15th World Congress on Computational Mechanics (WCCM-XV)
8th Asian Pacific Congress on Computational Mechanics (APCOM-VIII)
31 July – 5 August 2022, Yokohama, Japan

Ultrasonic Testing and Imaging of Out-of-plane Fiber Wrinkling in Multilayer Composites with Double-side Pulse-echo Methods

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Key Words: *Composites, Ultrasonic testing, Layered structure, Out-of-plane wrinkling, Imaging*

Abstract. Fiber reinforced polymers (FRPs) have been increasingly used in various fields. However, fiber wrinkling in manufacturing and service will have a great impact on the mechanical properties of composites, which requires non-destructive testing and evaluation (NDT&E) for potential structure defects[1]. Considering that a purely analytical approach relied on the assumption of plane wave, e.g. recursive stiffness matrix[2], fails to offer accurate ultrasonic Ascan signal for wavy FRP, this study builds dedicated FRP models with out-of-plane fiber winkling using the cloud-based commercial finite element simulation platform OnScale[3], in order to assess the fiber wrinkling in the layered FRP. Then the wrinkling imaging is performed in the ultrasonic Bscan imaging by information extraction from the echoed signals based on the principle of interply resonance, in which several parameters, including signal amplitude, phase, frequency, and bandwidth, are studied for improvement of imaging quality. The analysis result indicates that the single-side pulse-echo method may give false waviness imaging results at local regions attributed to the wave beam deviation from the fiber wrinkling. Hence, a double-side ultrasonic testing method is proposed, i.e. to excite ultrasound from both sides of FRP, in order to optimize the out-of-plane fiber wrinkling imaging quality. In the proposed method, two imaging results from each single-side pulse-echo are superposed with different weights at each specific imaging region, thereby improving the imaging effect. The proposed method has great potential on FRP characterization of fiber wrinkling in the manufacturing stage.

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