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Enhanced Inspection Methods to Characterize Bonded Joints: Moving Beyond Flaw Detection to Quantify Adhesive Strength

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ABSTRACT

The extreme damage tolerance and high strength-to-weight ratio of composites have motivated designers to expand the role of these materials in aircraft structures. With the improvements in various fiber reinforcements and resin systems, developments in manufacturing techniques, and increased knowledge of the material behavior, the next-generation airplanes have a much greater percentage of composite parts including the primary components. The Boeing 787 and Airbus 380 aircraft have vastly increased the use of composites for Principal Structural Elements including the fuselage and wings structures. This emphasis on composite construction has increased the importance of nondestructive inspection (NDI) methods capable of identifying interply delaminations, disbonds in laminate-to-laminate joints, and impact damage. Furthermore, it has also produced a need for NDI methods that can quantify bond strength. Bond deterioration in aging structures and bond strength in original construction are now critical issues that require more than simple flaw detection. While extensive development has been completed to mature the detection of delaminations or fiber fracture flaws in composites, the problem of assessing weak bonds has not been solved by the NDI community. Use of advanced inspection methods to measure the mechanical properties of a bonded joint and associated correlations with post-inspection failure tests have provided some clues regarding the key parameters involved in assessing bond strength. Recent advances in ultrasonic- and thermographic-based inspection methods have shown promise for measuring such properties. Vibrothermography uses the effect of externally-induced vibrations to excite a structure and observe the resulting heat patterns within the material. This approach may be sensitive enough to reveal subtle material differences associated with weak bonds such that the monitored thermal field can be correlated with the strength of the bond (properties of bond material). Similarly, specialized ultrasonic (UT) inspection techniques, including laser UT, guided waves, UT spectroscopy, and resonance methods, can be coupled with unique signal analysis algorithms to accurately characterize the properties of weak interfacial bonds. The generation of sufficient energy input levels to derive bond strength variations, the production of sufficient technique sensitivity to measure such minor, and often nonlinear, response variations, and the difficulty in manufacturing repeatable weak bond specimens are all issues that exacerbate these investigations. This paper will present several ongoing efforts to quantify bond strength and review a number of completed studies that provide a foundation for further evolution in weak bond assessments.

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