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APPLICATION OF 2D WAVELET TRANSFORM IN DAMAGE DETECTION FOR COMPOSITES

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Abstract: Local perturbations of composites in the structural mechanical response are small enough to be detected using wavelet transform methods. For this purpose, a distributed 2D continuous wavelet transform algorithm is developed. The algorithm uses data from discrete sets of nodes and enables monitoring of structural degradation.

The advantages of this algorithm are its dependence on local data and its ability to generate spatially continuous information. The calculation results showed that the continuous wavelet transform method is effective in describing both the deformations associated with longitudinal cracks and the deflection deformations associated with static or impact transverse loads.

Key words: continuous wavelet transform, structural degradation, longitudinal cracks, impact transverse loads, fast Fourier transform.

Ensuring the structural integrity of many sensitive structural systems requires methods for monitoring the structural health during operation. Most traditional algorithms for health monitoring methods are based on frequency and stiffness analysis, seeking to extract damage information from the measured changes in the structural stiffness and natural frequency of the structure [1]. The Fast Fourier Transform is a widely used tool for this kind of analysis [2]. The Wavelet Transform, as an extension of the traditional Fourier Transform, has become an effective tool for health monitoring methods in recent years. Wavelet transform is used to analyze the vibration signal in the time domain to detect damage in the composite structure. This transform is used to process the signals received by the sensors and determine the arrival times of the wave at the sensor locations, from which the impact location is calculated based on the theory of elastic wave propagation [3]. The technique for detecting delamination damage in a laminated composite plate is based on the energy change in the structural dynamic response characterized by wavelet analysis.

A fairly common technique at present is the spatial wavelet transform for detecting local disturbances in the structural response caused by cracks. Two cases are studied. The first case involves analyzing the deflection response of a composite with an already formed network of transverse and longitudinal cracks and subjected to static or impact loads [4]. The second case is related to the analysis of the displacement response of a composite structure in a plane strain or plane stress state. Structural damage is assessed using the wavelet signature curvature method. The signature is extracted from response signals that are detected at different locations, and the spatial distribution of the signature curvature is used to locate and quantify the damage. Spatial wavelet transform is effective for analyzing wavelet mode profiles characterizing the passage in a composite volume containing a set of transverse and longitudinal cracks.

This study is devoted to the analysis of a locally executed (in situ in embedded nodes) distributed algorithm for determining the location of defects/failures in a two-dimensional composite structure. The methodology uses a distributed two-dimensional wavelet transform, which is an extension of the fast Fourier transform.

The generalization of the continuous wavelet transform algorithm was performed as follows. In the first step, a two-dimensional fast Fourier transform was performed on the input signal of the 2D matrix. In the second step, a pointwise multiplication of the Fourier transform of the 2D mother wavelet by the corresponding entry of the matrix obtained as a result of the two-dimensional fast Fourier transform was performed. And finally, a discrete Fourier transform was performed on the matrix generated in the previous step. After the scale was determined and the fast Fourier transform coefficients for the mother wavelet were stored at each point of the computational grid, the entire 2D continuous wavelet transform algorithm can be implemented through distributed processing.

The signals recorded after the wave packets have passed through the volume can be analyzed using wavelets, which are used to analyze signals in the time domain. For this purpose, the time variable is initially replaced by a spatial coordinate variable. When damages (e.g. longitudinal and transverse cracks) and defects develop in the structure, the associated spatially distributed structural response, such as displacement, or deformation, or temperature field, will contain the corresponding additional information in the form of local disturbances (rupture, singularity). In the presence of a sensor network in experimental studies, a composite structure with defects can provide the necessary spatial signals. The continuous wavelet transform technique allows detecting the presence and location of a local disturbance in these signals, which makes it an effective tool for monitoring the structure of composite samples. This method is suitable for both dense and sparse sensor networks.

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