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A New Hexahedral Element with Embedded Interface for Crack Analysis in Delaminated Composite Beams

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Abstract

Existence of a crack in structures would lead to a sudden failure and damage. Establishing a precise analytical model for the cracked element would be a powerful tool to achieve the right answers in the analysis of the structure. The main aim of this paper is to formulate a hexahedral element with embedded interface for using in the analysis of delaminated composite beams. In this investigation, the kinematics of the discontinuous displacement field along with the virtual work principle, for a body with an internal discontinuity, is utilized. Based on the suggested interpolation functions for the discrete segments, and also the element displacement field, the element stiffness matrix is calculated. The proposed element can be used for modeling of the discrete cracks in three-dimensional problems, such as a laminated composite beam. Numerical example is analyzed for the accuracy test. The results indicated that utilizing sufficient elements yields suitable answers.

Keywords: Crack Analysis, Fracture mechanics, Embedded interface, Laminated composite beam.

1. INTRODUCTION

Due to the anisotropic and inhomogeneous property of composite materials, laminated composite structures are susceptible to several failure mechanisms like, delamination, fiber debonding, broken fibers and micro-cracks of the matrix. Delamination may arise due to the low resistance of the thin resin-rich interface existing between adjacent layers, poor manufacturing process, fatigue load and impact. Simulation of these phenomena are then crucial but still quite complicated. Since it can be done at many levels, like macroscopic or mesoscopic, quite complex computational tools may be required [1]. The simulation of delamination in composites is usually divided into delamination initiation and delamination propagation.

In the last decade, the Finite Element Method was applied successfully for simulations in the field of fracture and damage mechanics such as delamination. Decohesion elements could be of different types, like continuous interface elements or point decohesion elements. These elements use the cohesive model as the constitutive relationship between the relative displacements and the traction forces at the interfaces [2]. Cohesive models are based on the Dudgale–Barenblatt [3] cohesive zone approach, subsequently extended by Hillerborg [4], which gives a physical explanations of the failure process, whereas classical fracture mechanics lacks of a physicsbased description [5]. In the cohesive zone model, it is postulated the existence of a narrow band of vanishing thickness ahead of a crack tip which represents the fracture process zone. The bonding of the surfaces of the zone is obtained by cohesive traction, which follows a cohesive constitutive law [6].

The delamination analysis is still a serious problem in composite structures, which requires more attentions. This paper deals with mesh-free finite formulation for crack (delamination) analysis in laminated composite beams. In mesh-free methods, there is no need to define a new mesh size for achieving the correct answers after the crack propagation. By using the fracture mechanic theory, a three-dimension element is developed. This hexahedral element with an embedded interface has twelve nodes and thirty six degrees of freedom. Extensive finite element analyses were performed by utilizing the author's computer program, which includes the proposed crack (delamination) element.