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CONTROL SYSTEM DESIGN FOR A MORPHING WING TRAILING EDGE

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Summary: *Shape control of adaptive wings has the potential to enhance wing aerodynamic performance during cruise and high-speed off-design conditions. A possible way to attain this objective is to develop specific technologies for trailing edge morphing, aimed at variating the airfoil camber. In the framework of SARISTU project (EU-FP7), an innovative structural system incorporating a gapless deformable trailing edge has been developed. A related key technology is the capability to emulate and maintain pre-selected target wing shapes within an established margin, enabling optimal aerodynamic performance under current operational pressure loads. In this paper, the design of a control system aimed at preserving the specific geometry envelope under variable conditions, is numerically and experimentally explored. The actuation concept relies on a quick-return mechanism, driven by load-bearing actuators that act on morphing ribs, directly and individually. The adopted unshafted distributed electromechanical system arrangement uses servo-rotary actuators each rated for the torque of a single adaptive rib of the morphing structure. The adopted layout ensures compactness and weight limitations, essential to produce a clean aerodynamic system. A FBG-based distributed sensor system generates the information for appropriate open- and closed-loop control actions and, at the same time, monitors possible failures in the actuation* *mechanism. The research leading to these results has gratefully received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 284562.*

1 INTRODUCTION

Changing the wing shape or geometry for maneuver and general control purposes has its roots at the very early stage of the modern aviation. The Wright Flyer, the first engined aircraft, enabled roll control by changing the twist angle of its wing, by using cables directly actuated by the pilot. The increasing demand for higher cruise speeds and payloads led to more rigid aircraft structures, unable to change their shape to different aerodynamic conditions. The deployment of conventional flaps or slats on a commercial airplane is the common way to modify the wing geometry (other examples are the variable wing plant geometry on the F14 or the Concorde nose): however, they lead to discontinuities, in turn producing geometry sharpening, aerodynamic efficiency worsening and also noise emissions increase. Final wing geometry is generally a compromise allowing the aircraft to fly a range of conditions, at sub-optimal performance levels. Benefits could be increased if an inherent deformable wing would be referred to, either globally or locally (see for instance [1], for general aerodynamic performance enhancement or [2], for radiated noise reduction).

Wing shape morphing is a very promising area of research which offers substantial improvements in aircraft aerodynamic performance. It has interested researchers and designers over the years; a quite thorough survey may be found in [3], while early works may be found in the far past, [4]. Novel strategies have been considered in the last decade: for example, the idea of producing smooth variations of the geometry even in presence of large displacements distributed over a wider portion of the wing, is well documented, [5]-[6].

This general approach, however, gives rise to an interesting paradox: the same structure that has to withstand the external aerodynamic loads without suffering appreciable deformations, has to allow dramatic strains to let its shape match the target flight condition. Morphing structures require then a compromise between high load-carrying capacity and adequate flexibility. This target necessitates innovative structural and actuation solutions. When dealing with adaptive structures for lifting surfaces, the level of complexity naturally increases as a consequence of the augmented functionality. In specific, an adaptive structure ensures a controlled and fully reversible transition from a baseline shape to a set of different configurations, each one capable of withstanding the associated external loads. To this aim, a dedicated actuation system shall be designed. In addition, the adopted morphing structural kinematics shall demonstrate complete functionality under operative loads.

Several international researchers have been working on this topic by following different methods to significantly modify specific wing parameters to achieve better aerodynamic performance as for instance the upper skin curvature to delay the laminar transition point, [7]-[8], the local or global camber, [9]-[11], the wing span itself, [12]-[13] or the twist angle [14]-[15]. Some efforts have been focused on the development of kinematic chains [16]-[17] or the development of compliant structures [18]-[19]. These latter are designed to achieve large deformations by relying only upon the elastic properties of their structural components. This requires the balance between high load-carrying capabilities to sustain external forces and sufficient flexibility to realize the target shape smoothly under the actuation forces. Rigid-body mechanisms offer a direct solution to the morphing paradox. Actuation is carried out via a lever mechanisms driven by load-bearing actuators combing load carrying and actuation functions. Fewer actuators are typically required to control the morphing process whose overall benefit expected on the system level drives the additional mass, volume, force and power required by the actuation system. The authors of the present paper, follow this design philosphy in their work.

As it is, morphing is then a very general concept, applicable to a huge set of wing functionalities. So, it is necessary to specify an application in order to translate this idea into a device. Herein, cruise performance is addressed. Large commercial airplanes weight reduces up to 30% during a long range mission due to fuel consumption [20]-[21]. Such consistent changes in flight conditions can be compensated by varying the wing camber during the mission to obtain a near optimum geometry in order to preserve aerodynamically efficient flight. To reach this aim, several chord and span-wise concepts are developed in the literature.

Within the frame of SARISTU, project (EU-FP7), an innovative structural system incorporating a gapless adative trailing edge device (ATED) has been developed. Actuation is carried out via a lever mechanism driven by load-bearing actuators which combine load carrying and actuation capacities. Such an actuation architecture allows the control of the morphing structure by using a reduced mass, volume, force and consumed power with respect to conventional solutions. ATED function may thus be referred to as a continuous and quasi-static wing TE shape optimization control, [22]. By properly adapting the chord-wise trailing edge camber, the wing shape is controlled during cruise in order to compensate the weight reduction due to the fuel burning. As a result, it allows the trimmed configuration to remain optimal in terms of efficiency (L/D ratio) or minimal drag (D). Key benefits may be measured as reduction of fuel consumption or increase of range, expected to amount to 3% or more. Because span-wise variations can be also attained, design weight decrease through RBM reduction could be also potentially achieved. This paper deals with its control system design.

