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Transport properties in fibrous elastic rhombic composite with imperfect contact condition

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ABSTRACT

In this contribution, effective elastic moduli are obtained by means of the asymptotic homogenization method (AHM), for oblique two-phase fibrous periodic composites with two models (*spring* and *interphase*) of imperfect contact conditions. This work is an extension of previous reported results, where only perfect contact for elastic or piezoelectric composites for square and hexagonal arrays were considered. The constituents of the composites exhibit transversely isotropic properties. A doubly periodic parallelogram array of cylindrical inclusions under longitudinal shear is considered. The behavior of the shear elastic coefficient for different geometry arrays related to the angle of the cell is studied. As validation of the present method, some numerical examples and comparisons with theoretical and experimental results verified that the present model is efficient for the analysis of composites with presence of imperfect interface and parallelogram cell. The effect of the arrangement of the cells on the shear effective property is observed. The present method can provide benchmark results for other numerical and approximate methods.

1. Introduction

The transport properties of circular cylinders packed in regular arrays are of considerable interest in a number of fields. The transport property may be the electrical or thermal conductivities, the dielectric permittivity, or the elastic shear modulus in antiplane elasticity. The result is of interest in the field of materials physics where two phase materials containing rod- or fiber-like inclusions often occur. Knowledge of their electrical or thermal conductivities and their elastic properties is valuable. Calculations on ordered arrays of cylinders are therefore directly relevant to practical situations. The problem of calculating the transport properties will be discussed here in the context of stiffness elastic properties. However, the mathematics and the results obtained are immediately applicable to other associated situations.

In most composites, the fiber–matrix adhesion is imperfect; the continuity conditions for stresses and displacements are not satisfied. Thus various approaches have been used, in which the bond between the reinforcement and the matrix is modeled by an interphase with specified thickness, by Hashin [1], Guinovart-Diaz et al. [2]. Other assumptions suppose that the contrast or jump of the displacements in the interface is proportional to the corresponding component of the tension in the interface in terms of a parameter given by the constant of a spring. This type of imperfect contact (*spring type*) in the interphases of the composites was investigated by Benveniste and Miloh [3] among others and has been used later, for instance, by Achenbach and Zhu [4] and Hashin [5–7].

Molkov and Pobedria [8] reported the elastic effective coefficients for two-phase fibrous composite with rhombic array of periodic cells under perfect contact conditions. Recently, Abolfathi [9] applied a numerical algorithm to determine the homogenized elastic properties of bidirectional fibrous composites and Jiang et al. [10] analyzed different situations of parallelogram composite. In this work, micromechanical analysis method is applied to a periodic composite with unidirectional fibers and parallelogram cells, in particular, rhombic periodic cells. The analytical expressions of the homogenized elastic properties are calculated for two phase composite with imperfect contact conditions. Two approaches (spring and three phase models) are used for the calculation of the shear elastic effective coefficients of angular fibrous composites with anisotropic elastic constituents with no well bonded contact. This contribution is an extension of previous works of Rodriguez-Ramos et al. [11] and Guinovart-Diaz et al. [12] using the asymptotic homogenization method (AHM). The results in this paper are mainly focused on the impact of the fibers cross angles

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