Non-Destructive Evaluation for Detecting Major Damage in Internal Composite Structures

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ABSTRACT

Modern aerospace structures are characterized by the increased use of composite materials. Their complex manufacturing and maintenance, due to the possibility of tailoring the structural properties with orientation lay-up and modular assemblies, require in depth study and targeted experimental testing. Moreover, aircraft composite structures are often subjected to a wide variety of damage threats. High Energy Wide Area Blunt Impact (HEWABI) damage caused by Ground Service Equipment operations are the main focus of this research. Their detection and characterization is addressed using Ultrasonic Guided Waves. Representative aircraft composite panels have been manufactured and impacted to generate the damage modes of interest. A non-contact prototype has been developed to rapidly inspect and detect major impact damage modes (i.e., skin crack, stringer heel crack and skin to stringer disbond) via access only to the outside surface of the specimens. The technique relies on air-coupled ultrasonic transducers in a pitch-catch mode and a multivariate statistical outlier analysis. The successful performance of the technique is assessed with Receiving Operating Characteristic Curves that show excellent detection.

For a further characterization of the damage types and towards the estimation of the residual strength of the impacted stiffened composite panels, a modified system is under development. The next generation approach will rely on the extraction of the structure's Green's Function (GF) and will exploit the latter in both the damage detection and the damage tolerance phase. The Semi-Analytical Finite Element (SAFE) framework will be utilized to compute dispersion curves of the multi layered composite and to select the most sensitive frequency-mode combination to perform experiments. Additionally, the shift of the phase and group velocity dispersion curves is related to the alteration of the geometry or stiffness properties of the laminate. Different laminates have been modeled in the SAFE environment, and the related forced solution has been formulated to show how the GF can be exploited in the residual strength estimation. Experimentally-retrieved GFs of multiple laminates in pristine and damaged conditions are also presented.