FutureWings Project

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"Publishable summary"

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iChrome

Publishable summary

Summary description of project context and objectives

The FutureWings project is aimed at the theoretical study, and preliminary experimental validation, of a wing structure having the capability of changing its aerodynamic shape through the use of a new type of hybrid materials, which are based on the implementation of layers of piezo-electric fibers into laminates of composite materials.

Such a wing will be capable to deform on command, which means that it will be possible to modify aircraft aerodynamic loads without the installation of traditional control surfaces (ailerons etc.) in the wings.

In this sense, the application of the control devices is not conventional, because the piezo-electric active layers embedded in the composite material structure will be used to obtain the desired deformed shape of the wing and not only to control the dynamic behaviour of the wing structure, as it is presently done in a certain number of groundbreaking applications.

The deformed shape of the wing will be obtained exciting the active piezo-electric layers in a quasi-static manner, and that gives us the possibility to use a low electric power level: it is therefore expected that very low current intensity values and medium voltage values will be necessary to command the FutureWings structure.

A small scale model of Future Wing will be manufactured in the second period of the project: it will be realized through the proper design of the hybrid active composite laminate, based on the experience done testing ad hoc specimens of the same material and setting up calculation models, which have started in the first period. Mechanical tests on this model will be carried out to verify the technical feasibility of the FutureWings concept.

At the same time, a good part of the scientific efforts will be devoted to the theoretical study of the mechanical behaviour of an innovative aircraft based on the FutureWings concept, that is an airplane without high velocity control surfaces on wings (ailerons), without horizontal control surfaces (a fully deformable horizontal tail is considered) and without rudder (fully deformable vertical tail).

In addition, the complexity of problems and the novelty of challenges which characterize the Project, paves the way for the preliminary development of an integrated design tool which would allow a simplified and, at the same time, robust handling of the structural architecture of the components of an airplane.

The entire project is divided into 10 Work Packages and 23 Tasks having the following objectives which will converge into the single more above mentioned goal of the Project:

Obj. N.1: Characteristics relevant to the utilization of Piezoelectric Fibers Laminas into “active structures”. Measure of the structural characteristics (static, dynamic, effects of temperature). Are the laminas with PE fibers embeddable within laminates of composite material rather than simply be glued as MFC? Identification of future research to be done to improve their performance.

Obj. N. 2: Utilization limits of the Piezoelectric Fibers Laminas as structural active components. Which deformations imposed by the laminas with PE fibers are necessary to obtain the aerodynamic control of a wing? How many laminas of PE are necessary to produce such deformations? Is this number realistically applicable?

Obj. N.3: Comparison between the structural behaviour of a Future Wing and a Conventional Wing. What are the structural differences between a wing with embedded PE Fibers Laminas compared to a conventional wing (deformability, weight, simplifications, complexity)? What are the differences in their aeroelastic behaviour?

Obj. N.4: Development of new calculation techniques specific to the purpose. Development of analytical models for the calculation of active modular wing structures (Future-Wing Unit). Development of a computer code for the optimization of the active structure (balance between the lay-up of passive carbon-fibers layers in the structure and the distribution of the minimum number of active PE layers to get the aerodynamic forces consistent with the structural strength).

Obj. N.5: Integrability of Piezo Electric Fibers Laminas as structural active system in a wing. What are the technical limits (number and typologies of wire connections, insulation’s problems), drive (voltage, power) and control (software) that might prevent the installation and the use of a large number of PE Fibers Laminas in a wing structure?

Obj. N.6: Feasibility and limits of the Future Wings Airplane concept. To which extent the presence of Piezoelectric Fibers Laminas affect the mechanical response of the structure? What is the expected level of deformation that active elements can produce inside a structure? What are the technological limits to increase the performance of hybrid composite laminates having embedded Piezoelectric Fibers Laminas, and what still needs to be done to overcome such limits?

Description of work performed and main results

Theoretical and computational analysis

Looking at the first part of the Project, a theoretical model based on the classical elementary theory of the thin walled structures (lumped parameters model) has been developed; the warping constraint effects have been evaluated by means of the standard method of the elasticity equations. The effects of imposed shear strains in the panels (pure torsion) and imposed axial strains in the booms (differential bending) have been analyzed and modeled in a uniform beam (no taper, uniform and homogenous material) representing a wing-box with a simply connected cross section: this condition simulates the application of piezoelectric MFC patches on the beam panels.

A closed form solution has been obtained for the tip rotation angle due to torsional effects: the rotation angle of the beam tip depends linearly on the forced shear deformation component; moreover there is, obviously, also a contribute coming from the axial constraint in the booms, but this contribute becomes negligible (in first approximation) increasing the number of hyper static unknowns in the model. In other words, also in this case the effects of the constraint are very important only near the clamped root section, as it is well known.

In a technical but futuristic application of this technology, as a first result, it can be said that to deform complex and robust aero structures we would need to get large deformations actuators (for example providing maximum elongations at least equal to 10000 ppm or 15000 ppm).

