Ultrasonic Guided Wave Interpretation of Structural Health Inspections

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Abstract

Structural Health Management (SHM) combines the use of onboard sensors with artificial intelligence algorithms to automatically identify and monitor structural health issues. A fully integrated approach to SHM systems demands an understanding of the sensor output relative to the structure, along with sophisticated prognostic systems that automatically draw conclusions about structural integrity issues. Ultrasonic guided wave methods allow us to examine the interaction of multimode signals within key structural components. Since they propagate relatively long distances within plate- and shell-like structures, guided waves allow inspection of greater areas with fewer sensors, making this technique attractive for a variety of applications.

This dissertation describes the experimental development of automatic guided wave interpretation for three real world applications. Using the guided wave theories for idealized plates we have systematically developed techniques for identifying the mass loading of underwater limpet mines on US Navy ship hulls, characterizing type and bonding of protective coatings on large diameter pipelines, and detecting the thinning effects of corrosion on aluminum aircraft structural stringers. In each of these circumstances the signals received are too complex for interpretation without knowledge of the guided wave physics. We employ a signal processing technique called the Dynamic Wavelet Fingerprint Technique (DFWT) in order to render the guided wave mode information in two-dimensional binary images. The use of wavelets allows us to keep track of both time and scale features from the original signals. With simple image processing we have developed automatic extraction algorithms for features that correspond to the arrival times of the guided wave modes of interest for each of the applications. Due to the dispersive nature of the guided wave modes, the mode arrival times give details of the structure in the propagation path.

For further understanding of how the guided wave modes propagate through the real structures, we have developed parallel processing, 3D elastic wave simulations using the finite integration technique (EFIT). This full field, numeric simulation technique easily examines models too complex for analytical solutions. We have developed the algorithm to handle built up 3D structures as well as layers with different material properties and surface detail. The simulations produce informative visualizations of the guided wave modes in the structures as well as the output from sensors placed in the simulation space to mimic the placement from experiment. Using the previously developed mode extraction algorithms we were then able to compare our 3D EFIT data to their experimental counterparts with consistency.