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Modelling the tensile failure of composites with the floating node method

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Abstract

This paper presents the modelling of tensile failure of composites using novel enriched elements defined based on the floating node method. An enriched ply element is developed, such that a matrix crack can be modelled explicitly within its domain. An enriched cohesive element is developed to incorporate the boundaries of matrix cracks on the interface, such that the local stress concentrations on the interface can be captured. The edge status variable approach allows the automatic propagation of a large number of matrix cracks in the mesh. A laminate element is formed, such that a fixed, planar mesh can be used for laminates of arbitrary layups. The application examples demonstrate that the proposed method is capable of predicting several challenging scenarios of composites tensile failure, such as the large number matrix cracks, grip-to-grip longitudinal splits, widespread delamination, explosive splitting and distributed fibre breaking in the 0 plies, etc. The complete failure process of ply-blocked composite laminates, up to the final breaking of the loosened 0° strips, are here firstly reproduced by modelling.

Keywords:
floating node method, composites, modelling, matrix crack, delamination, open-hole tension

1. Introduction

Fibre-reinforced composites have been widely used in the aerospace industry due to their properties such as high strength-to-weight ratio and high fatigue resistance, etc. The accurate prediction of the failure of composites is important for ensuring the safety and optimality of the design of composite structures. The progressive tensile failure of composites is characterised by the development of a large quantity of matrix cracks and delamination [1]. Matrix cracks in angle plies often trigger the onset of local delamination and migrate their way to the 0 plies, causing fibre breaking of the 0 plies or delamination on their surfaces [1–4]. When the laminate is of a ply-blocked configuration, i.e., plies of the same fibre angles are bundled together, longitudinal matrix splits tend to grow, sometimes from grip to grip. They cause widespread delamination, which subsequently lead to the disintegration of the laminate prior to the breaking of the stand-alone 0 ply-block [1, 2, 4] (Figure 1). In fact, the breaking of the 0 ply-block itself is a challenging problem to be modelled. Fibre fracture rarely propagates along a well-defined path. On the contrary, it is often accompanied by an explosive occurrence of matrix splits, which separate the ply-block into loosened

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