exchanges among subsystems, which minimizes the expected total operation cost over scenarios of inflows to hydro generation units throughout the period of planning. Currently, the problem of long-term operation planning of the Brazilian interconnected system [1] is represented by a multistage stochastic linear programming problem, and the method applied to find the optimal solution is Stochastic Dual Dynamic Programming (SDDP) [2]. The SDDP method is based on multistage Benders decomposition. In the adopted algorithm, instead of solving all the subproblems of the scenario tree in the forward pass, only a subset (sub-tree) is chosen and solved. Cuts of the cost-to-go function are constructed in the backward pass for all nodes of the sub-tree. New values for the state variables are calculated in the forward pass. The sub-tree is selected by the Monte-Carlo method that uses classical random sampling and represents a small portion of the complete scenarios tree. Usually, the stopping criteria in the sampling-based algorithms for multistage stochastic linear programming is based on the statistical convergence criteria, i.e. we consider that the algorithm is converged when the lower bound on the optimal value (ZINF) is within the confidence interval of the upper bound on the expected value of the total operation cost (ZSUP). The stopping criteria can also incorporate non-statistical criteria, such as the stability of ZINF [3]. This work presents a new method for defining the sub-tree to be visited during the process of calculating the optimal operating policy in order to enhance the robustness of the results with regard to variations in the number of hydrological scenarios in the backward pass and variations in the sample of inflow scenarios. The proposed method, so-called selective sampling, applies multivariate statistical techniques to define the sub-tree. A convergence analysis of SDDP considering selective sampling is also performed. We perform a comparison between the performance of simple random sampling and selective sampling considering several study cases based on actual operation planning and expansion

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planning in Brazil. The results show that the proposed method yields a sharp reduction in the variability of ZINF estimator, otherwise a bias in the ZSUP estimator is observed, even though its variability also is reduced. Since this bias brings difficulties to achieve statistical convergence of the process, we propose a stopping criteria taking into account statistical and non-statistical criteria.

01543

A strategy to model the pre-order dispatch of LNG thermal plants in the long and mid-term models for generation planning in the Brazilian electrical system

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In Brazil, the generation planning of the electrical system is done in a centralized way by the Independent System Operator (ONS), which uses long and mid-term optimization models based on stochastic programming (NEWAVE and DECOMP, respectively) in order to determine an optimal long-term policy, to dispatch the hydro and thermal plants in the following weeks / months, and to obtain the weekly spot prices at each load level for the wholesale energy market. The generation dispatch is computed at the beginning of each time week/month, based on the current system conditions (set of past inflows and storage levels in each reservoir) and on a sample of future inflows scenarios for the hydroelectric plants, which are generated by Monte Carlo methods. Recently, Liquefied Natural Gas (LNG)-based thermal plants are being considered as an alternative to increase the generation mix in the Brazilian electrical system. However, contrary to conventional oil, coal, or gas-based thermal plants, the dispatch of LNG plants has to be pre-ordered K months before the moment of its actual utilization. Such time-linking constrains cannot be represented directly on the NEWAVE and DECOMP models, since the dispatch of these plants along each time interval are obtained at the node corresponding to the beginning of this interval. In this sense, this paper presents a general strategy to include the pre-order dispatch requirement of LNG plants in the stochastic dual dynamic programming (SDDP) and L-shaped algorithms that are applied to solve the stochastic programs in the NEWAVE and DECOMP models, respectively. In both algorithms, additional state variables related to the dispatch of LNG plants up to K months ahead were included in the cost-to-go function at each stage. A smart procedure, based on the use of artificial variables, was employed in order to limit the increase in the dimension of the state-space, so that it does not depend on the number of LNG plants in the system. Preliminary results of the application of this strategy are presented for a real large scale problem for the Brazilian system, composed of more than 120 hydro plants and 40 thermal units, which was solved in a reasonable CPU time. The convergence properties of the SDDP and L-shaped algorithms under the presence of such time-linking constraints are discussed, and a sensitivity analysis on the value of the dispatch lag K is performed. The impact of the inclusion of LNG plants in the system marginal costs for the wholesale market in Brazil is also analyzed. Finally, we show the clear advantages of the proposed approach as compared to an alternative "ad-hoc" approach that was initially conceived, where the dispatch of LNG plants would be determined a priori based on a statistical analysis of the results obtained in a previous run of the model. Such alternative approach would not require any modifications in the existing models used by the ISO.