2 SYSTEM ARCHITECTURE

Civil aircraft flight profiles are quite standard but different missions may be flown (fast or slow, at low or high altitude). Lift coefficient can span over tenth to unit while weight reduces by around a quarter as the fuel burns. The best aerodynamic configuration then changes, having to match new conditions. SARISTU project addresses medium-range aircraft (around 3h cruise flight). Chord-wise camber variations are implemented through trailing edge (TE) adaptations to get the optimal geometry for different flight conditions. Upgrades are herein estimated in terms of reduction of needed fuel or range increase, expected to amount to 3% or more. Lift-over-drag (L/D) ratio is the referenced parameter to catch those performance improvements, kept to its optimal value while weight and angle of attack change. Because span-wise action variability could lead to design weight decrease through Root Bending Moment (RBM) reduction, this potentiality can be further exploited. Morphing is enabled by a multi-finger architecture driven by load-bearing actuators systems (hidden in Fig. 1). To provide camber variation, devices are designed to work synchronously (2D-type) but can be activated differentially (twist). After info gained by a widely distributed strain sensor network, the control system drives actuators action. An adaptive, highly deformable skin absorbs part of the external loads and insures a smooth profile. The system keeps its structural properties while actuated, then allowing the preservation of a specific target shape regardless the action of the operational loads. Static & dynamic responses under external excitation, are considered.

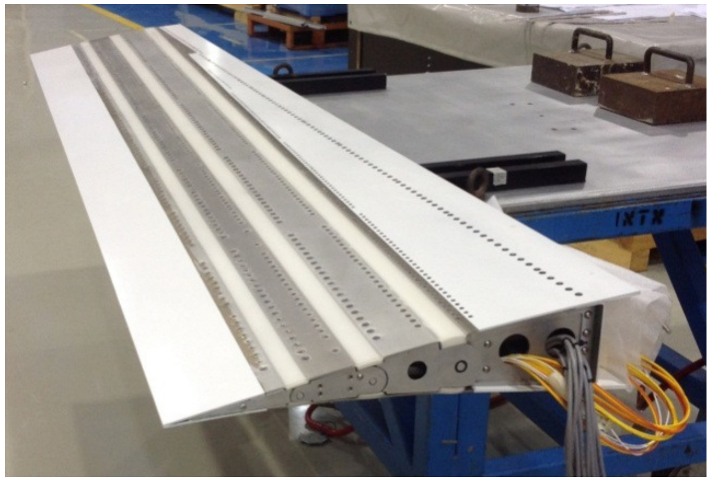

Fig. 1 – The Adaptive Trailing Edge (ATED)

3 ACTUATORS SELECTION AND LAYOUT

In order to reduce the actuation torque necessary to hold and move the ATE device, different kinematic architectures have been considered during the actuation system development. Reducing the actuation torque affect both actuation dimensions and weight. With a suitable ctuation kinematic it is possible to identify a suitable actuator that can be host in the available space of Saristu demonstrator. To actuate the ATED structure it is necessary to apply a torque on the second rib block. If the force generating this torque would be applied parallel to the camberline, the maximum available arm will be of the order of the wing local thickness. If this force will be applied perpendicularly to the camberline, the maximum available arm will be of the order of the ATED length. Considered architectures make use of these considerations and are derived by the quick return mechanism.

The first considered architecture has an arm rigidly connected to the second rib block. This arm rotate as the block itself. Torque is applied to the rib block by means of a force acting perpendicularly to this arm (if the friction can be considered equal to zero). This force is generated by a rotational servoactuator with a crank rotating with the actuator shaft. A simplified scheme of the kinematic actuation system is reported in Fig. 2:

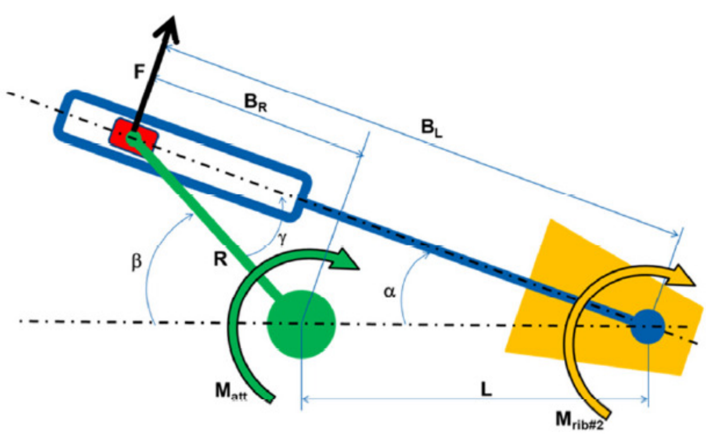

Fig. 2 – The Actuator Layout

The mechanical advantage MA of the mechanism (ratio between the loading moment and the driving moment) and the relation between the actuator rotation angle and the rib block rotation may be computed as:

$$MA = \frac{B_L}{B_R} \tag{1}$$

$$B_R = R\sin\gamma;\; B_L = L\cos\alpha - B_R \tag{2}$$

$$MA = \frac{L\cos\alpha}{R\sin\gamma} - 1 \tag{3}$$

$$R\cos\gamma = L\cos\alpha \rightarrow \gamma = \arccos\left(\frac{L}{R}\sin\alpha\right) \tag{4}$$

The mechanical advantage increases as the second rib block angle increase and this is much more evident as higher is the ratio between the arm length L (distance between the second rib block virtual hinge) and the actuation crank radius R. Similarly, formulas may be derived for the actuator rotation angle versus rib block rotation angle.

