IN-SITU LAMB WAVES IN LAMINATED COMPOSITE PLATES FOR SPACE APPLICATION: INITIAL INVESTIGATIONS

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The demand for reduction in weight while maintaining/increasing strength capacity has led the aerospace industry to develop composites as alternatives to metallic structures. Companies such as Lockheed Martin Michoud Operations and Northrop Grumman have recently developed composite tanks for the storage and transport of cryogenic liquid hydrogen and oxygen for use in future space craft and station operation. Due to the pressures and thermal fatigue imposed upon the tanks during operation, a need exists to ensure that delaminations, leaking, cracking, and other structural health degradations are detected early enough to prevent catastrophic failures. One solution to this structural health monitoring (SHM) need is through the use of guided surface waves known as Lamb waves. Through actuation of in-situ piezoelectric wafer active sensors (PWAS), Lamb waves can travel relatively long distances and interact with the geometry of the structure under scrutiny. Those same Lamb waves, after interaction with the structure, can then be readily collected with either the same PWAS (pulse-echo) or by additional PWAS (pitch-catch and array technology). In addition, standing wave techniques (through use of electro-mechanical impedance using the same PWAS) have shown great promise in the detection of defects local to the PWAS.

The laboratory for active materials and smart structures (LAMSS) at the University of South Carolina has made advances in experimental and computational modeling of Lamb wave propagation in composites for wave packet tuning purposes. USC has performed the SHM methodologies described above on a 16-ply quasi-isotropic composite plate in order to experimentally determine lamb-wave phase velocity dispersion curves (wave mode amplitudes as a function of frequency) as well as the effect of direction (relative to the ply orientations) upon the amplitude. “Loud and clear” Lamb wave propagation in the composite plate were successfully achieved using in-situ PWAS. Isolation of the S0 mode was achieved by tuning the S0, A0 and SH0 modes to create a desirable noise (A0 and SH0 wave modes as well as any additional background noise) to signal (S0 mode) ratio. Computational theoretical studies on composites work following Nayfeh theory, has led to the development of software that can predict the lamb wave dispersion curves for different kinds of composite material plates. The theoretical curves generated from the LAMSS software have been compared with the experimental curves from the mentioned 16-ply quasi-isotropic composite plate and the two curves showed good agreement.

With the objective of SHM of a composite tank such as the ones listed above, the ability of currently used PZT PWAS with standard room temperature operational installation to survive cryogenic temperature was tested at USC. The PWAS showed negligible differences between signals generated and received before and after cryogenic subjection (submersion in liquid nitrogen). It is predicted that operation of the standard PWAS at cryogenic temperatures will result in the break down of impedance signatures as well as a reduction of wave mode amplitudes generated by the standard PWAS. Experimental analysis of PZT PWAS cryogenic operational characteristics will be compared to prediction and will be presented within this paper. USC is currently creating a solution to cryogenic operations through use of adhesives, connections, and piezoelectric ceramics which maintain their properties (and in some cases develop improved properties) at cryogenic temperatures.

Key Words: Composite, Lamb wave