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Abstract:

Previous researches on the impacted composite laminates were mainly carried out according to the macromechanics-based homogenous strength theories, which ignore the local stress nonuniformity and strength difference between the fiber and matrix. In this paper, a new multiscale analysis method which combines the micromechanics of failure (MMF) theory for intralaminar damage and cohesive model for interlaminar failure is proposed. This approach is able to identify the failure modes of fiber and matrix in microscale as well as delamination between laminas. The finite element model of the multidirectional carbon fiber reinforced plastic (CFRP) laminate subjected to low-velocity impact is built on ABAQUS/Explicit platform. User material subroutine VUMAT is deveploed to analyze the micro stresses and determine the possible failure modes of fiber and matrix. Cohesive elements with bi-linear traction-separation law are employed to capture the onset and propagation of delamination. Finally, the structure response, fiber and matrix failure mode and delamination area are compared with experimental data under different impact energies, and the good agreements validate the effectiveness and accuracy of the novel method.

Key words: multiscale, micromechanics of failure, failure criteria, low-velocity impact, cohesive model

1. Introduction

Carbon fiber reinforced plastic (CFRP) composite has been widely used in airplanes and automobiles by the virtues of high strength and light weight, however its sensibility to alien impact is a widespread issue to the structure designers and users. Compared with high energy impact, the low-velocity impact appears more frequently during the manufacturing or maintenance processes of composite structure[1], in addition, the damage caused by low-velocity impact is more covert and even invisible which causes huge threat to the structure safety. Therefore, the research works on failure mode and evolution mechanism are crucial important to the structure design and safety analysis. Due to the high cost and impossibility to study each situation by experiment, numerical method has been gradually adopted to assist the research of composite subjected to impact. The damage mechanisms of CFRP composite can be classified into intralaminar damages such as fiber breakage, matrix crack and interlaminar damage namely delamination, the complexity of which results in difficulties during simulation.

In previous research works of intralaminar damage various strength theories were proposed, among which, Hashin[2] and Puck[3]criteria and their modified theories are frequently adopted, this can be seen in the works of Pinho[4], Donadon[5], Falzon[6], Liu [7] and Li[8]. These theories are capable to determine the damage mode of constituents based on physical failure mechanism, however, both of them are macromechanics theory, which treat composite as homogeneous material and have not considered the influence of local stress difference in various area caused by the different properties of fiber and matrix.