Higher is the L/R ratio and higher has to be the actuator rotation angle. This affects the maximum reachable mechanical advantage due to the fact that servoactuators available on the market have a mechanical limits to their rotation. This first architecture can reach higher mechanical advantage values but some limitations can be imposed by the maximum servoactuator rotation angle.

A second architecture wasconsidered, similar to the first one but in this case the actuation crank runs between the actuator shaft and the virtual hinge. This architecture cannot reach MA similar to the previous one. However, Respect to the former, this one gives less limitations on the actuator rotation angle, for a similar value of L/R.

The third architecture makes use of linear servoactuators and is a little more complicated than the first two. For this architecture, formulas are a little bit more complicated to be derived and depends on a lot of factors, so we will give only the a graph for a particular set of parameter values. It can reach the highest values of the MA with a limited stroke of the actuator. In addition the parameter values can be shaped in order to obtain particular behavior of MA versus the rib block rotation. Main drawbacks are the required space necessary both in chordwise direction and in thickness direction and the higher complexity of the system (two sliding block are necessary).

Considering advantages and disadvantages of the three architectures, the first architecture was selected due to:

- higher value of the reachable MA respect to the second architecture (limitation on servoactuators rotations do not seem so severe in our application due to the not so high rotations of the ATE device);
- less necessary available space and less system complexity respect to the third architecture.

Starting from these results, the main specifications for the actuators were defined, Tab.1. Available certified servoactuators have been screened on the market in order to derive the best of them suitable for ATED application. Considering actuator specs and individual performances the Bental RSA-06 actuator has been selected due to its contained weight (less than 0.5 Kg) and dimensions respect to the other candidates that satisfy the same specifications.

Parameter	**Assumption**	**Units**
Type of actuator	Piezoelectric or electromechanical (stepped motor)	
Max torque	6 (dynamic) or 15 (static)	[Nm]
Displacement	±45 (pk to pk)	[°]
Resolution	0.55÷1.1 (max actuator backlash) 0.1-0.05 (ATE device resolution)	[°]
Dimensions	100x50x200 (WxHxL)	[mm]
Weight	<1	[Kg]
Number of actuators	10	-
Actuator speed	> 10	[°/s]
Actuation signal max latency	< 10	[ms]
Nominal voltage	12 or 24	[V]
Power consumption	< 100	[W]

Tab. 1 – Servoactuators specifications

As highlighted in previous paragraphs, the actuation kinematic has an arm (actuation beam) that is rigidly connected to the second rib block. This arm rotates around the “virtual hinge” (the point around which the second rib block rotates during the movement of the ATE device) and transmits the actuation load (torque) from the actuator to the second rib block. During the design phase, it was chosen to connect this arm to the spar rigidly connected to the second rib block: these spars, together with the rib blocks and the skin, constitute a very rigid closed structure capable of bearing high loads. The chosen arrangement is showed in next Fig. 3.

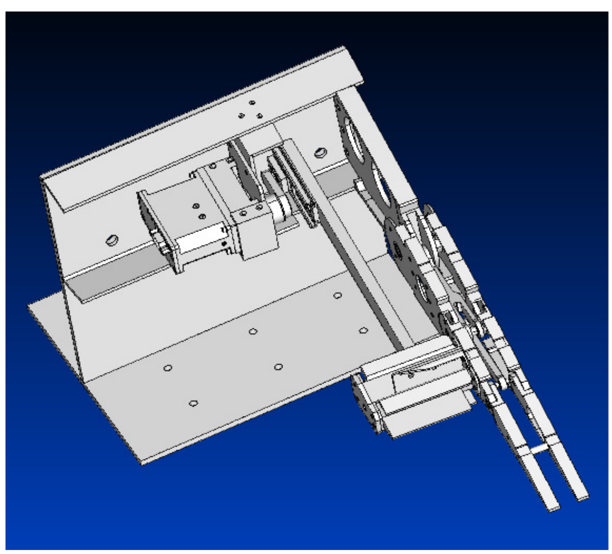

Fig. 3 - Actuator System Installation Detail

The worst case condition (Vdive) are very below the stress limits for both aluminum and steel. The actuation crank dimensions have been chosen in order to have the maximum possible mechanical advantage and to satisfy the ±45° of maximum actuator rotation. For each rib, the "virtual hinge" has been identified by considering the second rib block position in three different configurations: morphed up (max top deformation), morphed down (max bottom deformation) and unmorphed. Then, the actuators have been positioned as close as possible to the dead box spar. The distance between the actuator shaft and the virtual hinge has been then measured. The actuation crank dimension has then been fixed following the previously stated requirements and following a detialed stress analysis.

The linear guide design makes use of a COTS carriage that runs without lubrication in anodized aluminum profiles. DryLin linear bearings operate on glide pads unlike the common recirculating ball bearing systems. These bearings do not depend on the travel length and hence do not pose any condition on the minimum stroke length. In order to further reduce the occupied space, low profile guide systems were chosen.

Main advantages of this COTS component are:

- Small installation height between 6 and 12 mm
- Lightweight
- Numerous carriage options – also with pretension
- Maintenance-free, self-lubricating
- Corrosion-resistant
- Low wear with low coefficient of friction

The main disadvantage of this COTS component could be the friction between the carriage and the guide that can hinder the carriage sliding. This condition was experimentally verified to support the design phase outcomes.

4 SENSOR SYSTEM LAYOUT

The measurement task is to reconstruct the shape of the ATED, Fig. 4, from strain data retrieved from span-wise tip section and chord-wise middle bays sections.

