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Micromechanical modelling of packing and size effects in particulate elasto-plastic composites

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The aim of the presented study is to formulate the Morphologically Representative Pattern (MRP) model for elasto-plastic composites and to evaluate its applicability to describing the packing and size effects on their properties. The approach originates from the composite sphere Hashin model and its modification to the generalized self-consistent model by Christensen, cf. [1]. The concept was later employed in [2], within the morphologically representative pattern-based approach (MRP), to describe the packing and size effects in an elastic composite made of a continuous matrix and dispersed spherical particles. The MRP approach for elastic particle composites was extensively studied and verified with respect to the results of numerical homogenization in [3].

In the context of the model, the simplest variant is a 2-pattern approach where the representative volume element is approximated by two representative patterns: the first one governed by the n-phase generalized self-consistent scheme (n-GSC) and the second one described by the classical self-consistent scheme. To account for the size effect in the first pattern an interphase is introduced, having a thickness t_{int} independent of the particle radius and different properties than the basic two phases. To describe the packing effect, the coating thickness in the n-GSC pattern is specified by half the mean distance between nearest-neighbour particles in the representative volume element.

The extension of mean-field multi-scale models to nonlinear constitutive laws is usually done by incremental linearization of the material response at the computational steps. In the proposed model the method of secant or tangent incremental linearization is applied to compute the nonlinear response of a material in the elasto-plastic regime.

In the paper the predictions of the MRP scheme as concerns packing and size effects on overall elasto-plastic composite properties are compared with results of computational homogenization by the finite element method performed on the generated representative volume elements of prescribed statistical characteristics. The computational homogenization was performed on representative volume elements with randomly distributed non-overlapping spherical inclusions and controlled value of the packing parameter. The studied example is a composite consisting of a linear elastic ceramic phase and an elasto-plastic metal phase with plastic response governed by the Huber-Mises yield surface and power law hardening.

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