Accepted Manuscript

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J. Reinoso, M. Paggi, A. Blázquez

PII: S1359-8368(16)31256-2

DOI: 10.1016/j.compositesb.2016.10.042

Reference: JCOMB 4640

To appear in: *Composites Part B*

Received Date: 8 July 2016

Revised Date: 5 October 2016

Accepted Date: 16 October 2016

Please cite this article as: Reinoso J, Paggi M, Blázquez A, A nonlinear finite thickness cohesive interface element for modeling delamination in fibre-reinforced composite laminates, *Composites Part B* (2016), doi: 10.1016/j.compositesb.2016.10.042.

A nonlinear finite thickness cohesive interface element for modeling delamination in fibre-reinforced composite laminates

J. Reinoso[a,*], M. Paggi[b], A. Blázquez[a]

[a] *Elasticity and Strength of Materials Group, School of Engineering, Universidad de Sevilla, Camino de los Descubrimientos s/n, 41092, Seville, Spain*
[b] *IMT School for Advanced Studies Lucca, Piazza San Francesco 19, 55100 Lucca, Italy*

Abstract

Delamination events are major issues which notably affect the integrity of composite structures. To minimize the experimental efforts, there is an increasing demand for developing reliable numerical tools that can accurately simulate delamination initiation and propagation under mixed-mode loading conditions. The current investigation is concerned with the formulation and the finite element (FE) implementation of a new nonlinear finite thickness cohesive interface model for delamination analysis of fibre-reinforced composite laminates relying on the solid shell concept. The incorporation of geometrically nonlinear effects into the proposed interface formulation is motivated by the recent trend of producing composite structures that can experience large displacements prior to failure, as is the case of postbuckling in stiffened panels. The inelastic material behavior of the interface is modeled using two standard nonlinear decohesion laws: (*i*) an exponential-based, and (*ii*) a polynomial-based interface laws. Finally, the performance of the proposed interface element is demonstrated by means of several examples focusing on double cantilever beam (DCB) and rib-stiffened specimens. A excellent level of accuracy is achieved when comparing the numerical predictions and the available experimental data.

Keywords: A. Finite thickness interface. B. Cohesive zone modelling. C. Delamination. D. Finite Element Method. E. Fracture

1. Introduction

The setting up of advanced numerical models for the simulation of decohesion and/or delamination events has been an area of extensive research over the last two decades. These failure mechanisms play a crucial role in the structural integrity in many engineering applications involving layered composites, especially in aeronautical and aerospace components and more recently in automotive parts, among many others..

From the numerical perspective, these inelastic processes have been widely modeled using two popular FE-based strategies: (*i*) the so-called virtual crack closure technique (VCCT) [1], and (*ii*) Cohesive Zone Models (CZMs) relying on the corresponding interface model [2, 3]. In massive simulations, CZMs have been successfully adopted due to their high versatility and relative simplicity to be incorporated into research and commercial FE codes, especially in applications where the crack path can be clearly identified a priori. In contrast to linear elastic fracture mechanics (LEFM) strategies, CZMs enable the reproduction of the fracture process zone (FPZ) ahead the crack tip, wherein the nonlinear interfacial softening response plays an important role.

A general interpretation of CZMs can be conceived by referring the inelastic traction-separation law (TSL), which characterizes the degradation response, to a reference surface. This reference surface is typically identified as the middle surface between the two adjacent bodies (bulks) joined through the common interface.

*Corresponding authors
Email address: jreinoso@us.es (J. Reinoso)