8th International Conference on Composites Testing and Model Identification
S.V. Lomov, L. Gorbatikh, Y. Swolfs (Editors)
KU Leuven, 2017

Microscale Based Prediction of Matrix Crack Initiation in UD Composite Plies Subjected to Multiaxial Fatigue with Arbitrary Stress Ratios

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Keywords: Polymer composites, Digital Image Correlation, Mechanical properties, Finite elements

ABSTRACT

A significant part of the fatigue life of a Uni-Directional (UD) composite material can be attributed to the initiation of microcracks [1,2,3]. Thus, in order to achieve good predictive capabilities, the initiation of cracks must be included in fatigue life prediction methodologies. At the moment, only a few authors consider initiation for the prediction of the fatigue life of a composite laminate [4,5].

The predictive part for initiation in the majority of these works is based on the classical Wöhler (S-N) curve approach where initiation is quantified based on the remote macro-stress applied to the composite ply through a linear-logarithmic relation between the maximum and/or mean (when Goodman diagram is used) stress and the life to initiation. A difficulty when using S-N curves is the need for experiments to recalibration the logarithmic fit every time the fatigue load or multiaxial load condition is changed. Several authors have attempted to reduce the amount of required tests. The majority constructs a new damage parameter in an attempt to quantify the fatigue life e.g. [6,7,8,9,10,11,12]. More notable contributions are the work of Quaresimin and Carraro [13,14] who, using their master S-N curves based on the LMPS or LMHS in the matrix surrounding the fibres, are able to predict crack initiation for any global multiaxial stress state. And Kawai et al. [15,16,17,18,19] who, using the anisomorphic constant fatigue life diagram, are able to predict life for multiple stress ratio's. The presented approaches always fall short in some aspect of predicting the fatigue load. An integrated approach which allows predictions for every stress ratio with every multiaxial stress state does not yet exist.

In this work an integrated approach for the prediction of matrix fatigue crack initiation is presented. The approach allows to predict matrix crack initiation for a UD composite ply subjected to any multiaxial stress state, for TT, CC and TC loading and for any load ratio. The approach is developed based on phenomenological evidence from experimental studies about the damage types observed after failure The framework is validated against 5 datasets taken from scientific literature. Considering the natural scatter in fatigue related experiments, the validation provides a good agreement between observation and prediction.

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