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Computational homogenization of carbon/polymer composites with stochastic interface defects

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Abstract

This study concerns numerical determination of the basic statistics of the effective elasticity tensor for the polymer reinforced composite with the Carbon Black (CB) particles and including some interface defects. This is achieved by an application of the iterative generalized stochastic perturbation technique implemented as the Stochastic Finite Element Method (SFEM) and applied to the homogenization problem of such a composite. The interface defects are geometrically modelled as the semi-ellipsoidal voids into the matrix surrounding the CB particle, whose material properties, i.e. Young modulus and Poisson ratio have been chosen separately as the uncorrelated input Gaussian random parameters. These defects are replaced with the interphase whose stiffness is determined from spatial averaging of the defects and disjoint parts of the matrix. The SFEM homogenization study at the micro-level is carried out for 10 different volume fractions of defects in the interphase using the RVE with 27 particles and also with three components. Sensitivity analysis with respect to mechanical properties of the interphase together with the FEM computational error estimation for the homogenization problem are carried out prior to the principal stochastic analysis. We contrast the iterative SFEM with two other probabilistic numerical methods, namely the classical Monte Carlo scheme and also the semi-analytical probabilistic FEM strategy. These are all based on the same statistically optimized polynomial response functions of the input random Young modulus and Poisson ratio of the interphase. This study documents definitely remarkable impact of the defects on the stiffness tensor of the composite even for their relatively small volume fraction in this composite.

Keywords: Homogenization method; Semi-analytical method; Stochastic perturbation technique; Monte-Carlo simulation; Particle-reinforced composite;