ABSTRACTS

Non-destructive assessment of the effective elastic properties of laminate composite structures is motivated by various practical needs such as the demand for reliable input data for numerical simulation and design, control of material degradation during structure operation, etc. While propagating over a thin-walled structure, elastic guided waves (GWs) carry information about its material properties, i.e., elastic moduli, density, thickness, and lamination scheme. This provides a basis for the development of appropriate assessment strategies for ultrasonic NDT and SHM systems, especially in view of the achievements in non-contact and in-situ approaches for the GW excitation and sensing using laser and piezoelectric emitters and receivers.

This approach has been implemented for the evaluation of effective parameters of laminate carbon fiber-reinforced plastic (CFRP) composites fabricated from identical unidirectional plies. The developed method is based on the use of the Green matrix of the multilayered anisotropic structure under study in the Fourier transform domain. The effective elastic moduli and, if required, the thickness and density of each sublayer are obtained via the minimization of certain goal functions that specify the discrepancies between the measured and calculated GW characteristics and/or the polar sets of Green’s functions. Previously, we investigated the sensitivity of dispersion properties of fundamental and high-order GWs for various propagation directions to the variation of certain elastic constants in the sublayer stiffness matrix for different typical lamination schemes.

As a goal function, we tested two approaches: the sum of deviations between the calculated and measured group velocities, and the inverted Green’s matrix elements, which must be zero at the poles yielding GWs. The practical implementation of the developed method is discussed and illustrated by examples of effective material property restoration for several unidirectional, cross-ply and quasi-isotropic CFRP samples. In the experiments, GWs are excited by surface-attached piezoelectric wafer active sensors (PWAS) and acquired with a non-contact scanning laser vibrometer or other PWASs arranged in a distributed sensor network. The results obtained are validated against destructive tensile tests as well as by comparing the simulated and measured transient signals carried by excited GWs.

KEYWORDS
Elastic guided waves | Laminate composite materials | Effective elastic properties | Material characterization