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FAILURE RESPONSE OF FIBER-EPOXY UNIDIRECTIONAL LAMINATE UNDER TRANSVERSE TENSILE/COMPRESSIVE LOADING USING FINITE-VOLUME MICROMECHANICS

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ABSTRACT

The transverse damage initiation and extension of a unidirectional laminated composite under transverse tensile/compressive loading are evaluated by means of representative volume element (RVE) presented in this paper based on an advanced homogenization model called finite-volume direct averaging micromechanics (FVDAM) theory. Fiber, fiber-matrix interface and matrix phases are considered within the RVE in determining fiber-matrix interface debonding and matrix cracking. The simulated fracture patterns are shown to be in good agreement with experimental observations.

Keywords: transverse failure, RVE, interface, FVDAM.

INTRODUCTION

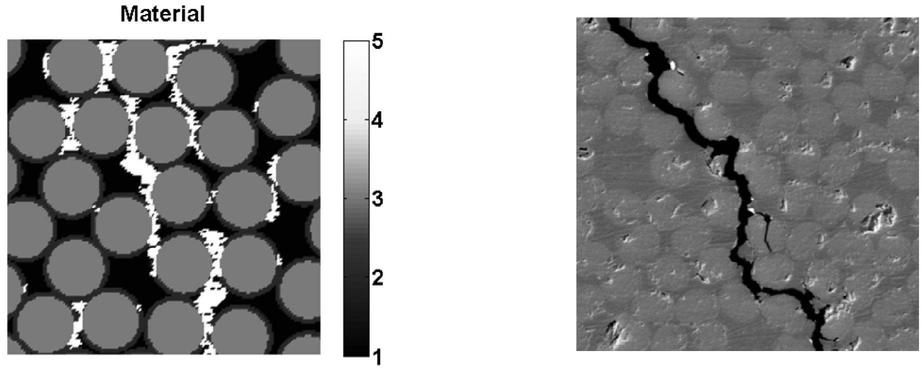
Transverse failure is one of the most important failure patterns in composites. Composite laminates that are subjected to complex loading usually show transverse cracking as the first observable phenomenon which often causes the first deviation from linear behaviour. In many applications such as pressure vessels and pipes the transverse cracking is not allowed to occur in the composite structure.

There are two primary failure patterns when the unidirectional composite laminate is subjected to transverse loading (tensile/compressive loading), one is the fiber-matrix interface debonding and the other is matrix failure. Therefore in this paper, the maximum-stress criterion for matrix damage and interface failure criterion under local normal and tangential stress conditions are implemented, while fiber failure is disregarded. Herein, a semi-analytical FVDAM-based damage model which accounts for the interface damage is presented and employed to predict transverse failure of unidirectional laminates.

RESULTS AND CONCLUSIONS

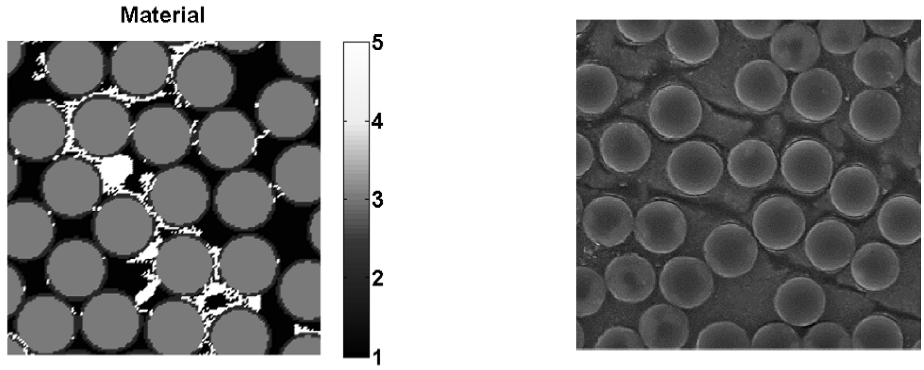
The RVE model based on FVDAM is used to predict the transverse initial damage and crack extension under tensile/compressive loading. The results simulated are validated with the experimental observations shown in figures 1 and figure 2. The failure patterns computed numerically are in good qualitative agreement with experimental results from static tensile tests obtained by Boming et and compressive test obtained by Aragones on AS4/epoxy composite system.

In the transverse tension case when the interface is weaker than the matrix, the initial damage manifests itself as interfacial debonding, and then cracking extends into the matrix along the path which is vertical to the loading. Conversely, in the transverse compression case, the initial debonding of fiber-matrix interface occurs, and then the matrix close to the debonding zone is damaged by shearing stresses along the direction oriented at approximately 55 degrees with respect to the direction of loading.



(a) predicted failure pattern (b) experimental failure pattern

Fig. 1 - Failure in unidirectional composite under transverse tensile loading



(a) predicted failure pattern (b) experimental failure pattern

Fig. 2 - Failure in unidirectional composite under transverse compressive loading

This study demonstrates that the current FVDAM-based damage model is an accurate, efficient and stable mechanical analysis tool for heterogeneous materials.

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