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IMPACT & DAMAGE LOCATION IN COMPOSITE STRUCTURES BY SPATIAL SIGNAL CORRELATION ANALYSIS

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ABSTRACT

This work proposes a novel and robust method for impact and damage location in composite structures. The method uses vibration-based techniques, spatial assessment and correlation of Frequency Response Functions, (FRF). A realistic case-study was deployed in a 1x1 m CRFP stiffened panel instrumented with 3 accelerometers. An experimental grid-point database method is used that is further refined by FEM simulations of the dynamic response of the structure. The method is able of repeatedly and accurately locate the impact point with high robustness to the environmental conditions. The method is extended to damage assessment.

Keywords: composites, vibrations, impact location, damage assessment.

INTRODUCTION

Impact events on composite structures are a serious threat to aircraft and spacecraft (e.g., debris, hail, birds, projectiles or maintenance tools impacts) as they may induce damage (e.g., barely visible impact damages, delamination) that degrade the structural integrity. The development of accurate and robust techniques for location of impacts and potential damage assessment are therefore of paramount importance, mainly for composites structures that are impact damage prone. This structural health monitoring approach takes avail from the development of smart structures with self-sensing capabilities.

Detection and location of impact events in structures has been performed adopting several sensing and data processing approaches (De Marchi, 2011). Vibrations-based methods, acoustic waves and Lamb-waves (using piezoelectric patches or optical fibres) have been widely investigated. Traditionally, triangulation procedures have been adopted for impact location (Coverley, 2003). The accuracy is in the cm range, but with some limitations in the case of non-linearity of the impact wave velocity and of a highly dispersive nature of impact waves (difficult to identify in complex structures).

Other methods are based on angle-of-arrival or time-difference of arrival (De Marchi, 2011; Perelli, 2012) have been proposed. Impact force history reconstruction techniques have also been investigated using model update methods, but these are time consuming and they rely on an accurate model of the structure behaviour. Other alternative has been the use model-free methods, such as neural networks (Sung, 2000; Sharif-Khodaei, 2012), which are adequate for structures with complex behaviour, but require a training phase with consistent signal patterns. A real-time impact and damage location system requires an efficient, accurate and robust location method, with a high probability of detection, and with a low complexity sensor system able of covering large area structures.

In this work a novel method for impact & damage location in composite structures is developed and deployed, in a large 1x1 m CFRP plate 3 mm thick and reinforced with 2 Z-shape stiffeners. The method uses vibrations responses, spatial assessment and correlation of FRF. The Z-plate is instrumented with a minimal number of accelerometers, optimally positioned with an algorithm, and O/O signal correlations are established. An experimental database of FRF is populated with a low spatial resolution. A FEM model of the Z-plate dynamic behaviour is built, which is calibrated and optimized by a data matching technique. The impact location is performed by a signal correlation analysis, matching the frequency response of the modelled Z-plate with the spatial frequency response of the structure. The reliability of the method is shown for impacts at different positions on the Z-plate, with different forces, and under different environmental conditions. Once the structure is impacted a damage assessment method is initiated. Damage location and severity are determined by a similar approach using a perturbation method. The initial perturbation matrix is firstly built using simulations, assuming locally simulated damages. The damage location and severity is then assessed based on signal correlation techniques between experimental and simulated FRF. This study deployed a method for repeatedly and accurately locating the impacts and damages in composite structures with high robustness to the environmental conditions.

RESULTS AND CONCLUSIONS

Fig. 1 shows the Z-plate with the instrumentation set-up and software for data acquisition, processing and display. The developed method is able of locating the impact site, with a high level of reliability and accuracy.

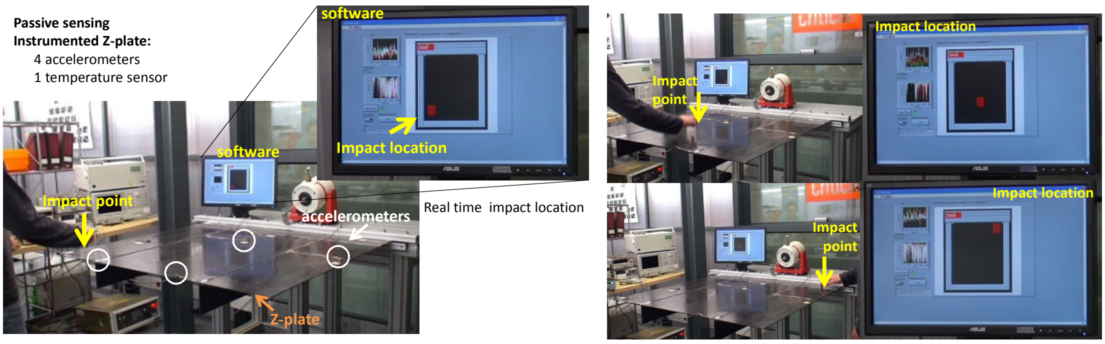

Fig. 1 - Instrumentation setup, data acquisition and display software: different impact points.

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