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Structural Mechanics of Thin-Ply Laminated Composites

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ABSTRACT

This work presents a numerical study of the mechanical response of spread-tow thin-ply laminates, complementing previous experimental studies on the unnotched and notched response of this new class of advanced composites.

The effects of geometry on the deformation and fracture of ultra-thin spread tows embedded in a multidirectional laminate were studied based on a three-dimensional computational micro-mechanics framework. It accurately represents the micro-mechanical response of ultra-low grades, including the mechanics of transverse cracking onset and propagation in tension and compression, the constraining effect observed in the laminae embedded in multidirectional laminates and the *in situ* effect.

New three-dimensional invariant-based failure criteria were then proposed to predict failure of unidirectional plies. To account for the effect of ply thickness when the laminae are embedded in a multidirectional laminate, appropriate definitions of the *in situ* properties were derived in the framework of the invariant-based failure criterion for transverse failure mechanisms. The failure predictions are in good agreement with the experimental data available in the literature, and with the predictions of computational micro-mechanics.

The proposed failure criteria was then implemented in a Smeared Crack Model to predict ply failure mechanisms in composite laminates. A preliminary verification was performed, showing the potential of this tool to predict failure of multidirectional laminates using only properties determined from tests carried out at the lamina level.

Finally, macro-mechanical analysis methods based on analytical models formulated at the homogenised laminate level are proposed to enhance the predictive capability of the strength and failure of composite structures. These tools are based on the Trace theory and Master Ply concept for prediction of the elastic properties, and on the concept of Omni Strain Failure Envelopes and Unit Circle failure criterion for laminate strength prediction. To predict the notched response of composite laminates, a Finite Fracture Mechanics model is presented. With this model, more reliable analyses of the notched response of laminated plates with through-penetration damage can be obtained without requiring fitting parameters or complex Finite Element Analyses.