Ultrasonic guided waves characterization of bonding quality on aluminum plates using an efficient 3D finite element inversion model

Daniel Pereira[1], Pierre Belanger[1]

[1]Department of Mechanical Engineering, École de Technologie Supérieure, Canada

Bonded stiffeners are widely used to enhance the performance of critical components in aerospace. For instance, a well-cured bond can provide the adhesion between a plate and a stiffener in order to increase the structural stiffness at a minimum weight penalty. The feasibility of feature-guided wave modes for the inspection of the bond line between stiffeners and host structures has already been investigated in the literature using different model-based inversion approaches. In this study, a novel inversion approach is proposed using an efficient GPU-based finite element (FE) model. The propagation of the ultrasonic guided waves was simulated in a three dimensional (3D) multi-layer structure in order to perform the inverse determination of the adhesion quality between two aluminum plates. The main contribution consists in providing a comprehensive waveguide model that, for a given excitation and acquisition configuration, can accurately account for the excitability, dispersion and attenuation of each mode. By doing so, the simulated data can be expressed in the wavenumber-frequency-amplitude domain that can be directly compared to the experimental dispersion curves using a simple and robust cost function and without any a priori knowledge of the waveguide. To validate the proposed inversion routine, experiments were conducted on a pair of aluminum plates bonded together using an epoxy resin. The feature-guided modes were excited by a piezoelectric transducer and measured using a laser vibrometer. Broadband (0-2000 kHz) experimental dispersion curves were obtained at several times during the curing period of the resin. At each measurement, the materials properties of the resin (Shear modulus, Poisson's ratio and density) were estimated by minimizing the cost function. The inverse scheme presented in this work was shown to be sensitive to variation of approximately 10% in the resin shear modulus. The estimated shear modulus remained in the range between 0.003 GPa (before curing) and 1.7 GPa (after 80 hours). After approximately 10 hours of curing and in line with observations in the literature, the shear modulus increases dramatically.