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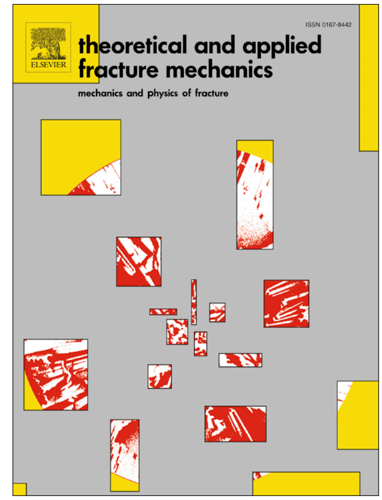

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Initiation and evolution of debonding phenomena in layered structures

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ABSTRACT: A new methodology based on a moving mesh technique and a multilayer formulation is proposed with the purpose to predict crack onset, evolution and coalescence of the interlaminar damage mechanisms. In particular, a numerical approach based on Arbitrary Lagrangian Eulerian (ALE) formulation combined with shear-deformable beam elements is implemented in a numerical procedure based on the finite element method. The moving mesh technique combined with a multilayer formulation ensures a reduction of the computational costs, required to predict crack onset and subsequent evolution of the debonding phenomena. The analysis is performed with respect to several onset configurations, including the case in which multiple debonding mechanisms with coalescence affects the interfaces. The proposed approach is quite robust to be implemented also in dynamics, in which the process zone is known to advance at high speed ranges. In order to verify the proposed modeling, a sensitivity study in terms of convergence and stability of the solution is proposed. Moreover, comparisons with existing results available from the literature are developed with the purpose to verify the reliability and the consistency of the proposed formulation.

Keywords: crack initiation, debonding, ALE, dynamic fracture mechanics, FEM.

1. Introduction

Layered structures, such as composite laminates or reinforced concrete beams strengthened with FRP materials, typically exhibit a low resistance to damage with respect to interlaminar damage mechanisms. In particular, such materials are typically composed of layers connected through interfaces, in which material discontinuities due to production processes or high interlaminar stresses may be generated [1]. As a consequence, the motion of interfacial cracks is basically constrained along interfaces, leading, during the crack advance, to very large debonding speeds and catastrophic failure mechanisms [2]. Therefore, in order to correctly reproduce the actual behavior of layered structures, a generalized approach is needed to predict, at first, the position in which the interlaminar damage occurs and, subsequently, the corresponding crack advance along the interfaces.

In the literature, several approaches and formulations able to predict crack growth in layered structures ranging from micro, meso and macro scales are proposed [3]. In particular, continuum models based on local or nonlocal approaches utilize proper constitutive formulations, depending from material parameters and internal variables [4]. Such analyses simulate the macroscopic

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