At the same time a very important amount of work has been dedicated to the simulation of realistic hybrid specimens made of composite materials and MFC patches. Bending and torsion specimens have been studied in detail for several weeks by means of non-linear FE analyses. At the end of this analysis, detailed drawings of the specimens have been prepared in order to proceed with the manufacturing and testing phases.

Experimental evaluations

A set of little strips of carbon/epoxy laminates and glass/epoxy laminates have been cut in a milling machine starting from thin plates made of 4 layers of 2 mm thick fabric. These strips, instrumented by means of biaxial strain gauges, have been used as specimens for measuring the elastic characteristics of the orthotropic substrates material used for the hybrid specimens.

The hybrid specimens have been manufactured in two different typologies: carbon/epoxy substrates and glass/epoxy substrates. The piezoelectric actuators made with MFC patches have been glued on both sides of the substrates. The possibility of a co-curing technique was evaluated, but due to the uncertainty of the final thicknesses and the stiffness characteristic of the specimens, it was decided not to use it.

The mechanical components of the test equipment have been produced, in particular a system of three linear slides controlled by computer has been realized and assembled. This slides allowed the positioning of the laser sensors that have been used to measure the initial deformation of the hybrid specimens, and the deformations induced by the piezo-electric actuators during the tests. A preliminary and novel version of the electronic control system of the piezo-patches has also been produced: in particular. a High Voltage Amplifier with 6 independent channels has been manufactured to the purpose.

Preliminary deformation tests of the hybrid specimens have been carried out: the comparison between experimental and numerical results shows a very good agreement, confirming the validity of the numerical models developed in the first part of the Project.

Measurements of the mechanical behaviour of the hybrid laminates specimens (piezo-layers + composite-layers and/or piezo-layers + aluminum-alloy-layers) will continue in the second part of the Project, and they will be accompanied by mechanical and functional tests on a small-scale model of Future-Wing.

Analysis of the flight mechanics of the “Future-Wings Concept Aircraft”.

A preliminary work aimed at determining the flight mechanics characteristics of an innovative aircraft designed under the “Future Wings” concept has started. In particular, starting from the CAD model of a reference aircraft that has been made available by the industrial partner of the Consortium, a parametric geometry of the aircraft with deformable wings has been constructed.

This parametric tool will be used to update the aircraft lists that is actually available in a flight demonstrator developed at the University of Pisa. At the end of this activity, the simulation of a flight of a Future-Wing aircraft configuration will be possible (at least an aileron’s maneuver will be simulated).

At the same time the basic principles and criticalities relevant to the development of a numerical aeroelastic model of a Future-Wing aircraft have been defined and discussed thank to the substantial contribution of the industrial partner of the consortium.

At the end of the Project, it will be possible to state an assessment of the aero-elastic and aeromechanical characteristics of an aircraft based on the Future-Wing concept, and a comparison with a conventional aircraft.

Expected final results and potential impacts

Scientific and technological contribution in the market of new materials

The FutureWings project is going to sign a significant step ahead in the knowledge of Piezo Electric Fibers Laminas behaviour, giving to the community more clear ideas on their exploitability as part of structural elements. More in general, it will allow an improvement in the knowledge and products development in the field of new materials (hybrid composite materials), and will contribute to the development of a European area of technological excellence in the market of new materials, that is one of sectors with the strongest potential economical development in the world in the decades to come.

The increase of scientific tools of investigations and technological know-how produced by the project, will provide an important contribution to the companies involved, and a potential strong increase in the possibilities of application of smart materials not only in the aerospace industry but also in the mechanical and civil engineering. Work opportunities for of young engineers, high-level technical staff, skilled workers and, at the same time, applied research opportunities will be hopefully much increased at the end of the project being the covered subject of actual and increasing interest from the industrial point of view.

As far as aeronautical applications are concerned, it is too early to draw conclusions, nevertheless from the initial knowledge developed in the first part of the Project, it seems that structural applications of Piezo Electric Fibers Laminas shall be accompanied by the development of more performing materials, even if the possibility of positioning self deforming structures starting from the wing tip, play a positive role in reducing maneuver loads and necessary deformations.

At the end of the project the small scale Future-Wing model, principally conceived and used for the experimental part of the research, will be a powerful tool for demonstrations during the dissemination activities of the project results.

Computer aided inventive design

A further development of a multi-disciplinary optimization software can lead to the development of new and very efficient methods, fast and flexible, for designing complex and highly integrated engineering systems, structures and machines. In fact, new software products will be early necessary in the project in order to be able of simulating a complex and completely new system: the Future-Wings Aircraft, where no previous experience and reference data exists, nor can be used to define in a good form its technical specifications.

This type of software will allow to get new skills in an innovative field that can be called “Computer Aided Inventive Design”. This will not be just a simple new CAD code, but a software tool that will help in the first design phase that, as it is well known, strongly depends on the quality and the skills of the personnel involved.

In other words it will be a first tangible approach to a new design tool aimed to “virtually handle”, in real time within a computerized virtual environment, the shape of new products belonging to completely different technological fields and that, at their early stage, are only in the mind of the more experienced designers.

Again, the development of a new European area of technological excellence in the global market of computerized and integrated products design, will be possible starting from FutureWings project results.