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Plenary Lectures

DLR'S RESEARCH IN SMART STRUCTURES FOR AERONAUTICAL APPLICATIONS

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Summary: Smart Structures technology called Adaptronics in Germany covers the entire field of making the elasto-mechanical behavior of structures adaptable. The main objectives are vibration control, noise reduction, shape control and structural health monitoring. The lecture gives a survey on DLR's recent research in these four fields with respect to aeronautical applications.

1. Introduction

The need for adaptive aeronautical structures has gained during the past years due to the increasing demands on civil aeronautics to both positively influence global climate change and to improve local noise and air quality. The ACARE group recommends the civil aircraft industry to reduce their emissions per passenger kilometer ($CO2 < 50\%$, $NOx < 80\%$, noise $< 50\%$) until 2020. Air traffic is presently increasing by 5% per year, about doubling the global economics growth of 2.6%. This means the air traffic will double within the next 20 years. Presuming that kerosene will stay the main fuel in use the specific fuel consumption must be reduced by 50% only in order to keep the emission level constant to today. Adaptive structures in civil aircraft industry are able to contribute to these goals in four different fields of research. First, morphing technology is able to adapt the wing shape to different flight conditions while enabling laminar flow. Second, vibration control contributes to an improved comfort and safety. Third, active structural acoustic control contributes to noise reduction and enables lighter structures. Fourth, structural health monitoring based on structurally imbedded sensors and actuators enables adapted maintenance intervals of lightweight structures and contributes to improved safety.

2. DLR's recent research in morphing

Intensive research has been performed within the field of morphing airframes over the last 20 years. DLR is mainly involved in civil transport aircraft research. The focus of the recent research lies on the continuous flexible gap and step less smart droop nose, on adaptive systems for flow sensing and control, and on the smart slat for active control of the radiated sound. The smart droop nose research is pursued on a full scale level with wind tunnel tests complemented by bird strike consideration, deicing, and fatigue. The smart slat research is still on a level of the initial proof of concept. Morphing wing technologies usually aim for an optimal flow for all different flight conditions. An alternative or even complementary approach to influence the flow conditions is blowing out pressurized air. A novel technology for improving the efficiency of high-lift systems is to influence the boundary-layer of airfoils with highly deflected flaps using the Coanda-effect.

3. DLR's recent research in vibration control

As one example of DLR's activities in vibration control the lecture presents the active vibration reduction of the Power Control Unit (PCU). Measurements and numerical simulations have been performed and will be presented.

4. DLR's recent research in active structural acoustic control

Lightweight structures mode from carbon reinforced plastics are characterized by a poor insulation at low frequencies. Active Structural Acoustic Control (ASAC) is a method of Adaptronics to replace passive measures of soundproofing. Active CFRP-Panels for investigating the possible reduction of low-frequency turbulent boundary layer noise have been designed and tested in DLR's acoustic wind tunnel. Recent research is focused on strategies of feedforward control even for stochastic or broadband disturbance sources. The extended systems boundaries of a double panel system consisting of the fuselage shell and the lining is utilized to improve the coherence and the causality of an active feedforward control system. Simulations as well as experiments in DLR's transmission loss facility have been performed on realistic aircraft panel structures.

5. DLR's recent research in structural health monitoring

Since the active influence of the elasto-mechanical behavior is the core of Adaptronics, Structural Health Monitoring (SHM) based on guided Lamb waves is a research field. Ultrasonic inspection based on Lamb waves is a promising technique due to their ability of propagating over large distances and their sensitivity to structural damages. Lamb waves exhibit various modes which simultaneously propagate with different velocities through the structure. In order to reduce the complexity of the multimodal wave field DLR's research aims to selectively excite and receive particular modes. Moreover, the design of actuators and sensors being directional selective as well is part of the recent research. The development of actuator and sensor network consisting of robust actuators, sensors, wires with electrical insulation and plugs is within DLR's core interest. Recent developments are presented in the lecture showing the integration of the networks into composite manufacturing processes of a full size fuselage panel with large cutouts.

6. Concluding remarks

DLR's experience in the field of Adaptronics for civil transport aircraft has evolved within the past 15 years from initial internal projects over nationally funded collaborations to European interdisciplinary teams. The research covers the most relevant application scenarios of Adaptronics. The experience of the past shows clearly that the challenges of developing adaptive aeronautical structures can only be tackled in interdisciplinary teams comprising experts from materials research, structural mechanics, aerodynamics, aeroelasticity, flight mechanics, and systems engineering.