SUMMARY OF DOCTORAL THESIS

Probabilistic analysis of composite materials with hyperelastic components

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A major topic of this dissertation is determination of the effective material parameters of composites with stochastic interface defects in their hyperelastic mode of strains. This is done with a joint usage of specially designed laboratory experiments and probabilistic homogenization. For this purpose a theoretical introduction is provided and suitable computational algorithms are proposed. These are applied and validated for the objective composite under uniaxial stretch. The objective composite consists of high density polyurethane matrix made of Laripur LPR 5020 and 5% of carbon black F60 reinforcement. The proposed approach is designed for an arbitrary isotropic hyperelastic potential and is validated with success for the Mooney-Rivlin, Arruda-Boyce and Neo-Hookean constitutive models. It introduces a concept of the augmented material model, which describes dependency of the effective material parameters on an extent of the stochastic interface defects. It is described by their volume fraction, which is also the only input random variable in this study; it has a Gaussian distribution. Further, the modeling strategy for mechanical properties of the hyperelastic interphase in direct neighborhood of the CB particles is proposed. It is used in verification of an influence of the input random variable on the composite effective material parameters, effective strain energies and effective stress under uniaxial stretch; this is done in the deterministic and stochastic context. Next, a computational algorithm for determination of statistical estimators of the input random variable is introduced and applied for the objective composite. Numerical calculus is made in a hybrid approach within a framework of the stochastic finite element method. The deterministic part is computed in the FEM system ABAQUS on the basis of a cubic Representative Volume Element and the probabilistic calculus is performed symbolically in the computer algebra system MAPLE 2018. Probabilistic part is computed with use of three independent methods, which are the generalized iterative stochastic perturbation technique, the crude Monte-Carlo simulation and probabilistic semi-analytical method. Probabilistic characteristics are computed for the composite state variables. They include the expected values, coefficients of variation, skewness and kurtosis.

Keywords: probabilistic homogenization; hyperelasticity; particulate composite; particle-reinforced composite; stochastic perturbation technique; Monte-Carlo simulation; semi-analytical method; interphase; interface defects; multiscale approach.

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