Development of On-line Damage Monitoring System for Evaluation of Composite Cockpit during Static/Fatigue Structural Tests

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Abstract

The mechanical evaluation of an aeronautic structure is a common activity performed during the development phase of an aircraft. Artificial damage is induced in the aerostructure in order to assess its performance during flight, where the apparition of damage should not affect the safety of the aircraft. Therefore, a continuous evaluation of induced damage during mechanical testing is required. Nowadays, inspections are usually performed during scheduled and non-scheduled stops of the tests, basically, by ultrasonics. The obtainment of inspection registers is limited since most of the inspections are performed manually, and the apparition or evolution of an indication is directly marked on the structure. On the other hand, performing manual ultrasonic inspections during mechanical loading are not allowed due to safety issues. Any breakage of the targeted structure, tooling or the hydraulic infrastructure can affect seriously the human team performing the work.

In this work, a full system for continuous monitoring of damage progress during structural tests has been developed. The system is based in thermographic inspections, allowing the detection of fiber breakages and/or appearance of delaminations in a composite cockpit. The system can be utilized at test stops but also during mechanical loading (even in static or fatigue). It consists of a thermographic camera attached to a semi-automatic tool, together with an illumination source for heat excitation. The position of the camera is controlled by a semi-automated positioning tool connected to a software interface capable of (i) locating the thermographic camera on selected positions for assess the progress of the damage, (ii) storage the data coming for the scheduled/non-scheduled inspections (performed by active thermography), (iii) detecting the apparition or evolution of damage during mechanical loading in real time, (iv) performing quantitative/qualitative analysis of damage severity, between many other functions. Finally, results from a composite cockpit structure are presented for validation of the system.
1. Background and Objectives

Structural tests are part of the certification process of an aerospace product. The main objective is to ensure performance, quality, safety and reliability of the final components. Structural tests on CFRP parts require Non-Destructive Testing (NDT) during execution to check the behaviour of the component and check the evolution/apparition of artificial defects like impacts, delaminations, cracks, etc. Indication monitoring can be performed by several methods.

The aim of this project is to develop innovative Non-Destructive Testing (NDT) techniques to on-line monitor CFRP damages during structural tests execution. The demonstrator is based on infrared thermography method, and it has been selected as the best solution for these issues according to (1). has included one ND technique.

NDT instrumentation can perform automatically and without human intervention data acquisition and analysis and will transfer results to the structural test control system in real-time. This approach will allow to: avoid human intervention; reduce inspection time; improve inspection quality by providing NDT data positioning and recording; simplify system automation; and provide processed data by means of image processing and data fusion, extracting automatically relevant information to support structural test follow up and associated decision making procedures.

The NDT demonstrator has been validated at subcomponent level and in a realistic scenario.

2. Results and Conclusions

The process of NDT monitoring during structural tests and in parallel with them has been tested and probed, recording indications in real time. Possibilities of remote controlling of the NDT system have been developed as well, having the possibility to change several parameters remotely.

The system architecture is based in a client-server configuration, having the possibility to access remotely to all the information and data acquired, through IP network.

The NDT technique chosen for the system is Infrared Thermography, chosen as the best cost-effective solution for implementation. Based on this technique, Passive Thermography is used to monitor in real-time the structural tests during loading of the structure; and Active Thermography is used when structural tests are stopped, to assess and evaluate the damage in more detail (scheduled and non-scheduled inspections). Different algorithms have been tested and implemented for each one in order to properly monitor and filtering only the relevant information (Passive) and to post-process the data acquired to ease the evaluation process (Active).

In addition, the system developed includes the following tools:
- Inspection Area Mapping
- Comparison of NDT registers (and other inspection records: visual, UT, …)
- Evolution curves of Damage Index
- Positioning of the NDT system is partially performed in a remote way, by means of motors and drivers.
To industrialize the system, lines of development should revolve mainly around the following topics:
- Go in deep with the relation between damage index and a real parameter of damage (close collaboration with industrial manufacturers is needed).
- Improvements in mapping tools
- Improve integration between NDT system and structural tests platform
- The electromechanical platform should be scaled according to the part/s being inspected and specific for it. Once defined should be integrated with the NDT system.
- Depending on the scope of the inspections, more than one NDT system could be used.
- Improvements in Comparison tools.

Figure 1 shows the main developed concepts of the system: view of the system operation on CFRP cockpit; software windows including on line monitoring and schedule inspection options (like image processing algorithms, etc.); automated tools for indication detections, etc.

Figure 1. View of main possibilities of NDT system based on IR thermography for structural tests monitoring of CFRP cockpit.

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