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COMPOSITE STRUCTURE MONITORING USING WAVELET ANALYSIS

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Introductions. The interaction of Lamb waves with delamination occurring in laminar composites has been studied in many experimental and analytical works. The results indicate that Lamb wave packets are separated into transmitted waves and reflected waves, with mode conversion occurring at the edges of the composite specimens, generating new modes. Delamination of laminated composite specimens can be detected either by observing the reflected waves in a Lamb wave source-receiver configuration or by observing the changes that occur in the transmitted waves as they are recorded by the receiver [1]. In the generator-receiver configuration, reflected waves are generated when the Lamb wave enters and leaves the delamination, and the reflection at the exit slightly exceeds the amplitude characteristics of the input wave. The reflected and transmitted waves vary with the delamination length. This effect is the basis of the localization method for delamination. This method records the time of flight of the reflected wave. It was found that reflected Lamb waves will not be recorded for symmetric excitation when the delamination exists in the midplane. New wave packets can be observed due to mode conversion in the delamination.

In experimental studies, it was found that delamination can cause a delay in the arrival time of the transmitted Lamb wave. Lamb waves travel independently and with different speeds in the two layers separated by the delamination, and the delamination length can be determined by measuring the difference in the arrival times of the two wave packets. Effects such as wave superposition make Lamb wave signals difficult to interpret. Therefore, efficient signal processing is of paramount importance to extract useful information from the wave receiver signals. Wavelet transforms are effectively used to extract time-domain features, which in turn facilitates the quantification of the position and size of delamination in composite samples. Lamb waves are dispersive, meaning that their group and phase velocities vary with frequency. As a result of dispersion, the received signal will have a lower amplitude and a longer duration than the excitation. This can cause a decrease in resolution. The solution to this problem is to use a windowed tone to narrow the excitation bandwidth and effectively minimize the dispersion effect.

Aim. The aim of this study is to analyze the possibility of using a broadband signal obtained by recording Lamb waves, which are used as excitation for detecting delaminations in composite plates. The advantage of this method is that the material simultaneously contains Lamb waves with different wavelengths [2]. This method is based on the fact that for a certain delamination length, only some specific frequency components are violated. The presented technique can be reduced to a direct problem, which consists of several stages. At the first stage, aspects of the theory of guided waves are analyzed. Then, finite element modeling is performed to verify the feasibility of the proposed method. At the last stage, the delamination length is estimated as a basic element of mechanical deformation in the local volume of the laminated composite.

Materials and methods. In a laminar composite specimen with top and bottom surfaces as boundaries, Lamb waves can be excited and can propagate over relatively large distances. Lamb waves are dispersive and multimodal. The dispersive nature means that the group and phase velocities of Lamb waves depend on the frequency, and the multimodal nature means that there is more than one mode at any given frequency. For an isotropic plate, this technique assumes the use of the Rayleigh-Lamb equation as the basic equation for wave propagation. This equation contains as modal parameters the wave number, angular frequency, longitudinal and transverse components of the wave propagation velocity, and the geometric characteristics of the specimen. Lamb waves have symmetric and antisymmetric modes. The motion of particles of the composite material in one plane is characterized by symmetric modes, and the motion outside a fixed plane is characterized by antisymmetric modes. The solution of the Rayleigh-Lamb equation contains the relationships between the wave number and frequency. Below the cutoff frequency of higher modes there is only one valid solution for symmetric or antisymmetric modes and, accordingly, only fundamental solutions.

Results and discussion. In this study, the forward problem of wavelet transform was solved. It was found that the detected signal from Lamb waves varies with the delamination length. The analysis of the numerical calculations performed showed that the lowest frequency that is disturbed by the delamination decreases monotonically with the delamination length. In addition, this technique allowed us to construct a method for quantitatively estimating the delamination length, which consisted of two steps: analyzing the test signal for a certain delamination, choosing the lowest frequency that is disturbed by this delamination, and finally determining the delamination size from the dispersion curve of the Lamb wave modes.

Conclusions. In this paper, a new Lamb wave testing method is proposed based on spatially fixed generation and wavelet analysis. It is shown that Lamb waves with different wavelengths can be generated under multi-frequency excitation. In addition, the finite element simulation results show that the frequency components that are perturbed by the delamination depend on the delamination length. A frequency component is considered to be perturbed if the relative change in the wavelet coefficient is greater than 15%.

REFERENCES

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