Modelling of deformation and fracture of composite structures using monitoring data from optical fiber strain sensors

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ABSTRACT

The idea of creating materials that together with the basic functions allow to collect information about their condition is very relevant for polymeric composite laminates. The application fields of these materials are developing so rapidly that the current state of numerical and experimental methods for assessing their performance, strength and durability does not always meet the desired requirements. Therefore, it is important to enhance traditional methods for analysis of the mechanical state of composite laminates with new reliable approaches based on non-destructive solutions. One of the self-diagnostics concepts that can be implemented with regard to laminated composite structures involves fiber-optical strain sensors. The capabilities of such sensors to measure the mechanical state of the surronding area are derived by using fiber Bragg gratings (FBGs), which provide periodic change in the refractive index of the core of an optical fiber subjected to external influence. The operation principle of such sensors is based on a comparison of the wavelength of the light transmitted to and reflected from the Bragg grating.

Embedded into composite laminates, fiber-optical sensors have a wide range of advantages. In particular, they are able to withstand strains comparable with strains of the composite structures; are immune to electrical interference; can be integrated during the manufacturing process of the materials and allow to monitor the composite structure during both manufacturing and exploitation.

This work is aimed at creating methods for evaluation of the mechanical state and prediction of mechanical properties of laminated composite structures using mathematical models that take into account the microstructural features and which parameters are underpinned by the real-time monitoring data from the fiber-optical strain sensors with Bragg gratings integrated into the structures.

The proposed scheme for assessment of the stress-strain state and further failure of composite structures is based on elaboration of a combined numerical-experimental technique. Numerical part of this technique is connected with multiscale finite element modelling of composite structures under quasi-static loading conditions. Experimental part is based on real-time measurement of strain values at the predetermined control points using FBG sensors, with their consequent application for validation of numerical modeling results.

An iterative algorithm for refinement of the models' parameters is offered. It comprise solution of the inverse problems in accordance with the data received from the FBG sensors to ensure a match with a given precision of numerical and experimental results. This allows to create numerical models of the composite structures that consider the microstructural parameters of the materials and deliver more accurate results. The proposed scheme is implemented and demonstrated on the test examples.

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