The primary structure is characterized by four interconnected boxes composed by five bays. The most forward box is rigidly connected to the wing box through an interface spar; the remaining ones are moved by active ribs upon the action of actuators. Actuation leverages move synchronously each rib; thus making the entire structure to morph. A morphing TE based on active ribs requires the usage of soft/rigid skin materials. The edge profile of rib blocks is assessed to accommodate foam segments of the morphing skin. The adopted solution is to transmit loads in span-wise direction while morphing is achieved via chord-wise movement. A sensor system network should give a full box shape information.

In order to reduce number of actions over the morphing skin and any kind of assembly chain interferences, two kind of sensorized structures are selected: shape beams and ribbon tape. The shape beam is a sensorized cantilevered beam with integrated fiber optics. The sliding beam is opportunely guided to copy the skin profile as an independent structural system able to measure camber variations. The guide itself is opportunely designed to compensate the air gap due to the different thickness of the skin and allowing the skin profile to transfer its curvature to the beam. Basically at least three point of interest are considered corresponding to the rib hinges. This solution is the result of a cooperation among structural (University of Napoli, CIRA), manufacturing (Aernnova) and sensor (Inasco, Technobis) technology partners.

Ribbon tapes, is a very thin and flexible glass fiber reinforced patch. The span-wise deformation is expected to be coherent with standard glass FO so that ribbon tapes can be directly bonded in the inner side of the metallic tip cover and then connected to form two measurement lines in order to drastically reduce the number of channels. Structural reshape for a circular recess allow the patch-cord cable to be safely hosted inside the tip without any interference with the skin installation. Span-wise monitoring system design resulted from a cooperation among structural (CIRA), manufacturing (KVE) and sensor (Inasco) technology partners, with contributions of all the sensor technology team of the Saristu project.

Two effects are envisaged for sensors aimed at monitoring the camber shape variations of the ATED:

- ATE span-wise bending;
- ATE chord-wise bending and torsion.

Span-wise torsion is not directly detected but can be determined through the relative bending of the different ribs. All the strain data detected by this sensors net, are read and then stored by a data acquisition system that is to be used for the morphing trailing edge contains the following components

- Deminsys Interrogator
- A laptop or equivalent for monitoring the signals.
- An optical switch for multiplexing signals.
- Power supply for the Deminsys system and the PC.

The max sampling frequency being 20 KHz, the interrogation times can span the duration of the cruise flight (3h) in segments of 9 minutes, **Errore. L'origine riferimento non è stata trovata.**.. As the system is basically static during that those time frames, the sensors will not have to be sampled all at once but use of an optical switch is possible. According to the maximum number of FBGs available per channel, an estimation of the total number of FBG per channel and the total number of channel as well, can be finally formulated.

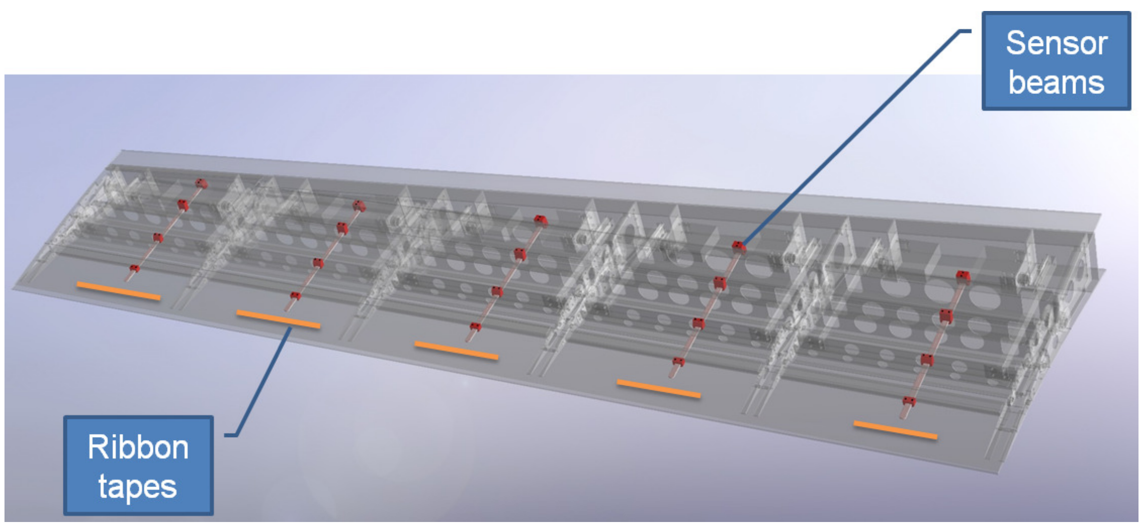

Fig. 4 – Sensor Architecture Sketch

The max system sampling frequency being 20 KHz, the needed interrogation time periods can be up to 9 minutes. As a quasi –static structural behaviour is investigated, the sensors do not need a simultaneous recording, but can be alternatively sampled by using an optical switch. Established the max number of FBG to be deployed over the structure, the system configuration resulted as detailed in the already cited **Errore. L'origine riferimento non è stata trovata.**..

5 CONTROL LOGIC

SARISTU proposes a state-of-the-art actuation system, including advanced structural electromechanical actuation system, developed by CIRA with the specialist support of Fraunhofer ENAS. An SRF (Safety, Reliability and Failure) approach was implemented to evaluate system airworthiness in a low-critical aircraft control surface, such as ATED, by pursuing:

- Simplicity: "direct-drive" actuation, without gearboxes;
- Redundancy: duplication of actuation per morphing rib;
- Fault tolerance: continued operation after single-actuator fault.

