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DYNAMICS OF THE ENERGY SPECTRUM OF DELAMINATION PROCESSES IN COMPOSITES

Pysarenko Alexander Mykolayovich[1]

1. candidate of physical and mathematical sciences,
associate professor of the department of physics
Odessa State Academy of Civil Engineering and Architecture, UKRAINE
ORCID ID: 0000-0001-5938-4107

The combination of low specific gravity with relatively high strength and rigidity are factors that determine the frequent use of laminated fiber composite plates in various industries. The disadvantages of using laminated composites include insufficient impact resistance with a simultaneous increase in both surface and volume concentration of cracks of varying length and direction, as well as an increase in the intensity of delamination processes observed in the volume of the composite sample during its long-term operation [1]. Various structural damages cause changes in structural mechanical properties, and this property has been widely used for structural damage detection. Techniques such as modal frequency approach, transmission function analysis, resonance model, mechanical impedance approach, comparison of piezoelectric conductivity signature with baseline undeformed signature, and wavelet transform method have been used for structural damage detection in laminar composites.

However, in most of these approaches, the basic concept is the presence or absence of a local volume of deformations. Only a small number of works are devoted to the large-scale analysis of structural damage [2]. In other words, the problem of describing micro-deformations within the framework of a dynamic model of a composite structure arises. Micromechanical models of composite damage include the method of describing damage using tensor internal variables, the development of damage dynamics analysis within the framework of the theory of generalized elasticity [3], the study of mesoscale damage, and models of microcrack damage and crack expansion.

The objective of this study is to determine the location and size of delamination damage in a composite plate using structural vibration data. The methodology for analyzing the structural vibration results of laminar composites includes two steps. In the first step, the structural damage proxy function is extracted from the vibration response data of the structure with known delamination damage including its location and size. Meanwhile, the corresponding relationships between the proxy function and the real delamination damage parameters are established. In the second stage, the structural deformation database is analyzed. The final goal of the analysis is to determine the location and size of the unknown delamination damage based on the vibration response data of the structure with such unknown delamination damage. This is because the real-time vibration response data can be easily measured.

The main content of the analysis method is to obtain vibration response data using the established structural dynamics model and extract the proxy function for different locations and sizes of delamination damage using the wavelet transform of structural vibration responses.

The vibration signal corresponding to the structural deformation was initially decomposed into several sub-signals $S_k(t)$ for different frequency ranges. In this case, the original structural response signal is

$$S(t) = \sum_k S_k(t). \quad (1)$$

The energy of the k-th sub-signal is

$$U_k = \int_0^T |S_k(t)|^2 , \quad (2)$$

where
T *is the sampling time.*

A non-dimensional index vector for the intact and delaminated composite plates has the form

$$V_k = \{c_1^0, c_2^0, c_3^0, \dots\}\left\{\frac{U_{k,1}^0}{U^0}, \frac{U_{k,2}^0}{U^0}, \frac{U_{k,3}^0}{U^0}, \dots\right\}, \quad (3)$$

where the superscripts "0" denote the intact damage plates and $c_j^0, j = 1,2,3, \dots$ *are the deformation coefficients.*

Summary and conclusions. In this work, the technique of damage analysis depending on the composite delamination is improved. The technique is based on statistical processing of the energy of structural dynamic reactions decomposed using wavelet analysis. The spatial distribution of the delamination area in the composite plate is obtained. The smallest detectable extent of the delamination area is about 0.13% of the total area of the composite plate. The results of the study also show that only a few vibration sensors uniformly distributed over the side surface of the laminated composite sample are required to detect damage from delamination of the composite structure using this technique. It was found that the size of the structural damage depends on many factors, such as the extracted parameters of the structural damage features and the signal processing technology, etc. In addition, the distance between the vibration signal recorders and the local area of the structural damage has a significant effect on the accuracy of damage detection. The analysis showed that the size of the delamination crack, which is located in the range of 0.14 - 1.8% of the plate area, corresponds to the distance between the generator and the vibration signal sensor, approximately equal to 38% of the length of the laminated sample plate.

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