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COMPOSITES DELAMINATION ANALYSIS USING WAVELET TRANSFORMS

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Mechanical systems that include elements made of reinforced composites are used quite often in a wide range of industries. Long-term operation of such structural units leads to a fairly wide range of damage, among which we can mention delamination, matrix cracking, fiber rupture and bond failure at the interface [1]. A combination of these types of mechanical damage can lead to a malfunction of the entire system. These factors are sufficient reason for the need to develop systems for monitoring and early detection of both formed defects and a network of local damage foci that are at the initial stage of formation. The complex and anisotropic structure of reinforced composites makes it difficult to perform detailed monitoring of mechanical damage [2]. Traditional non-destructive testing methods such as X-ray, acoustic emission and eddy current require expensive equipment and strict environmental conditions. They are also impractical for use in field conditions.

Due to these features of physical processes in composite structures, the non-destructive testing technique based on the analysis of the characteristics of vibration processes in the volume of rimmed composites is quite popular both in experimental and analytical studies. Dynamic response, modal parameters and spectral analysis are used in the field of material damage detection. Among the numerous methods of signal analysis, the Fourier transform method is one of the most widely used and well-established methods [3]. Macroscale mechanical damage often occurs as a result of the development or accumulation of micro damage. Therefore, it is very important and significant to detect damage at an early stage of its development. However, it is on the microscale damage grid that the accuracy and unambiguity of the Fourier transform method may raise questions. Thus, the wavelet transform-based method for analyzing the vibration signal in the local volume of composite material is gradually adopted in many fields due to its good localization in time and frequency characteristics [4]. A large number of research works have been devoted to the problem of vibration analysis of damaged laminated composites.

However, only a few effective and practical methods have been found for the early detection and sizing of damages such as internal delamination. Therefore, this paper continues to analyze the method for effectively detecting internal delamination in fiber laminated plates by combining the numerical analysis of structural modal parameters with the wavelet packet decomposition of vibration signals.

This damage detection technique is based on the use of wavelet packets, which are a generalization of a set of compactly supported wavelets. A set of modulated, expanded, and translated initial functions forms a family of wavelet packets with fixed parameters. Discrete wavelet transforms satisfy the energy conservation condition, so the waveforms can be normalized as unit vectors. The components of the initial function are factors of the inner product with the modulated waveform whose parameters are the fixed components. If the initial function is large, it can be concluded that one of the fixed parameters indicates the presence of significant energy near the scan frequency. Therefore, wavelet packet decomposition is effectively used to analyze vibration response, especially non-stationary signals. The analysis of the technique showed that the wavelet packet decomposition of the signal has a better localization effect than a single wavelet, and therefore is used to adaptively select the appropriate bandwidth according to the characteristics of the signal. These characteristics can be used for both detection and resolution enhancement in both frequency and time domains to identify damage to composites.

The calculation method allowed us to specify the equivalent relationship between the energy of the wavelet transform and the energy of the original signal. A change in the energy in the original signal modifies the energy spectrum of the response signal decomposed into wavelet packets. The sum of the squares of the partial intensities of the decomposed signal in the energy spectrum of wavelet packets is considered as an energy characteristic in each subspace of the frequency range. In each subspace of the frequency range, the energy of the wavelet packet is determined by the length of its samples in the subspace. The calculation method of wavelet transforms was verified on a model of multilayer carbon fiber-reinforced epoxy composites consisting of five rectangular plates with the orientation [00/900/900/00]S. The calculation results indicate that with the increase of the delamination area of the composite material, the natural frequency decreases. In addition, the relationship between the natural frequency and the delamination size was investigated. The calculation results indicate the possibility of comparing the percentage changes in natural vibration frequencies with the delamination areas in the volume of the laminated composite. The normalization was performed for the absolute value of the percentage change in natural frequency (ωd – ωk)/ωk, where k and d are the intact and damaged frequency, respectively. The frequency range for the analysis was limited to 80% of the natural frequency interval for the first six modes. The change in mechanical properties caused by composite delamination can be determined from the response signal under random excitation when the energy spectrum of the wavelet packet decomposition is used as an index of the change caused by damage.

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SYSTEM ANALYSIS OF QUALITY CONTROL PROCESSES IN THE PRODUCTION OF CEREALS AND OILSEEDS

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Quality management is an integral part of modern production of food and feed products based on cereals and oilseeds. It is the quality assurance at all stages of the production system that is the key to sustainable safety and quality of the final product, which is the basis of market competitiveness.

Given the complexity and interconnectedness of all stages of the production process, which at least includes the selection, storage and processing of raw materials, only the implementation of a systematic approach allows optimizing each stage of the cycle. In order to take into account modern challenges that form specific internal and external risks and opportunities, the initial stage of establishing systematic production management is the development of a basic model. Such a model should include the minimum necessary elements of the quality management