System	Characteristics	Properties
Interrogator	System	**Deminsys**
	Number of systems	**2**
	Frequency rate	**20KHz**
	Resolution	**3 pm**
	Channels	**4**
	Max number of multiple readings	**8**
	Weight	**600 gr**
	Power supply	**20 W**
Chord-wise sensors	Assembly	**Sensor beam**
	Total number of FBG	**40**
	Total channels	**5**
Span-wise sensors	Assembly	**Ribbon tape**
	Total number of FBG	**10**
	Total channels	**2**

Tab. 2 Sensor System Components

A fully-electric ATED reduces classical drawbacks of hydraulic systems and overall complexity, yielding also weight and maintenance benefits. Lack of supply buses, improved torque control, enhanced efficiency, removal of fluid losses and flammable fluids bring to further benefits. A general limit of electromechanic actuators is the possibility of jamming failures that can lead to critical aircraft failure conditions.

The adopted unshafted actuators layout allows achieving further weight savings. This architecture uses both inherent rotation sensors on each actuator and a FBG-based distributed sensor system to synchronise the different elements action and to monitor localized failures. Distributed actuation also enables the motion of individual ribs, enforcing for instance twist angle, leading in turn to further features as load alleviation. Starting from the structural design, the actuator electrical arrangement was defined.

The connections to the control system hardware, signal conditioning electronics and routing to each actuator was defined. Relative actuator movement with regards to transition times and velocity discrepancies between each rib segment were considered to synchronize each actuator. As a last step, control system components were selected. Resulting scheme is reported in Fig. 5.

The connection between control system (dSPACE Embedded System) and actuator controller was specifically designed and verified together with the implemented equipment.

6 RESULTS

The controller was real-time implemented in a DSP Board. Two architectures were considered: open loop and closed loop. In the former, the controller executed the driving command on the basis of the off-line predictions of the actuator shaft rotations needed to reach specific ATED morphing angles. In this case, the control strategy is defined open loop (feed-forward). As a result, the controller gives no feedback on the achieved trailing edge shape. In the latter, the controller monitored the actual ATED shape information either given by the FBG-based sensor system distributed over the structure or the actuator rotation levels given by the servo so that the controller actions could be real-time adjusted. Then, the control strategy is defined as closed loop (feedback control). Both open and closed loop control architectures were developed and tested.

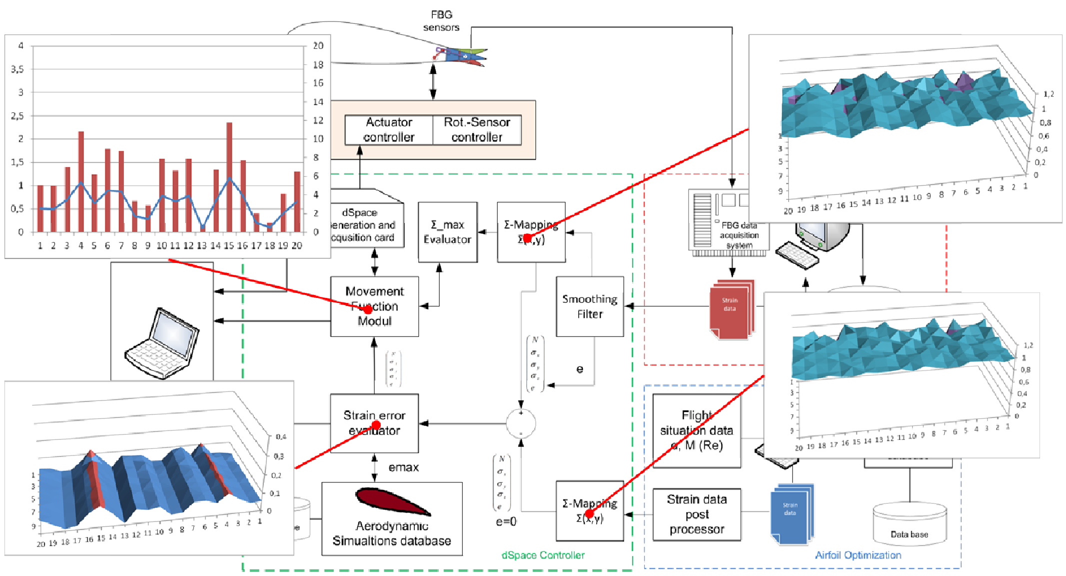

Fig. 5 –Control system schematics.

In both experimental campaigns, the actuation mechanism was driven to enforce the structure to the desired shape (±5° of morphing). The experimental results were compared with the CAD model expectations. The actual displacements of ATED structure in morphed conditions were measured and compared with the numerical predictions. The error was evaluated by the sum of square errors between the experimental and simulated data. The position of the ATE device in terms of morphing angle was obtained by minimizing this error function. The results are reported in Fig. 6. The range of ATED morphing, assessed by the minimum of the error function, was estimated in the range [-4.91°, 5.21°]. The deviations with the respect to the CAD shape are given in Fig. 7– Fig. 9 for the baseline and the full morphing deployment (+5°, -5°) respectively. Control system performance, such as actuation time, slew rate, resolution and stability were also assessed. Shape recovery capability of the feed-back control architecture was evaluated along with controller stability and robustness. Such tests were performed by impacting the trailing edge tip with an hammer after commanding the morphing deployment, Fig. 10. Strain map distribution sensed by the sensor system was also off-line processed in order to reconstruct ATED shape in morphing conditions. The differences between the actual and target shape was identified by the respective correlations with the strain levels and found satisfactory.

