Micromechanical and Numerical Analysis of Shape and Packing Effects in Elastic-Plastic Particulate Composites

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The combined effect of reinforcement shape and packing on the macroscopic behaviour of particulate composites is presented. The proposed semi-analytical modelling method combines the Replacement Mori-Tanaka scheme and the analytical Morphologically Representative Pattern approach. The concentration tensors of non-ellipsoidal inhomogeneities are found numerically using simple simulations of a single particle. The extension to the regime of non-linear material behaviour is performed by employing the incremental linearization of the material response in two variants: tangent and secant, depending on the definition of the current stiffness tensor. The metal matrix is assumed to be a ductile material with linear elasticity and the Huber-von Mises yield function with the associated flow rule. The inclusion phase is considered to be a linearly elastic material with parameters relevant to a ceramic. The results are compared with the outcomes of numerical simulations and predictions of the classical mean-field models based on the Eshelby solution, e.g., the Mori-Tanaka model or the Self-Consistent scheme. The statistical volume elements have randomly placed inclusions with a selected shape. Five shapes of inhomogeneities are selected for the analysis: a sphere, a prolate ellipsoid, a sphere with cavities, an oblate spheroid with a cavity as well as an inhomogeneity created by three prolate spheroids crossing at right angles. It is found that the proposed modification of the Morphologically Representative Pattern approach can be used as an alternative to computational homogenization in the case of elastic-plastic composites with different shapes and packings of particles.