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Optimization in Biomechanics and Biomedical Engineering

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01258
Shape optimization of an artificial bypass graft using genetic algorithms

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Shape optimization has been applied in the field of medical engineering. It is our goal to establish an optimization framework that is suited to perform shape optimization of complex geometries in compute-intensive applications. In medical practice, bypass grafts provide a way to restore blood flow in critically stenosed or occluded arteries, and, together with stenting, constitute the most typical treatment in such cases. In this paper, we develop a mathematical algorithm to optimize the geometry of an idealized artificial bypass graft. In shape optimization, the goal is to minimize an objective function over a domain that depends on shape or design parameters. Setting aside effects that arise from model simplifications, the resulting optimal shapes depend heavily on the goal of the optimization specified through the objective function. Then the objective function needs to be carefully chosen to capture the physics of the addressed problem. In this work, the numerical analysis of the blood flow phenomena uses the finite element method approach and a geometrical model of the artery. Blood flow is described by the incompressible Navier-Stokes equations and the simulation is carried out under steady flow conditions. The streamline upwind/Petrov-Galerkin formulation is adopted in order avoid hydrodynamical instabilities and turbulence caused by convective terms. The optimization of the bypass geometry of an idealized artificial graft is searched aiming to minimize the shear rate integral. The shapes are described either using sinusoidal or elliptical functions. Design variables are given parametrizing the bypass geometry. Two coefficients are fixed to ensure proper connection of artery to bypass. An evolutionary genetic algorithm is considered in order to calculate the optimal shape geometry. The developed algorithm makes use of four operators: selection, crossover, elimination/substitution and mutation. Once an initial population is created, the genetic algorithm supported by an elitist strategy will seek to increase fitness as it operates. New populations are generated following the previous one according to principles of reproduction, mutation and "survival of the fittest". Optimal shapes for the two different bypass graft geometries are obtained. These models will enable us to replicate temporary physiologic changes due to the vascular interventions or changes in physiologic conditions enabling design and evaluation of medical devices.

01374
Shape Optimization of Cemented Hip Implants

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Total Hip Arthroplasty is a successful treatment for bone disease or in fracture repair. It consists of the replacement of the natural joint by an artificial one, which has two components: an acetabular cup and a femoral stem. The femoral stem is placed into the femoral marrow cavity with or without bone cement. Loosening is the most important cause of failure in cemented hip stems and it is possible to identify mechanical and biological reasons related with aseptic loosening. In fact, cement fatigue, cement-bone and cement-prosthesis interfaces debonding, as well as the biological response to the prosthesis are important

causes of failure. Moreover, implant performance also depends on the bone adaptation to the presence of the stem. This remodeling process can lead to an excessive bone tissue loss and, consequently, can compromise the durability and a future revision surgery. These factors depend on the prosthesis design, namely the stem material and shape, and also on cement mantle thickness. In this work the stem geometry and cement thickness is analyzed using shape optimization methodologies in order to maximize the prosthesis performance. The new stem shapes are obtained solving a multi-criteria optimization problem where the objectives are contact stress on the cement-bone interface, contact stress on the cement-stem interface, stress on the cement mantle, and the remodeling process in the proximal bone tissue. A total of 20 design variables were defined. The first 14 are geometric parameters defining four key stem sections. The other 6 variables describe the cement mantle thickness variation. Initial shape is based on a highly successful cemented commercial prosthesis. Geometrical constraints are considered to obtain clinically admissible shapes. With the multi-criteria shape optimization process non-dominated points with better primary performance and less stress shielding after surgery were obtained. However, the prediction of the long-term performance of optimized hip stems is necessary to confirm the relation between initial conditions and implant success. Therefore, in the future an integrated model for bone remodeling and cement-stem and cement-bone debonding should be used. From a computational point of view, the new hip stems obtained with the shape optimization model have better performances than the initial shape. Furthermore, the cement mantle optimization is very important in order to enhance cemented total hip implants.

