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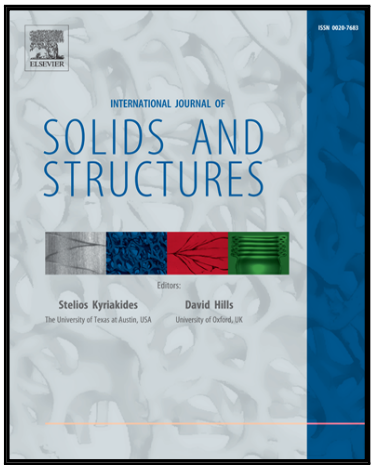

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A Cohesive Zone Model and Scaling Analysis for Mixed-Mode Interfacial Fracture

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Keywords: adhesion; damage criteria; delamination; mixed-mode fracture; interface; cohesive zone model; traction-separation relations.

Abstract

A semi-analytical methodology is developed to study mixed-mode interface fracture that combines beam theory and cohesive zone interactions. The method is validated with predictions from a non-linear commercial finite element package and results in the literature. Compared to commercial finite element packages, the method is significantly faster (>1000X) and robustly converges. Scaling equations are extracted that predict load, crack length, damage zone length and mode-mix. These equations can be used to extract cohesive zone interactions from experimentally obtained load-displacement data.

1. Introduction

Bi-material interfaces are prevalent in multiple natural and engineering applications from adhesive joints and composites to thin film transfer and self-assembled monolayers (SAMs). To design such layered structures which can potentially fail due to interface cracking or to design a process requiring delamination, an understanding of mixed-mode interface fracture is of utmost importance.

Significant contributions to the understanding of bi-material cracks were made through analytical approaches using linear elastic fracture mechanics (Williams 1959, Sih and Rice 1964, England 1965, Comninou 1977, Hutchinson, Mear et al. 1987, Rice 1988), experiments (Charalambides, Lund et al. 1989, Wang and Suo 1990, Liechti and Chai 1992) and numerical simulations (Lin and Mar 1976, Smelser 1979, Sun and Jih 1987, Kang Yong and Hyung Jip 1988). While many experimental investigations included an adhesive interlayer and found the critical energy release rate to be a function of the mode-mix, some experimental studies without an interlayer (Ryoji, Jin-Qiao et al. 1994, Banks-Sills, Travitzky et al. 2000) obtained a similar result. In the former, the toughening effect was attributed to increased viscoplastic dissipation in the epoxy. Fiber bridging or asperity shielding (Evans and Hutchinson 1989) from interfacial roughness may have been the cause of toughening in the latter studies.

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