PHYSICAL AND MATHEMATICAL SCIENCES

UDC 699.88

DETERMINING THE DESTRUCTION PROCESSES IN COMPOSITES BY ACOUSTIC EMISSION

Pysarenko Alexander Mykolayovich,
Candidate of Physical and Mathematical Sciences, Associate Professor
Odessa State Academy of Civil Engineering and Architecture
Odesa, Ukraine

Abstract: The objective of this study is to investigate the damage mechanisms in laminated composites under steady tensile loading using the acoustic emission method. Using the dominant failure mechanism model, correlations were established between the observed damage growth mechanisms and the amplitude-varying acoustic emission results. The developed model of field correlation can be used to detect the local damages growth process in composite laminates under multiple damage modes.

Key words: acoustic emission, laminated composites, field correlation, damage mechanisms, delamination phenomena.

Changes in acoustic emission characteristics in laminated composites subjected to periodic external loading may be due to matrix cracking [1, p. 108039], interfacial bond failure, and fiber rupture effects [2, p. 842] in composites. Detailed information on composite material failure mechanisms and their failure mechanisms is provided by fixing the radiation source network. The main problem with the acoustic emission method is the differential analysis of acoustic emission signatures generated by different damage mechanisms [3, p. 1042]. The main deformation mechanisms registered in engineering practice include delamination in the matrix volume, longitudinal splitting and fiber rupture in laminates.

The amplitude of acoustic emission is a basic parameter for characterizing the accumulation of mechanical damage. In particular, it was found that the amplitude of the acoustic signal varies depending on different failure modes. Deformation mechanisms that can be correlated with low amplitude are associated with matrix cracking. On the other hand, high-amplitude events are associated with fiber rupture [4, p. 1451]. In addition, the analysis of the spectral distribution characteristics of acoustic emission can also be used to identify damage mechanisms in carbon-epoxy composites.

However, the issues of acoustic emission research related to damage mechanisms in self-reinforced polyethylene composites are poorly understood. To ensure the reliability of these structural materials, the study of their damage and failure mechanisms is very important. In addition, the study can also be useful for the optimal design of structural materials. In this work, the damage mechanisms in self-reinforced polyethylene composites were investigated using the acoustic emission method.

The numerical results of the specified model for laminated multilayer composite structures allowed us to analyze the main types of mechanical damage. For all cases, there was primarily a plastic rupture of the matrix material. In addition, in sample $[90]_8$, fiber detachment from the matrix was observed. However, the range of damage types was most fully revealed in sample $[45]_8$. In particular, the sample showed fiber detachment from the matrix, plastic deformation of the matrix and matrix cracking, as well as fiber elongation with slight fiber splitting. The calculated characteristics of sample 0^0 were characterized by fiber rupture with some fiber detachment from the matrix, matrix destruction and fiber elongation. The phenomenon of delamination was detected in sample $[+45_2/-45_2]s$.

It was found that the peaks of acoustic emission activity, which changed with mechanical loading, could be related to the stages of damage initiation. The number of peak acoustic emission events increased significantly as the ultimate load was approached. The influence of the stacking of laminated layers in the composite structure on the deformation and acoustic emission response was demonstrated by comparing the responses of specimens $[45]_8$ and $[+45_2/-45_2]s$, respectively. The tensile strength was approximately 2.3 times higher for specimen $[+45_2/-45_2]s$ than for specimen $[45]_8$, and the acoustic emission responses of both specimens were significantly different. The number of recorded acoustic emission events for sample $[+45_2/-45_2]s$ was approximately twenty-six times greater than that in sample $[45]_8$. A correlation between the amplitude of acoustic emission events and matrix plastic deformation and matrix cracking was established using a clean laminated composite specimen loaded to 14% strain. This load corresponded to the tensile strength. Most of the recorded acoustic emission events for specimen $[45]_8$ were associated with matrix plastic deformation and matrix cracking.

The correlation between high-amplitude events and fiber breakage was also tested using sample $[45]_8$. A mechanical load histogram was calculated for this sample. Analysis of the histogram shape indicates the existence of low-level (below 60 dB) and mid-level (60 to 80 dB) and high-level (above 80 dB) events for the entire emission amplitude range. Low-level events can be clearly associated with fiber-matrix bond failure, matrix plastic deformation, and matrix cracking. Mid-level events, which is typical for specimen $[90]_8$, can be correlated with deformation types such as fiber pullout from the composite matrix.

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