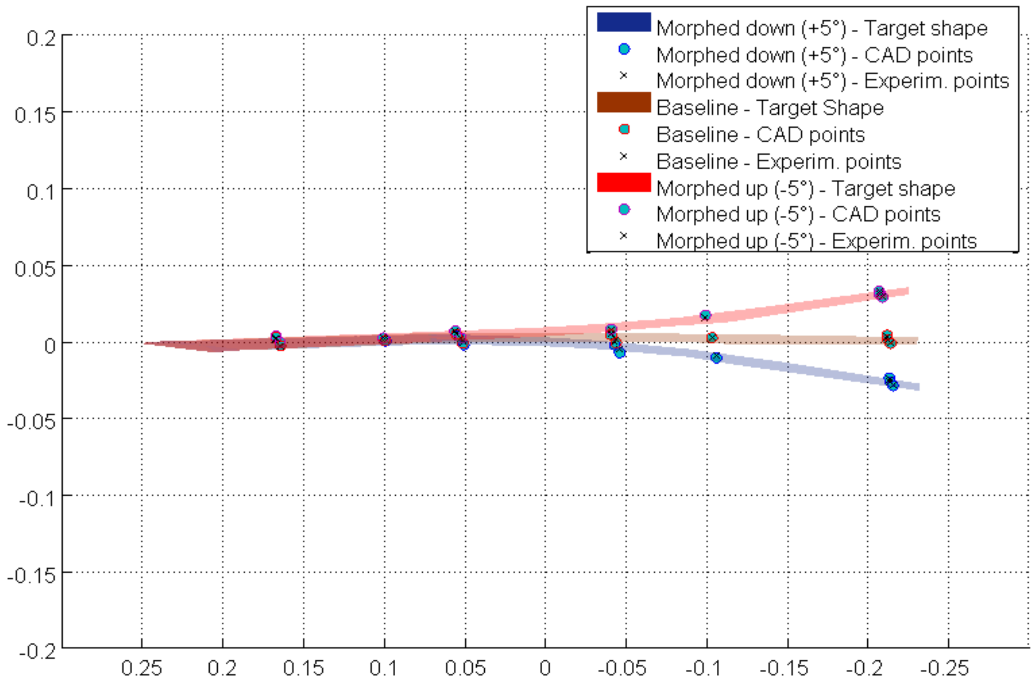

Fig. 6 – Comparison Between Actual and Expected Shapes.

