Toward the determination of optimal initiation and propagation interfacial crack shape

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Abstract

Multi-material interface problems are encountered in many industrial sectors as they often appear in assembled parts or heterogeneous materials. Additionally, structures made from these elements are nowadays increasingly employed, especially in aeronautic and aerospace applications, wherein composite materials are used primarily for weight reduction. In such materials, the fiber-matrix interface is a key aspect of global mechanical properties since it drives damage initiation and load transfer. It is therefore crucial to predict the fiber-matrix interface debonding in order to prevent or control the damage in composites.

Debonding initiation and propagation at the fiber-matrix interface of a single-fiber micro-composite loaded transversely is assessed using the Coupled Criterion (CC). The latter requires the crack path for its implementation. Among the possibilities to describe the potential crack shape, stress isocontour-based and energy-based shape solutions, corresponding respectively to the shapes maximizing either stress or energy conditions, can be employed. The stress isocontour-based shapes are numerically efficient because they can be derived from a single linear elastic calculation without releasing any nodes. However, this approach fails at describing the optimal CC solution when the solution is driven by the energy condition.

This work aims to determine the optimal fiber-matrix debonding shapes. These determined shapes are then used to predict both crack initiation and propagation. Stress isocontour-based and energy-based shape solutions are compared. Both approaches yield different crack front topologies, with those based on the energy condition aligning more closely with experimental observations. Additionally, regardless of the interfacial fracture properties, the initiation loadings predicted by the CC using energy-based shapes are always favorable. Once the initiation debonding shape topology is assessed, further propagation is addressed by identifying the crack path that maximizes Griffith's criterion. The final debonding topology is then compared with experimental observations to validate the developed crack shape determination approach.

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