Accepted Manuscript

Modelling fracture and delamination in composite laminates: energy release rate and interfacial stress

J.L. Curiel-Sosa, B. Tafazzolimoghaddam, Chao Zhang

PII: S0263-8223(17)33609-7
DOI: https://doi.org/10.1016/j.compstruct.2018.02.006
Reference: COST 9356

To appear in: *Composite Structures*

Modelling fracture and delamination in composite laminates: energy release rate and interfacial stress

JL Curiel-Sosa[a,b,*], B Tafazzolimoghaddam[a,b], Chao Zhang[a,b,c]

[a]*Department of Mechanical Engineering, University of Sheffield, Sir Frederik Mappin, Mappin St, Sheffield, S1 3JD*
[b]*Computer-Aided Aerospace and Mechanical Engineering Research Group (CA^{2}M), University of Sheffield, Sheffield, UK*
[c]*School of Mechanical Engineering, Jiangsu University, Zhenjiang, China*

Abstract

This article presents an approach for modelling fracture and delamination, based on the partition of finite elements and on the energy release rate due to crack propagation in cross-ply laminates. The energy release rate is implemented within an Extended Finite Element Method (XFEM) framework. This approach is enabling the prediction of delamination propagation without pre-allocating damage zones. No element deletion techniques were used either. Mesh refinement was not needed for the propagation of cracks. Virtual testing of transverse cracks –eventually triggering delamination in cross-ply laminates– is presented to show the technique efficiency. Thus, a maximum energy release rate of $0.9\,kJ/m^2$ is found for a transverse crack within $[0^o, 90^o]_s$ laminate. When maximum energy release rate is reached, delamination in the $\{0^o/90^o\}$ interface is triggered. Furthermore, delamination in a composite double cantilever beam is simulated and presented in some detail. The results were compared with experimental outputs and/or by other numerical means showing an excellent correlation.

Keywords: , A. Laminate, A. Composites, B. Delamination, C. Finite element analysis (FEA), modelling, energy release rate

1. Introduction

There are a number of un-resolved –or partially solved– problems on modelling of composite failure when several types of failure are involved. Among the outstanding problems:

- Interaction of distinct damage modes[1], so-called mixed-modes damage, i.e. the evolution of more than one damage mode, computed simultaneously. During last decades a vast amount of damage modelling based on the Finite Element Method (FEM) has been based on Continuum Damage Mechanics (CDM) integrating distinct damage internal variables [1]. However, those variables are frequently computed independently of each other evolution which is against the natural mechanism of damage in composites. Exceptions to this include the works by Curiel Sosa et al. [2] or by Matzenmiller et al. [3] amongst others. Naturally, CDM fails to represent the discontinuity of the strain field or displacement field associated to cracks.

- Connection of level of damage with fracture. The link between CDM and fracture mechanics is by a great deal outstanding on composite structures failure modelling. Some advances can be referred though, for instance, the works by van Dongen et al. [4], Turon et al. [5], Iarve et al. [6].

- Interaction of interlaminar fracture, i.e. delamination, and intralaminar fracture, e.g. matrix cracking or fibre breakage/kinking, see the works by Zhao et al. [7] or by Abdullah et al. [8].

Potential shortcomings associated to fracture numerical strategies in composites are highlighted next. Re-

*Dr EurIng Jose L. Curiel-Sosa
Email address: `j.curiel-sosa@sheffield.ac.uk` (JL Curiel-Sosa[a,b,])
URL: `www.ca2m.group.shef.ac.uk/` (JL Curiel-Sosa[a,b,])

[1]Damage modes are defined herein in a general sense and attending to the scale considered as: matrix cracking (tension and shear), matrix crushing (compression), fibre breakage, fibre kinking, disbonding (matrix-fibre) and delamination.