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Multiphase continuum models for fiber-reinforced materials

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Abstract

This contribution addresses the formulation of a generalized continuum model called *multiphase model* aimed at describing more accurately the mechanical behavior of fiber-reinforced materials. Improving on the classical macroscopic description of heterogeneous materials by an effective homogeneous Cauchy medium, such models rely on the superposition of several continua (or phases) possessing their own kinematics at the macroscopic level and being in mutual interaction (in the same spirit of deformable porous media). Up to now, they have only been formulated based on phenomenological assumptions and the identification of the corresponding constitutive parameters remained unclear. The aim of this paper is three-fold. First, a homogenization procedure is described, enabling to derive constitutive parameters from the resolution of a generalized auxiliary problem on a classical heterogeneous microstructure. Second, analytical and numerical derivation of these properties is performed in various cases. Finally, illustrative applications on boundary-value problems assess the validity of the homogenization procedure and illustrate the relevance of such generalized models which are able to capture scale effects and to model crack bridging and delaminated configurations at the macroscopic level. It is also shown to encompass results of shear-lag models for analyzing stress transfers in fiber/matrix composites.

Keywords: fiber-reinforced materials, homogenization, generalized continuum, scale effects, crack bridging

1. Introduction

Fiber-reinforced materials, consisting of short or long linear inclusions embedded in a surrounding matrix, offer extremely interesting mechanical performances compared to more conventional materials. Optimal properties are achieved through careful design of many parameters such as fiber volume fraction, elastic modulus contrast, fiber orientation, fiber aspect ratio, ductility or brittleness of each phase, quality of the interface, and many more.

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