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Development a refined numerical model for evaluating the matrix cracking and induced delamination formation in cross-ply composite laminates

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Abstract
In this study, at first the dominant micro scale failure modes including fiber-matrix debonding and matrix cracking are studied in 2D RVEs extracted from the layer 90° in different cross-ply laminates. To model the debonding and matrix cracking formation in RVEs, cohesive zone model (CZM) and Extended finite element method (XFEM) are applied. Then to investigate induced delamination formation originates from the tips of matrix cracking as a secondary damage mode, the cohesive surfaces are embedded at the interfaces of different plies in considered lay-ups. Generally, a parametric study is done on different cross-ply laminates with various thickness of layer 90° to obtain the in-situ strength due to matrix cracking and induced delamination by a numerical tool for the first time. The verification of results with the available analytical models shows an acceptable agreement. Then, by considering the long unit cells, the sequences of different damage modes formation are investigated numerically and some physical phenomena including the formation of new matrix cracking in the random locations between the previous cracks, matrix cracking saturation, symmetric and staggered pattern of matrix cracking formation and the axial stress redistribution due to each damage formation are represented in different $[0/90_n]_s$ and $[90_n/0]_s$ for the first time.

Keywords: debonding, matrix cracking, delamination, cohesive zone, extended finite element method.

1. Introduction

Nowadays, fiber-reinforced composite materials are used widely in different engineering applications and in many components due to their high stiffness and strength to the weight. However, the mechanical and thermal response of composite materials may be affected by several damage mechanisms in which the fiber matrix debonding and matrix cracking are of the primary damage modes. Although the initiation and propagation of these damage modes will not cause the collapse of the structure directly, however, they instantly will decrease the strength of the damaged layer a bit [1]. Furthermore, the matrix cracking formation can lead to the induced delamination formation, which has significant effects on the strength of structure [2]. It is worth noting that transverse fracture behavior of 90° plies in cross-ply composite laminates can be affected by two significant factors including the constituent properties as well as the interfacial properties.

Many researchers have studied the impacts of the probable damage modes in the response of composite materials through two significant approaches based on micromechanics of RVEs and multiscale hybrid models. The performed researches using models based on