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Perturbation-based Stochastic Multi-scale Computational Homogenization Method for the Determination of the Effective Properties of Composite Materials with Random Properties

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Abstract

Quantifying uncertainty in the overall elastic properties of composite materials arising from randomness in the material properties and geometry of composites at microscopic level is crucial in the stochastic analysis of composites. In this paper, a stochastic multi-scale finite element method, which couples the multi-scale computational homogenization method with the second-order perturbation technique, is proposed to calculate the statistics of the overall elasticity properties of composite materials in terms of the mean value and standard deviation. The uncertainties associated with the material properties of the constituents are considered. Performance of the proposed method is evaluated by comparing mean values and coefficients of variation for components of the effective elastic tensor against corresponding values calculated using Monte Carlo simulation for three numerical examples. Results demonstrate that the proposed method has sufficient accuracy to capture the variability in effective elastic properties of the composite induced by randomness in the constituent material properties.

Keywords: Composites; Effective elastic properties; Computational multi-scale homogenization; Stochastic finite element method; Perturbation technique

1. Introduction

Given the opportunities they present to design for high-performance, composite materials have found extensive applications in a broad range of engineering fields. At the same time they have stimulated enormous research interest. It is the heterogeneous nature of composite materials at the microstructure level that makes the direct (micro-scale) modelling of the material behaviour impractical at structural or component scales.

An important issue when designing with composite materials is to be able to describe adequately the overall material properties on the basis of material parameters of the constituents, such that the structural or mechanical safety of the system can be demonstrated. This requirement demands some knowledge or consideration of variability

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