Stochastic multiscale heat transfer analysis of heterogeneous materials with multiple random configurations

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Abstract

This study presents a new stochastic multiscale analysis approach to analyze the heat transfer performance of heterogeneous materials with random structures at different length scales. The heterogeneities of the materials are taken into account by periodic layouts of unit cells, consisting of randomly distributed inclusion dispersions and homogeneous matrix on the microscale and mesoscale. Based on the reiterated homogenization, a novel unified micro-meso-macro stochastic multiscale formulation is established and the scale gap is correlated by means of two-scale asymptotic expansions. Also, the stochastic multiscale formulae for computing the effective thermal property and temperature field are derived successively. Then, the stochastic prediction algorithm coupled with the finite element method is brought forward in details. The accuracy of the implemented stochastic multiscale analysis is verified by comparing the results against the experimental data for three scales heterogeneous materials with several different material combinations. The comparison demonstrates the usability of the proposed stochastic multiscale method for the determination of the thermal behaviors. This study offers a unified multiscale framework that enables heat transfer behavior analysis of heterogeneous materials with multiple random configurations.

Keywords: multiple random configurations, heat transfer problem, reiterated homogenization analysis, micro-meso-macro formulations, stochastic multiscale model