Toughening due to shear kinking in composites

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ABSTRACT

In the current study, we explore the regimes of two competing crack growth mechanisms in composites: self-similar crack extension as a result of fiber tensile damage and 90° kinking as a result of matrix shear damage. Through finite element calculations it is shown that the two damage zones extend and simultaneously shield each other under loading. Such cooperative shielding of the damage zones has a synergistic effect on the composite strength and toughness. Although the constitutive properties of the damage zones determine their relative extent, it is assumed that the preferred direction of crack extension is governed by the maximum energy release rate. The numerical values of strength and toughness against tensile/shear damage are obtained for a range of relative strength and ductility of the two damage zones. It is shown that a relatively weak and ductile shear zone is capable of increasing the macroscopic toughness by orders of magnitude. Conditions for the existence of such shear bands are stated for a range of orthotropy and a comparison is made on the toughness, strength, and preferred crack growth directions. The numerical model is then applied for an elliptical hole to examine the other extreme form of stress concentration. The extent of the shear damage is enhanced by the severity of orthotropy and initial stress concentration. As a result of this, for sufficiently long shear damage zones a panel with a sharp crack is much tougher and stronger than the one with a circular hole.