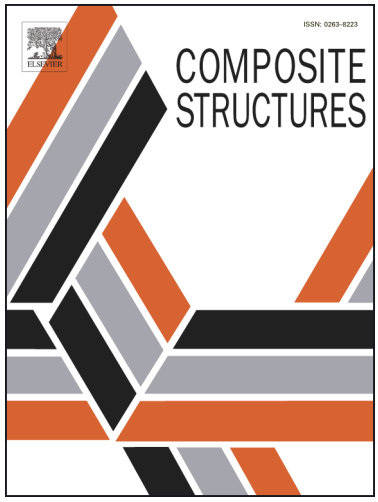

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Intraply failure criterion for unidirectional fiber reinforced composites by means of asymptotic homogenization

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Abstract

This work focuses on the determination of failure envelopes of unidirectional fiber reinforced composites. A two scale analysis is considered and the mathematical theory of asymptotic homogenization is applied to model the problem. For a given stress applied to the macro level, it is possible to assess stresses at the micro level domain. Three regions of the micro level are considered: matrix, fiber and the interface between them, and each region is ruled by its own failure criterion. A methodology to determine failure of composites using the homogenization is proposed. In the methodology, the strengths of the composite are used to determine the strengths of the constituents: a curve fitting adjustment is applied to calculate the strengths of the matrix and an analytical procedure is used to obtain the strengths of the fiber and interface. Then, the strengths of the constituents are used to evaluate failure criteria at the micro level, and the numerical failure envelopes are built. The advantage of the proposed methodology is that it is capable of calculating numerical failure envelopes with good approximation to experimental envelopes and also to the Puck & Schürmann criterion, requiring only five unidirectional strengths of the composite as inputs.

Keywords: asymptotic homogenization, homogenized elastic properties, unidirectional fiber reinforced composites, failure analysis, micromechanics

1. Introduction

Structural designs that use composite materials require prediction of failure initiation in order to conceive a safe and reliable structure. The knowledge of different failure mechanisms of polymer reinforced composites is crucial to use those materials effectively [1]. Due to the anisotropic nature of composite materials, it is not so simple to predict their mechanical behaviour [2].

An useful way to verify whether the composite is going to fail is by constructing failure envelopes. They correlate various stress combinations that cause failure, creating a boundary between a safe and a non-safe (failure) region. The failure envelope must follow some rules: it must be closed in order to prevent infinite strength and must be convex, so that the unloading from a stress state will not lead to additional failure [3]. The envelopes can be constructed using macromechanical and micromechanical approaches.

In a macromechanical analysis, the lamina is the object of study and it is usually treated as a homogeneous orthotropic material, and the failure criteria use the lamina strengths together with the lamina stresses and strains to predict failure of the composite [4]. One of the best known failure criterion of this type is the Tsai-Wu [5]. In the same line, Liu and Tsai [3] proposed a quadratic failure criterion and degradation of

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