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A METHOD OF NUMERICAL MATERIAL TESTING FOR COMPOSITE MATERIALS

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ABSTRACT

A method of numerical material testing is developed for characterizing equivalent or macroscopic mechanical and/or other physical properties of composite materials with heterogeneous microstructures. The proposed method is prepared for testing on a variety of heterogeneous microstructures and nonlinear material behavior of constituents and their interfaces under various patterns of macroscopic loading. The numerical material testing in this method is intended to be carried out by means of the finite element method with a quasi-static implicit solution scheme in conjunction with the homogenization theory for periodic microstructures, i.e., unit cells.

The multiscale analysis with the proposed method is as follows: First, we prepare a periodic microstructure (unit cell) and assume an appropriate constitutive model for the equivalent homogeneous medium. Secondly, a series of numerical material tests is performed to obtained the homogenized or macroscopic material behavior according the assumed functional form of the assumed constitutive equation. Thirdly, the material parameters involved in the equation are identified by using the discrete data obtained in the numerical material tests. Fourthly, we carry out a macroscopic analysis. Finally, if necessary, by extracting the time-series of macroscopic deformation history form the macroscopic analysis result and by applying it as a series of boundary conditions, the localization analyses are performed to evaluate what has actually been happening inside the microstructure during the macroscopic deformation process.

The essential feature of this development is the re-organization of the relationship between microscopic and macroscopic physical quantities in the framework of two-scale finite deformation kinematics[1] to realize the homogenization and localization analyses by general purpose finite element software. Owing to this feature, material parameters of a variety of anisotropic constitutive models, whose material parameters are in general hard to obtain, can readily be identified by means of the data obtained by the numerical tests. Anisotropic plasticity and hyperelastic models might be typical examples in this context. The general versatility of the proposed method is demonstrated in several representative numerical examples dealing with such macroscopically anisotropic materials.

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