Micromechanical Modelling of Composites Based on Asymptotic Homogenization Method

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Abstract

Advanced composite materials and structures are widely used in various areas of modern engineering. Commonly, these materials are highly inhomogeneous with the dimensions of unit cell much smaller than the overall dimension of the structure. As a result, the coefficients of the differential equations describing mechanical behavior of these composite materials are rapidly varying functions in spatial coordinates. Consequently, the resulting boundary-value problems are very complex. They are so complex that the numerical methods (e.g., Finite Elements) applied directly to the original boundary-value problem for a composite structure are inappropriate in their standard form. Therefore, it is very important to develop rigorous analytical methods in order to reduce the complexity of the original boundary-value problems.

An issue of a high significance in micro-mechanics of advanced composites is determination of the effective properties of highly inhomogeneous composite materials, which will naturally depend on the spatial distribution, geometric characteristics and mechanical properties of the constituent materials of the composite. The micro-mechanical analysis of composite materials made up of reinforcements embedded in a matrix has been the focus of investigation for many years. At present, different methods are developed and applied in micro-mechanics of composites. Various asymptotic approaches to the analysis of composite materials of a regular structure have reached their conclusion within the framework of the mathematical theory of multi-scale asymptotic homogenization. Indeed, the proof of the possibility of homogenizing the composite material of a regular structure, i.e., of examining a homogeneous material instead of the original highly inhomogeneous composite material, is one of the principal results of this theory. Asymptotic homogenization method has also indicated a method of transition from the original problem (which contains in its formulation a small parameter related to the small dimensions of the unit cell of the composite) to a problem for a homogeneous material described by a set of the effective properties. This transition is accomplished through the solution of the problems formulated on the unit cell of the composite material. The solution of these unit cell problems allows determining the effective properties and distribution of local fields, e.g., displacements and stresses. The indicated results are fundamentals of the asymptotic homogenization.

The presentation will cover the basics of multi-scale asymptotic homogenization method. Simple example will be used to illustrate the asymptotic homogenization technique. The general asymptotic homogenization models will be further introduced and applied to the analysis of composite materials and thin-walled composite structures of a practical importance, including wafer-reinforced shells, orthotropic grid-reinforced composite shells and plates, and sandwich composite shells with cellular cores of different geometrical configuration. In particular, one of considered examples represents micromechanical modelling of the carbon nanotubes. The analytical expressions for the effective stiffness moduli of these composite reinforced shells and plates will be presented.