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FEA in elasticity of random structure composites reinforced by heterogeneities of non canonical shape

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ABSTRACT

One considers linearly elastic composite media, which consist of a homogeneous matrix containing a statistically homogeneous random set of aligned homogeneous heterogeneities of non canonical shape. Effective elastic moduli as well as the first statistical moments of stresses in the phases are estimated. The explicit new representations of the effective moduli and stress concentration factors are expressed through some building block described by numerical solution for one heterogeneity inside the infinite medium subjected to homogeneous remote loading. The method uses as a background a new general integral equation proposed in Buryachenko (2010a,b), which incorporates influence of stress inhomogeneity inside the inclusion on the effective field and makes it possible to reconsider basic concepts of micromechanics such as effective field hypothesis, quasi-crystalline approximation, and the hypothesis of "ellipsoidal symmetry". The results of this reconsideration are quantitatively estimated for some modeled composite reinforced by aligned homogeneous heterogeneities of non canonical shape. Some new effects are detected that are impossible in the framework of a classical background of micromechanics.

1. Introduction

A growing recognition that the properties of composite materials (CM) involve different scales reflects the explosive character of the progress in modern nano- and micromechanics caused by the development of image analyses and computer-simulation methods on one hand and advanced experimental techniques (such as X-ray tomography and electron microscopy) and improved materials processing (prescribed structure controlled by processing) on the other.

Research shows that composite mechanical properties greatly depend on the fiber shape (Zhou et al., 2005). To obtain a better load transfer mechanism and better stress distribution, many different fiber geometries have been experimented and analyzed. Kozaczek et al. (1995) studied a single non ellipsoidal inclusion in an infinite medium, which can be considered as a limiting case of a dilute concentration of inclusions. They demonstrated that the shape of the inclusion plays a role in the stress distribution in the grain boundary region; sharp corners raise stress more effectively than rounded edges of oblong-shaped precipitates. CM reinforced by shaped head fibers provide additional mechanical locking in comparison with straight fibers. Zhou (1994) probably first introduced this concept and showed that matrix composites with dumbbell-shaped steel wires have higher strength than those reinforced by straight wires. Tsai et al. (2005) analyzed stress profiles induced during pullout of two chosen shaped head families using a finite element analysis (FEA). Bagwell and Wetherhold (2005) (see also Wetherhold and Lee, 2001) investigated shaped fiber ends produced by end-impacting and knotting fibers to facilitate anchoring, similar to work with bone-shaped short fibers produced by Zhu and Beyerlein (2002) who evaluated the mechanical behavior of enlarged-end short fibers by experimental pullout of aligned fibers from a polyester matrix. Zhou et al. (2005) developed a FEA procedure for inclusion shape optimization maximizing the stiffness of CM and demonstrated that the enlarged-end short fiber with many threads is more desirable.

It should be mentioned that micromechanical modeling and simulation of random structures are becoming more ambitious because of the advances in modern computer software and hardware. Such methods, usually referred to as *computational micromechanics* (see, e.g., the representative works Gusev et al., 2002, Lusti and Gusev, 2004, Duschlbauer et al., 2006 and references therein), are based on both the wide exploration of Monte Carlo simulation and periodization of random media (see, e.g., Sab and Nedjar, 2005) with forthcoming numerical analysis for each random realization of multiparticle interactions of microinhomogeneities. However, at the present level of computer hardware and software, they are practical only for realizations containing no more then a few thousand inhomogeneities.

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