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Numerical modelling of matrix cracking, splitting and delamination in composite laminates using cohesive zone elements

Yu Shi[1] and Constantinos Soutis[2]

[1]University of Chester, Mechanical Engineering, Thornton Science Park, Pool lane, Chester, CH2 4NU, UK, y.shi@chester.ac.uk

[2] Aerospace Research Institute, University of Manchester, James Lighthill Building, Sackville Street, Manchester, M13 9PL, UK, constantinos.soutis@manchester.ac.uk

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Failure of a composite laminate is a challenging task due to the complicated damage modes that can be developed and interact in the form of intra- and inter-laminar cracking. Initiation of matrix cracking and axial splitting (intralaminar modes) can be estimated by employing appropriate failure criteria based on fracture mechanics [1], while inter-laminar cracking (delamination) can be predicted by using cohesive zone elements. However, in order to capture the matrix cracking/splitting interaction and propagation, which can affect the development of delamination, more detailed analysis is required. In this work, the cohesive zone elements are proposed to be inserted within individual plies, along the fibre/matrix interface. The computationally simulated crack density is verified by comparing with the theoretical equivalent constraint model (ECM) developed by Soutis and co-workers [2, 3] and validated by measurements and observations in cross- and angle-ply laminates subjected to tensile loading. It is shown that a good agreement is obtained and found that the accuracy of the numerical approach is dependent on assumed material properties such as intra- and inter-laminar fracture toughness, the interface stiffness as well as the FE mesh density. Moreover, the proposed methodology is used to simulate the low velocity impact behaviour of composite laminates where the first damage mode is axial splitting developed in the bottom ply, followed by delamination of the neighbouring interface and multiple cracking events in the remaining plies. The successful prediction of splitting improves the accuracy of the simulation and compares favourably to experimental data. In particular, the cohesive zone elements modelled the matrix cracking formation, propagation and crack closing during rebounding of the impact projectile, something that is difficult to be detected by X-ray radiography or any other non-destructive detection technique, which can underestimate the severity and extent of internal damage [4]. The study can be extended to estimate laminate residual strength and fatigue life, something that could be investigated in near future work.

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