MULTISCALE ANALYSIS OF MICRO-SCALE STRESSES AT THE LAMINATE FREE EDGE

Christopher Cater[1], Robert K. Goldberg[2], Xinran Xiao[1*]

1-Michigan State University, 2-NASA Glenn Research Center

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ABSTRACT

In composite laminates, the property mismatch between plies of varying orientations results in stress gradients at the free edges of the composites. These free edge stresses can cause initial micro-cracking during manufacture, and are a significant driver of delamination failure. The free edge effect has been well understood at the laminate or lamina scale (or meso-scale). The influence of the microstructure (at the length scale of individual fibers) on free edge cracking, however, is less known. This work aims at a qualitative understanding of the effect of microscopic features on initial micro-cracking at the laminate free edge. An IM7/8552 carbon fiber composite with a laminate stacking of [25/-25/90]S is investigated, which is known to be vulnerable to free edge initiated failure.

A two-scale multiscale finite element (FE) approach is utilized to model the micro-scale stresses near the laminate free edge. At the lamina level, a homogeneous and orthotropic meso-scale model is used to capture the free edge stress fields. A computational homogenization approach is used to map the meso-scale strains onto a micro-scale FE model that explicitly models the fiber and matrix constituents. For comparison, the analysis with FE micro-models is carried out with two sets of boundary conditions: one with periodic conditions at all six boundaries, referred as periodic only, the other contains one free edge (coincident with the laminate free edge surface) and five periodic boundaries. The analysis was carried out for a [25N/-25N/90N]S composite laminate, known for its vulnerability to free edge cracking. The effects of both thermal and mechanical loading were investigated separately to understand the influence of thermal cooldown during manufacture and tensile loading of the composite laminate. The multiscale analysis helped explain the trend of free edge pre-cracks and

progressive damage during extensional loading observed in experiments.

*presenter, 2727 Alliance Dr, Lansing, MI 48910, Tel: (517) 884-1606, E-mail: xinran@msu.edu