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# A Parameterized Delamination Model for Use in Complex Damage Characterization of Composite Laminates in Ultrasonic Inspections

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Ultrasonic damage detection and characterization is commonly used in nondestructive evaluation (NDE) of aerospace composite components. However, in real materials and structures, the dispersive waves can result in complicated behavior, particularly in the presence of complex damage scenarios and structural components. Accurate three dimensional finite element models (FEMs), using PZFlex, of guided wave interactions with realistic damage scenarios can be used to study quantitative NDE ultrasonic damage detection techniques numerically, to supplement or replace expensive experimental testing. Novel data analysis techniques such as filter reconstruction imaging methods can be used to create practical comparisons between experimental and simulated data. To compare experimental and simulated data, however, the FEM must accurately simulate the physics of an ultrasonic inspection. This requires that information about the damage be known *a priori* (e.g. through CT scans of the laminates). While possible in a research setting, this is typically not the case for real inspections in which the goal is to characterize the unknown damage. This work will describe a means of parameterizing a FEM of a composite laminate for use in a damage characterization scheme. The FEM is parameterized with a multidimensional damage model capable of describing the complex amage typical of low impact strikes in composites. The damage under consideration in this work is described by the spiraling, multilayer delamination depicted in Figure 1. Experimental laser Doppler vibrometer (LDV) wavefield data and the FEM simulated vibration responses are post-processed using the 3D Fourier transform so that the wavenumber-frequency spectra can be readily compared, building on the results and methods in [1]. The purpose of the parameterized damage model is for use in a probabilistic damage characterization methodology, discussed in a companion presentation [2]. The composite laminate model and the ultrasonic inspection are simulated using PZFlex and allows for iterative refinement of the damage. The increasing model fidelity enables fast localization of the damage followed by subsequent refined characterization.

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