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ACOUSTIC EMISSION IN LOADED REINFORCED COMPOSITES

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Introductions. The wide range of failure modes of reinforced composites under static and/or fatigue loading conditions is a consequence of several factors, namely the heterogeneous nature, anisotropic characteristics, and the relative brittleness of the matrix/fiber. These failure modes may include, but are not limited to, transverse matrix cracking, fiber breakage, splitting (cracking of the matrix along the fiber), and finally delamination [1]. Transverse matrix cracking is the most studied failure mode. The reason for its intensive study is that it causes severe degradation of stiffness and is usually the first mode encountered in the service of composite structures. Predicting, assessing and quantifying the nature and extent of damage in composite materials is critical because such failures can result in significant economic losses [2].

The most common solution that is applied in the operation of structures containing composite elements is an in situ monitoring system that can analyze and quantify component damage during operation. To achieve this ultimate goal, many researchers resort to monitoring methods using acoustic emission [3]. In the initial stage, acoustic emission is used to detect various emissions based on failure modes. It should be noted that in subsequent stages, the ability to identify such failures during operation entails the implementation of a method for determining their location and size. The field of acoustic emission-based failure analysis of reinforced composites has attracted much attention in both analytical and experimental work on mechanical damage detection. There are two different approaches to the analysis of acoustic emission features in reinforced composites. The first approach is concerned with the analysis of the propagation features of acoustic waves based on the study of their amplitude [4]. The second technique focuses on the study of the wave packet shape.

Aim. A fundamentally different approach is illustrated by the analysis of acoustic emission features based on wavelet transformations. Disassembling the function into harmonic components is replaced by considering the signal as a structure containing a number of orthogonal basis functions of finite length, called wavelets, according to this method. Each wavelet is distributed along the entire time axis with a given signal frequency. The signal frequency is related to a certain wavelet level. The structure of a signal, for example, crack propagation, can be analyzed by its local features. In this work, acoustic emission signals were analyzed during fatigue loading of unidirectional reinforced composites. The initial conditions for the signals were compared to three different stages of the fatigue loading process. The calculation of the main characteristics of the signals was performed using wavelet transforms.

Materials and methods. The basic wavelet transform in this paper was applied to an arbitrarily square summable real function and transformed into a series of shifted and extended waveless sums. The practical efficiency of numerical calculations was significantly increased by using wavelets based on faster algorithmic transforms. The wavelet transform technique for analyzing acoustic wave packets was based on the choice of a continuous input function. Such a function defines a continuous wavelet transform and specifies a scale level equivalent to the relative frequency and time shift. The main property of the wavelet equation containing the input function is reversibility. Inverse wavelet reconstruction is implemented using the Fourier transform. One of the main advantages of using wavelet transforms is that the input wavelet function satisfies the following conditions: wavelets must have zero DC component, they must act as bandpass filters (the signal can only be transmitted in a certain range), they must decay quickly in both positive and negative directions.

Results and discussion. The validation of the developed model was carried out by calculating the acoustic emission in a reinforced composite specimen subjected to cyclic loading with a constant amplitude. The calculations showed the presence of two distinct stages in the fatigue load curve. The first stage accounts for 5–10% of the total fatigue life. This short period of high activity can be explained by a large number of new damages occurring in the weaker component of the reinforced composite specimen, i.e., in the matrix. The second stage corresponded to lower levels of acoustic emission activity. The slope of the fatigue curve during the second stage was quite constant. The constant nature of the slope in this region indicates a linear increase in acoustic emission activity and is mainly caused by the continuous friction of the fracture surfaces created in the first stage. This stage accounts for about 75–80% of the total fatigue life.

Conclusions. The use of discrete wavelets for the analysis of acoustic emission in the volumes of reinforced composites is a rather promising method of non-destructive testing of the occurrence and development of mechanical damage. It was found that the friction-related peaks in the fatigue curve exist mainly in the first two stages. Using the wavelet transform, it becomes possible to decompose the emission signal into different levels of wavelets. Each level corresponds to the components of the decomposed signal in a certain frequency range. This facilitates the study of internal defects in the material. Based on the data collected at different stages of the acoustic fatigue curve, it can be concluded that the radiation associated with the matrix has a high frequency and high energy.

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