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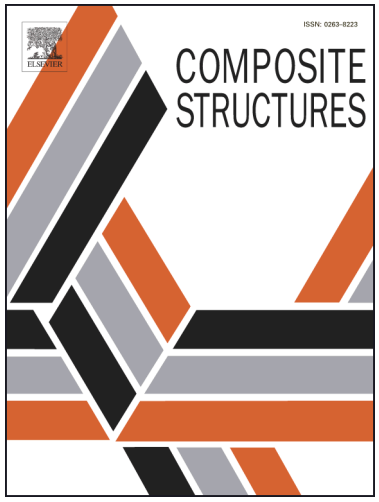

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Emergence of pseudo-ductility in laminated ceramic composites

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Abstract

In this article, we explore the origins of pseudo-ductility in the inelastic response of laminated ceramic composites. By pseudo-ductility, we mean the engineered ductility of ceramic laminated composites by a strategic placement of the weak interfaces. For purposes of modeling, a phase-field based brittle fracture approach is adopted and we use it to numerically study the response of such composites. This approach has the advantage of seamlessly modeling the growth of cracks through the interface as well as into the lamina. A finite element implementation of this brittle fracture model is carried out, using which the response of laminated ceramics is computed and compared with available experimental evidence in the literature. This implementation is also used to study the influence of geometric and material properties on the response, especially the damage propagation through ceramic laminates. Along with important geometric aspects such as the lamina thickness distribution and interface geometry, we also study how material properties like Young's modulus and critical energy release rate of the interface may play a role in the engineered pseudo-ductility.

Keywords: laminated ceramics; brittle fracture; phase-field; delamination; pseudo-ductility

1 Introduction

Ceramics are extremely strong but brittle materials. Their high strength to weight ratio makes them attractive for body armor, turbine blades and many other critical applications; but their usefulness is limited by the brittleness. In metals, the growth of a crack is inhibited by the plastic zone ahead of the crack tip. Processes taking place within the plastic zone dissipate the excess elastic energy available to the body during a crack growth process. The inability of ceramic materials to deform plastically under normal operating conditions is the root cause for their brittle failure. Added to this is the issue of high variability of maximum strength in ceramics, attributable to the microscopic flaws formed within the ceramic bulk during the manufacturing process [8],[6]. By suitably modifying its fracture behavior, the strength of a ceramic component may be increased significantly whilst simultaneously realizing a pseudo-ductile failure. In the literature, several schemes have been tried out towards this end. One amongst them is the addition of short high-strength reinforcement fibers into the ceramic bulk. These fibers carry load only after the ceramic bulk has

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