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A numerical study of transverse cracking in cross-ply laminates by 3D finite fracture mechanics

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Abstract

Transverse cracking in cross-ply laminates is a key failure mechanism which needs to be understood in order to predict the failure initiation in these laminates. A new 2D model has recently been presented (García et al., Int J Solids Struct 51, pp. 3844-3856, 2014) for predicting the first crack onsets in cross-ply laminates under tensile loading, which is based on the coupled criterion of the Finite Fracture Mechanics (FFM). This 2D model is able to predict a strong size effect on the critical strain leading to the first crack onsets, which agrees with some experiments found in the literature. However, some earlier studies have shown that the 3D effects can be relevant in determining the origin of the size effect found in these experiments. Therefore, a 3D application of the coupled criterion, which formulates this criterion as an optimization problem, is proposed here. The objective function to be minimized, under the two stress and energy criteria described previously, is the critical strain leading to the first crack onset. The finite number of variables of the optimization define the crack geometry after its onset. Since the crack geometry is parametrized, the variables in the optimization are the parameters defining the crack geometry. The objective function is evaluated by combining FRANC3D and Abaqus. As occurs in the 2D model, the results predict the strong influence of the transverse-ply thickness on the process of transverse cracking. In particular, a slightly larger critical strain is predicted for thinner laminates. In addition, the optimal crack position also varies with the thickness: a free-edge crack onset is predicted for thick laminates, whereas for thin ones, the inside and free-edge crack positions are essentially equivalent.

Keywords: A. Lamina/ply, B. Transverse cracking, C. Computational modelling, C. Finite element analysis (FEA), finite fracture mechanics

1. Introduction

The relevance of fiber-reinforced composite materials in some industries, where the lightweightness is a key aspect of design, has increased drastically during the last decades due to their exceptional properties per unit weight. Nowadays, these materials are used on first-level structures, e.g. spanning the majority of the airframe in new airliners. The high strength-to-weight ratio of composites is one of the main advantages which has motivated their application in lightweight structures. However, this advantage can

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