POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

PNRR 117 Research Field: TOWARDS AN EFFECTIVE FIBER OPTIC BASED HEALTH AND USAGE MONITORING FOR COMPOSITE AERONAUTICAL STRUCTURES

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The use of composite materials in aircraft structures is constantly increasing to enhance the performance of new aircraft. At the same time, however, considering the life cycle of products is now essential to increase their sustainability. Photonics is one of the KETs that can be exploited to achieve these goals. In fact, Health and Usage Monitoring Systems based on Fiber Optic Technology for monitoring the operating condition of primary structural components are now mature, with the aim of being able to optimize maintenance interventions, avoiding unnecessary too frequent operations or foreseeing their increase only when necessary, all to the benefit of improving maintenance costs, optimizing the life cycle of the product, and ensuring flight safety. Within this scenario, although relevant examples (in the scientific literature) of the use of these HUMS systems for shape sensing and damage detection of monitored components do exist, these do not currently find use in actual aerospace applications due primarily to the difficulties of installing fibre-optic sensors and to the added weight and bulk required by the ancillary instrumentation required to operate the complete system. This research will address exactly these limiting aspects of the use of fibre-optic structural monitoring technology by taking advantage of recent advances in integrated photonic technology and developing so-called Photonic Smart Veils that, by incorporating both fibre-optic sensors and related interrogators based precisely on integrated photonic

	technology, will overcome the technological limitations underlying the preclusion of the use of fibre-optic monitoring technology for aviation use. The proposed research contributes to the achievement of the objectives of the fourth mission of the PNRR: M4C2 - Dalla ricerca all'impresa. This research contributes to the achievement of the objectives of the fourth mission of the PNRR by developing professional training and strengthening the research and technology transfer chain.
Methods and techniques that will be developed and used to carry out the research	The first part of the activity will develop a sensorised foil (PSV) that will house both the fibre-optic sensors and the connection system. Depending on the availability of sufficiently miniaturized interrogators on the market, the next step may be to include in the monitored element the entire measurement chain to achieve the full integration of the monitoring system. PSV development will require intensive technological activity, consisting of the following steps: 1) Choice of materials (several pre-preg composite materials, commonly used for the production of aircraft components will be considered); 2) Development of techniques for embedding optical fibres within sensorised composite elements. 3) Evaluation of the invasiveness of PSVs embedded within structural composite elements. An appropriate case study will then be identified with the design of simplified but still representative structural elements of the application case so that they can be tested at the University labs. The second part of the activity will be devoted to the development of numerical models and algorithms for the analysis of signals recorded by fibre-optic sensors to effectively implement a strategy for monitoring the health status of an aircraft component during its operational life. The following activities will be addressed: 1) Evaluation of strain and stress levels in the component subjected to normal operational loads and identification of simplified geometries representative of specific parts of the monitored components 2) Development of algorithms and numerical approaches aimed at identifying possible nucleation areas of delaminations to monitor their propagation under operational loads 3) Identification and definition of the general architecture of the SHM

	monitoring system. Algorithms and numerical models will be developed and validated through experimental activities performed on simplified but still representative elements of specific parts of the structural element chosen for the activity. More complex sensorised prototypes up to the actual component may be produced by exploiting Leonardo's production facilities and the skills developed within the research project for complete experimental validation of the chosen component within an operational deployment scenario. A 6-month internship at Leonardo Helicopter Division is planned to implement the final HUMS system on the final prototype. A 6-month period abroad is foreseen at TU Delft.
Educational objectives	The specific objective of this PhD is to develop multidisciplinary skills in the field of aeronautical structures. In addition to the development of technologies and strategies for monitoring, the candidate will acquire familiarity with all aspects related to the production processes of composites, starting from the numerical design phase up to the more purely technological and experimental aspects. Moreover, through this project, the candidate will develop an attitude open to innovation and exchange between the research and industrial worlds, with a general focus on the preservation of the ecosystem, reduction of the impact of climate change through technological innovation and promotion of sustainable development. In this sense, the education will be complemented by a broad variety of soft skills, including presentation of the research, report writing, outreach, dissemination, and preparation of industrial progress meetings.
Job opportunities	The PhD graduate will have high-quality theoretical and technological expertise in the field of aerospace structures. The competencies acquired during the research will be appealing for manufacturers, which require highly skilled engineers having the capability to understand and manage design and manufacturing processes as well as to develop and apply ever more efficient maintenance strategies.

Composition of the research group	2 Full Professors 1 Associated Professors 1 Assistant Professors 5 PhD Students
Name of the research directors	Prof. Paolo Bettini

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Leonardo S.p.A.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	TU Delft (NL)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.