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# CRACK INITIATION AND TUNNELING IN LAMINATED COMPOSITES

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## ABSTRACT

The difficult challenge of simulating diffuse and complex fracture patterns in tough structural composites is beginning to yield to conceptual and computational advances in fracture modeling. Recent successes include the refinement of cohesive models of fracture and the formulation of mixed stress-strain and traction-displacement models that combine continuum and discrete damage representations in a single calculation.

In this study, we shall use such a multiple scale modeling method to tackle one of the remaining mysteries in composite laminates, i. e., the damage initiation and propagation through transverse intraply microcracks accompanied by local delaimnation. The transverse microcrack is believed to begin as a localized defect, which spawns a roughly circular crack, which propagates to the ply interfaces and then extends through the ply as a tunneling crack. The tunneling crack may be accompanied by local delamination but exactly when this happens is not known. Most literature studies of this problem assume plane conditions, which are applicable only after the tunneling crack has propagated; and the local delamination is usually completely ignored. The true initiation event, the tunneling process, and the initiation of the delaminations are rarely modeled as three-dimensional problems. As a result, the critical question of whether to represent microcracks discretely or by their spatially averaged effect on stiffness via a continuum damage model remains unanswered.

We will formulate a reasonably simple description of this complex sequence of events that can be embedded in the whole composite and lead to confirmed predictions of delamination initiation. We will achieve this by combining the advantages of cohesive zone models (CZM) and the extended finite element method (X-FEM). Using cohesive zone models for composite delamination has proved to be very effective owing to the fact the potential delamination paths are known *a priori*. However, the nucleation and tunneling of a transverse microcrack cannot be known in advance. Therefore, we will make use of the X-FEM, which can model arbitrary crack nucleation and growth, to describe the transverse crack initiation and tunneling. The possible local delamination attached to the tunneling crack will be accounted for by the CZM elements planted along the interfaces. The stochastic issue of transverse crack initiation will be investigated using Monte Carlo methods.

We expect that, through this high-fidelity structural modeling with crack descriptions down to the microcrack level, we can develop much better understanding of the transverse crack initiation process and lower the minimum gauge length over which damage processes can be modeled with the fidelity needed for a virtual test.