01390

Inverse dynamic analysis of the upper limb

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The upper limb is composed of an open chain mechanism: the shoulder girdle, the elbow and the wrist. The shoulder girdle is the most complex and determinant mechanism, exhibiting the largest range of motion of all human body, being its kinematics fundamental to study the upper limb motion. This study presents a musculoskeletal model of the upper limb, based on data from the Virtual Human Project published by Garner et al. [1,2], to study joint and muscle forces. The biomechanical model is composed of 6 rigid bodies constrained by 6 anatomical joints (the acromioclavicular, the sternoclavicular, the scapulothoracic, the glenohumeral, the humeroulnar and the radioulnar) and 22 muscles described by 37 individual lines. As a result of the high number of muscles, the number of unknown forces outnumbers the number of equilibrium equations and the problem of load sharing is indeterminate. To overcome this indeterminacy, an optimization procedure is the most commonly considered method. In this approach it is assumed that muscles work is in agreement with a certain defined criteria, which result from minimizing a specific target function. In this study, our goal is to estimate muscle forces by the minimization of an objective function that represents muscle oxygen consumption [3]. The muscular activations, which control muscle force, are defined as design variables. The optimal problem is subjected to boundary constraints of the activations and muscle forces, to the equilibrium of equations of motion, which must be fulfilled, and to two additional biological constraints that prevent the glenohumeral and scapulothoracic joints from dislocating. The results show that our model is able to provide a solution for the muscle force sharing problem associated with the minimization of oxygen consumption in a prescribed human task.

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01458
Bone Remodelling Optimization Using the Natural Neighbour Radial Point Interpolator Method

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A topology optimization model based on deformation energy methods was developed for predicting bone density distribution. The bone structure is assumed to be a self-optimizing anisotropic biological material which maximizes its own structural stiffness. A novel law for the biologic behaviour of the bone anisotropic material is proposed, based on experimental data available in the literature. This new law permits to correlate the bone density with the obtained level of stress. The numerical method used in the analysis is the Natural Neighbour Radial Point Interpolator Method (NNRPIM), a recent developed meshless method [1,2]. The NNRPIM is an efficient and flexible interpolator meshless method, which presents various advantages in the topologic analysis comparing with other numerical methods such as the Finite Element Method (FEM). The NNRPIM uses the Voronoï concept [3] to force the nodal connectivity and to construct an integration mesh, both completely node-dependent. It is this node-dependency that gives the NNRPIM the advantage comparing with the FEM. The interpolation functions possess the delta Kronecker property, which simplifies the imposition of the boundary conditions. The viability and efficiency of this method were tested on a 2D model for a proximal femur under single and multiple loading conditions. The main aim was to obtain optimal designs of the femur internal biological structure using an initial body cortical bone femur-shaped body. The results show that high bone density levels are distributed along the diaphysis and form arching struts within the femoral head. The pattern of bone density distribution and the anisotropic bone behaviour predicted by the model in the single load and in the multiple load case were in good agreement with the structural architecture and bone density distribution occurring in the natural femur. This approach validates a novel method to simulate the bone remodelling process, which can be used in the future to predict the fracture repair and the treatment of bone diseases.

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01522
Arterial mechanical properties characterization with an interior point algorithm

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Atherosclerosis is an arterial disease which can be viewed from a mechanical standpoint as a modification of the the arterial wall mechanical properties, leading to pathophysiological hemodynamics conditions

in the cardiovascular system. Thus, the motivation of the present work is to develop computational techniques for identifying regions with altered material parameters in order to provide complementary data that may aid aid the diagnosis process. Some methods that deal with this problem using other techniques were presented previously [1]. To achieve our goal we set up an inverse problem via the minimization of a cost functional related to the error between the displacement field given by our mathematical model and the target displacement field, denoted by $\bar{u}$ which is somehow obtained through a medical image processing technique. The mathematical model makes use of a variational problem stemmed from continuum mechanics. In this first approach, we assume that the material behavior is purely elastic, linear and nearly incompressible within the range of infinitesimal deformations. Thus, our design variable is the elastic moduli at each point of our continuum. Hence, when the functional reaches its minimum we obtain a distribution of the Young modulus throughout our domain of analysis. The iterative process for minimizing the cost functional is started considering specific numerical values for the elastic modulus according to data previously published [2]. The numerical algorithm used for the optimization problem is FAIPA (Feasible Arc Interior Point Algorithm, see [3] for more details). This has demonstrated to be a good optimizer for nonlinear problemas as well as for large scale problems. Numerical examples are presented and discussed.

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