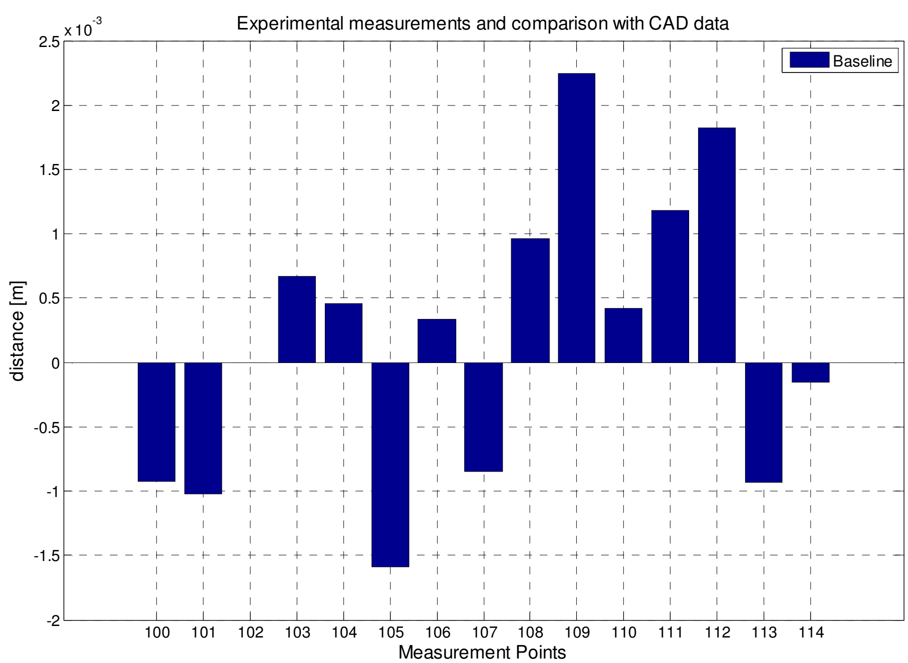

Fig. 7 – Shape deviation in baseline configuration

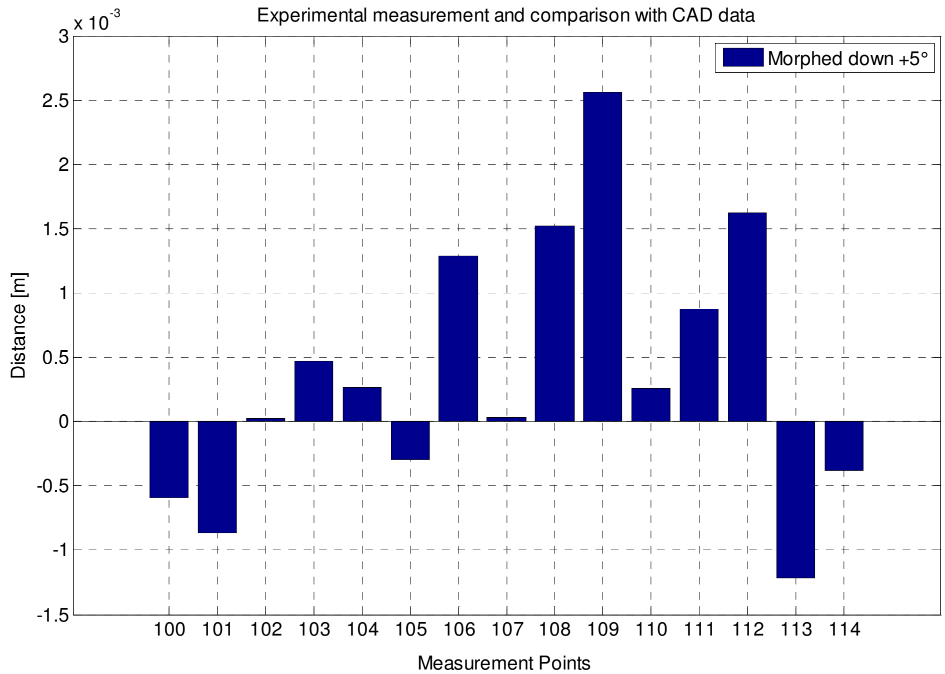

Fig. 8 – Shape Devation in Morphed Down Configuration

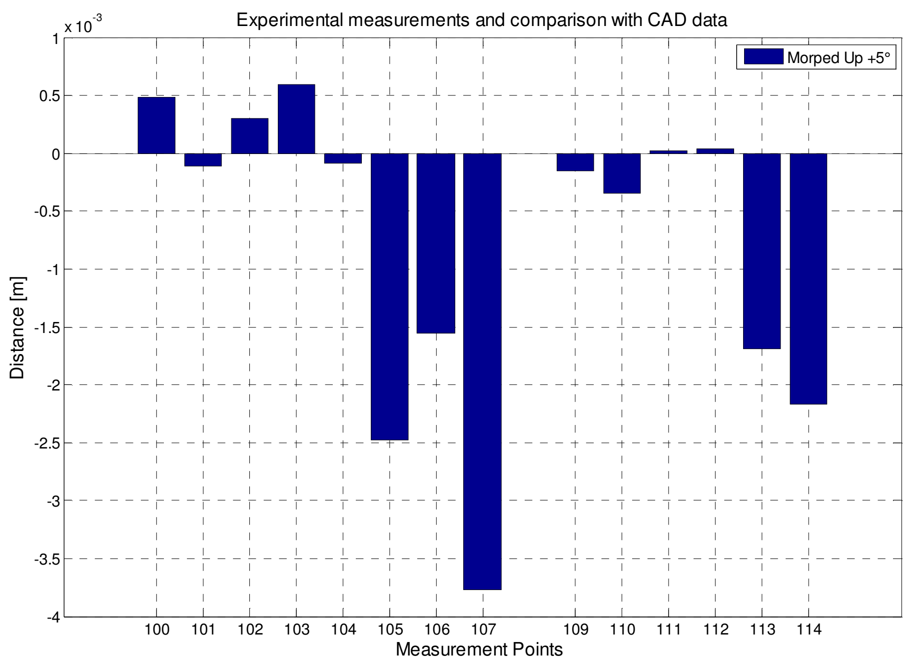

Fig. 9 – Shape Deviation In Morphed Up Configuration

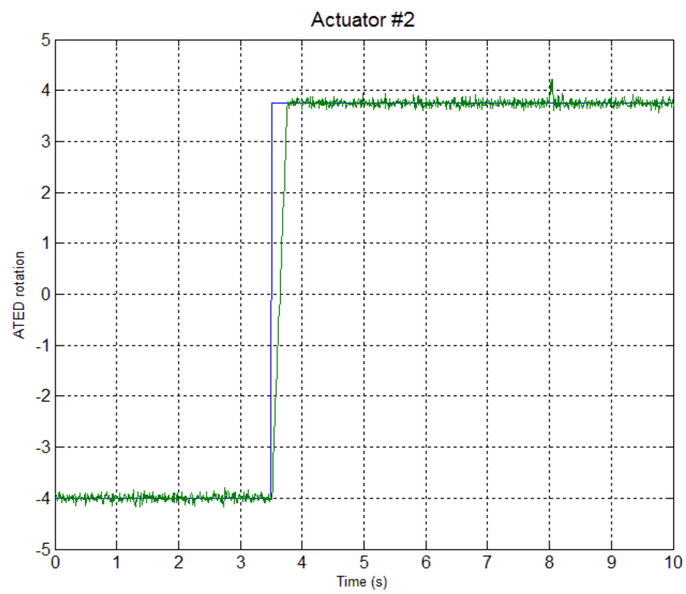

Fig. 10 – Controller Robustness Tests Through Hammer Excitation

7 DISCUSSION: IMPLEMENTABILITY ON REAL A/C

The technology herein presented has been developed with reference to a real representation of an aircraft. Then, its specifications derive from realistic load computations and assembly conditions. Its configuration is however defined with respect to a clean wing, i.e. without command and control surfaces. Moreover, in order to properly asses the deriving polar and the consequent L/D estimatetions, the whole aicraft should be considered, in order to properly taking into account the presence of the horizontal tailplane that compensates for centre of gravity excusrsions and concurs to global produced lift. From the point of view of deign, no impressive variations are expected, because what can change is a variation of the absolute value of the load, maybe its distribution, but nothing to drastically variate the dimensioning of the main components. The same applies to the algorithm logic or the sensors installation. Indeed, from the point of view of the real integration in a wing, referring to the investigated layout, an overall simplifcation should derive, as a consequence of the larger room available, as the device is moved to the wing chord. Some considerations should also be spent regarding the control algorith,m. The sustem is in fact based, as by now, on a feedforward, slow control logic that copmapres the measured strain to the target ones, derived from the target shapes. The different forms are established on an off-line computations and refer to the estimated performance of the engines (fuel consumption). This can be improved for at least three steps: referring to the real, reconstructred shape and comparing it to the reference (amnaytical or numerical) shape; referring to the actual wing performance, by inserting the new morphd geometry into an aerodynamic code, vaerifying the results and adjhusting the control effort, consequently; finally, because fuewl consumption is addressed target shapes should be derive d real-time form information directly derived from the instantaneous fuel consumption. Then, the passage from a mock.up to a real aircraft should consider at least the following points:

