APPLICABILITY OF WAVELET TRANSFORM FOR THE DEFECT ESTIMATIONS IN GLASS FIBER-BASED COMPOSITE STRUCTURES BY ULTRASONIC NON-DESTRUCTIVE TESTING

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Glass fiber-based composite materials are widely used for the construction of various structures of industrial and household applications. The most common applications are wind turbine blade (WTB) and aircraft wings which operates under cyclic loads and fiber-reinforced plastic pipes [1, 2]. Ultrasonic non-destructive testing (NDT) due to its deep penetration feature, high sensitivity, availability of wide range of transducers producing different types of waves (*e.g.* longitudinal, shear, Lamb waves etc.) and ability to extract the defect features from only one side access, is widely used for the detection and estimation of defects, flaws and delamination in the composite structures. However, the interaction of ultrasound with multi-layered composite materials causes complex mechanism such as scattering, attenuation, reflection, refraction of propagating waves and mode conversion etc. which in turn reducing the signal to noise ratio (SNR) by producing nonstationary correlated noise. Therefore, the signal processing of the received ultrasonic signals is necessary for the identification and estimation of size and location of defects.

The objective of this work is to develop the signal processing approach based on discrete wavelet transform (DWT) for the estimation of size and location of the defects located on composite structures by denoising and processing the received ultrasonic signals after an experimental investigation. The DWT is one of the most promising signal processing techniques for noise removal from the non-stationary signals [3, 4]. The ultrasonic signals are decomposed into a sum of elementary signals called as wavelets. By manipulating the wavelet coefficients with the utilization of proper thresholding techniques enable the reduction of noise and distortions from the signal.

Two different objects: a segment of WTB containing two artificially constructed disbond-type defects (15 mm and 25 mm diameters) by milling process on its trailing edge and a multi-layered pipe containing three side-drilled holes (6.3, 5.1 and 4.4 mm lengths respectively each having diameter of 0.7 mm) are considered for the investigation. Both objects contained the glass fiber reinforced layer in its structure. Apart from the attenuation, dispersion of propagating waves, the biggest problem in order to locate and estimate the size of defects in both objects (WTB and multi-layered pipe) under investigation is the nonstationary structure noise caused by scattering of ultrasonic waves by the fibers. In both cases, the DWT based algorithm is developed and applied on the received ultrasonic signals to extract the defect features with significant accuracy.

In the case of WTB, a pair of contact-type piezoceramic transducers (center frequency of 190 kHz and -6 dB bandwidth up to 300 kHz) fixed on moving panel with 50 mm separation, operating in a pitch-catch mode (one transducer as a transmitter and other as a receiver), generating/receiving ultrasonic guided Lamb waves are used to scan up to 500 mm over the defect-free and defective regions with a scanning step of 1mm. In order to proceed the contact-type ultrasonic testing, a conical-shaped protection layer of 2 mm diameter is attached to the bottom of each transducer. The transmitter was excited by 150 kHz, 3-period rectangular burst signal and receiver recorded the signals with a sampling frequency of 100 MHz. The low-frequency ultrasonic system "*Ultralab*" developed by Ultrasound Research Institute of the Kaunas University of Technology was used for the experimental analysis and data acquisition. The disbond-type defects of 15 mm and 25 mm diameters located on WTB were accurately detected after applying DWT on experimental B-scan following with amplitude detection technique which was not possible without processing.

In the case of plastic pipes, a pulse-echo immersion technique is used for the detection of defects. The ultrasonic longitudinal wave generated by the piezoelectric transducer (the aperture 19 mm and the resonant frequency of 5 MHz) propagates through a three-layer pipe structure. The transducer was excited by 140 V pulse of 80 ns duration and A-scans and B-scans are recorded by scanning the transducer along the length of pipe. The reflection of waves occurs by layer boundaries, discontinuities, front and back surfaces of layers. Moreover, the wave shape and spectral components were significantly altered by the inhomogeneous middle layer (Glass fiber-reinforced layer). The experiment was performed by using the imaging system "*Izograf*" developed by Ultrasound Research Institute of the Kaunas University of Technology. In the case of multi-layered fiber-reinforced pipe, the measurement error did not exceed ±1 mm.

Hence, the signal processing technique based on DWT is useful for the identification of defects in all composite structures producing complexity in characteristics of received ultrasonic waves due to multi-layered and fiber reinforced structure.

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