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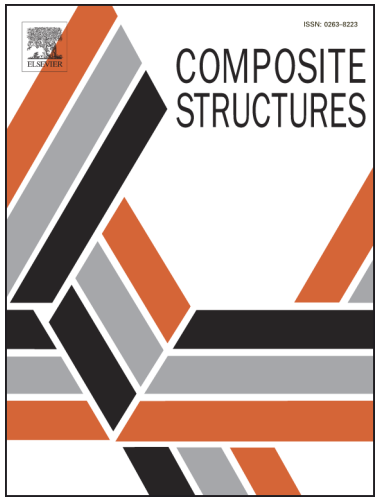

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Material parameter identification of the elementary ply damage mesomodel using virtual micro-mechanical tests of a carbon fiber epoxy system

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Abstract

A general multiscale hierarchical framework is proposed to identify the material parameters of a mesoscale model using numerical simulations based on virtual micro-mechanical tests. The identification of the material parameters is usually done with several experiments on different laminates. These experiments are replaced by virtual tests on a microscale finite element model with the same load conditions than the real experiments. The microscale model represents the unidirectional ply geometry based on its constituents, fibers and matrix, with their corresponding properties and the damage behavior of the matrix and interface between them. Under the defined load conditions, the homogenized stress-strain behavior of the laminates is obtained and then, the constitutive model parameters of the ply damage mesomodel are identified. As an example, the proposed framework is applied to identify the material parameters of the elementary ply damage mesomodel developed at LMT-Cachan. It is shown that, when the materials, geometry and load conditions are correctly defined in the micromodel, the real experiments can be replaced by virtual tests. As a result, the amount of experiments can be reduced saving costs and time. In addition, further studies can use the proposed methodology based on virtual micro-mechanical tests to improve the current mesoscale models.

Keywords: Multiscale modeling, Micro-mechanics, Virtual tests, Unidirectional ply, Damage mesomodel, Finite element method

1. Introduction

Accurate numerical models of fiber-reinforced composites are a key factor to reduce the amount of experiments in the design process of a structural component for current airplanes, boats or cars. The complete design process involves experiments at different scales, from millimeters where the material behavior is tested with coupons under simple loads, to meters where the structural component is tested under realistic loads (see the certification process of a composite aero-structure [1]). Therefore, the current approach is to reduce the amount of experiments by using virtual mechanical tests at the different scales to save time and costs [2–4]. On one hand, virtual tests can mimic experiments in the coupon level which completely describe the material behavior until failure; on the other hand, they can model elements or components under realistic loads to determine the deflection, stress and failure. To perform a virtual mechanical test, three ingredients are needed: (i) material models of the constituents, (ii) the geometry, and (iii) the load with appropriate boundary conditions.

In order to perform accurate virtual tests, a large number of studies have developed continuum models of fiber-reinforced composites at different length scales. At least three numerical scales can be distinguished: micro, meso and macroscale. The lower scale is the microscale where fibers and matrix conform a specific geometry. The dimensions go from several microns up to one millimeter. In the microscale, each constituent,

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