- The instalaltion should be thought with respect to a movable surface (flap), that in turn would mean a different approach and costraints for the installation, including

cable routing;
- Finer computation of the achievable L/D and a consequent better prediction fo the attainable benefits;
- Modulation of the load, moving from a (virtual) aircraft to another (real);
- Easier overall installation, deriving from a larger available inner space.
- Integrate real-time controllers, implementing fuel consumption rate as reference variable.

The concept is derived by combining classical and new technologies, all assembled into a new prodct. In this way there are well assessed components (the sensor system, the control system itself, the actuator system, the structural system), combining with other more innovative products, like the mprphing skin. While the classical components are not reasonably going to give rise to complex issues on the maintenance and the reliability (classical kinematic, actuator and sensor chain models may be referred to) the innovative skin should be imagined to undergo a long testing period in order to characterize its beahviour outside of the standard design domain above all with respect to fatigue and aging. Following these and the former considerations it is trivial to consider that a reliable maintenance plan should be designed, in order to properly address the eneginneering problem concerning the fliability of these devices. An unsolved problem should in the end be cited and concern the use of a loltitude or a reduced number of motors. Without going into details of controllability, it is clear that a large number of devices ensure the differential actuation, while a reduced set confines its finction to the uniform camber adaptation. Moreover, if a large number of devices is redundant and guarantees the global survivalability fo the system also in case of failure of some motors, it also needs shorter maintenance periods. This aspect will be nvestigated in further jobs of the authors concerning the development of the introduced device as generic load modulator. Failure and Hardous Analysis (FHA) should be also thought as the conclusive part of this path. Summing up all these terms the actual cost of the device will be derived, that is a good measure to evaliuate its real applicability to real aircraft and then, to real world. So, from the workability point of view the main items shall be discussed:

- Maturation of the morphing skin technology;
- Ensure the aging and the fatigue behaviour of the overall system;
- Definition of a suitable maintenance plan;
- Compute costs and benefits, on the basis of the reference architecture.

As a very last point, an expected impact on the general design is expected by the aeroelasticity studies. In fact, because the referred system is a deformable one, it has trivially more degreeds of freedom with respect to a standard one. This is why a higher modal density is expected toigether with a more extensive and compelx coupling of the dfferent modes. Furthermore, because the camber deformation devices are extended, reduction proceses should be properly adjusted. This would in the end result with a necessary update of standard rpocesses and codes, to face with this new challenge

8 CONCLUSIONS AND FUTURE DEVELOPMENTS

The herein presented work deals with the development and implementation of a morphing system made of integrated actuators and sensors, driven by a control architecture, strating from well-assessed technology. In this case, an innovative smart confguration is achieved by the properly assembly of standard components. In this way, many of the complications connected to the realisation of a novel device are skipped, dealing with reliable, already tested components. The adaptive trainlig edge variates the global wing curvature in order to compensate the wight variation of the aircraft during cruise, as a cosnequence of the fuel consumption. In the same way, it can adapt the same wing camber as a function of the actual take-off weight, depending on the hosted passngers and their luggage (or the boarded goods – cargo).

Nevertheless, issues still remain because of the innovative approach aimed at providing the wing system with new capabilities. They are referred to specifications assessment, architecture definition, installation aspects and implementation strategy. The specifications should be improved by considering a complete aircraft, so to compute the overall effect of the trailing edge device on the overall aircraft aerodynamic polar. Device layout shall also derive from the global reference geometry, so to assess the better engineer deployment of the device along the wing span and its chord. In the case of a real aircraft, the ATED herein referred to, shall be installded along the flap zone, so that complications are expected, following the implementation of a complex kinematic system on a movable surface. On the other hand, available rooms should be far more adequate to host the innovative componets with respect to the wing tip zone. Indeed, studies to verify the possibility of inserting such systems in the aileron are currently performed by this same team and other researchers. Implementation strategy shall instead refer to real-time adjustemnt, derived from information coming from the objective parameter value, that is herein represented by the fuel consumption instead of being derived from extrapolation on the reconstructed geometry.

Speaking in detail of the implemnted architecture, herein discussed, some aspect can be directly improved, without referring to extensive changes into the approach as the abovementioned ones. The actuator system design shall be integrated with the structural design, so to come to a unique active structural, load-bearing system, instead of merging to componets, separately developed. Sensor system is constructed on the basis of an extended network, made of fiber optic FBG (Fibre Bragg's Gratings). This reduces the cables number drastically. However, form real implementation it comes out that this number remains high. In order to further improve this aspect, wirelss systems should be addressed, irrepsective of the nature of the sensor material or nature. Of course, such an architecture leads to further complications, mainly associated to the inner architecture (need of defining a sutable path of signal transmission), to the sensors feeding and the compatibility with the other, existing aircraft systems. Control system capability should move from adaptive feedforward architectures, based on pre-built strain maps, to real-time feedback systems, sensible to the selected objective parameter; therefore included into the overall aircraft avionics

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