11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

# INFLUENCE OF INCLUSION MORPHOLOGY ON EFFECTIVE BEHAVIOUR OF ELASTOPLASTIC MATRIX-INCLUSION MATERIALS

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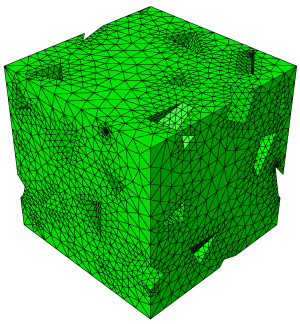
**Key words:** *inclusion morphology, elastoplasticity, pores, particles.*

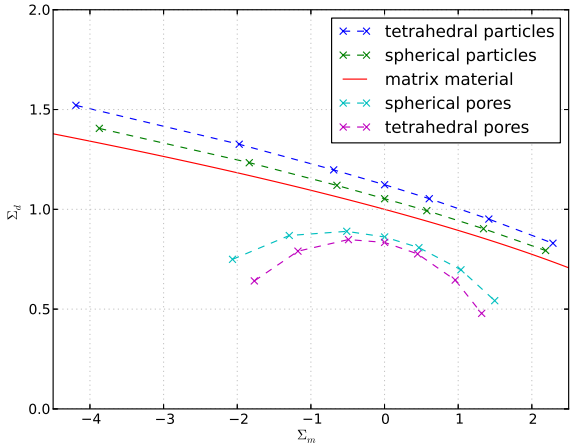
The present contribution addresses the effective behaviour of two-phase materials with a matrix-inclusion configuration. Various homogenization schemes for elliptic-shaped inclusions have been developed in the last decades (see [1]), and extended to non-linear problems (e.g., [2]). More recently, these analytical approaches were complemented by numerical analysis (e.g., [3]). Though, the inclusion morphology in real materials may deviate from the elliptic shape, which was treated in [4] for plain strain elasticity.

Our goal is to highlight the influence of inclusion morphology on the macroscopic behaviour considering elastic and plastic properties in three dimensions. For this matter, two cases are investigated: porous materials and materials reinforced with rigid particles. The homogenization of material properties is performed numerically. Finite-element models of representative volume elements (RVE) are generated with random, periodic geometries while varying certain material parameters (inclusion fraction and morphology, and matrix material behaviour). The inclusions are modelled as either tetrahedral or octahedral bodies with concave or convex faces, characterized by different surface/volume ratios and comprising spheres as special case. For the matrix material linear elasticity and ideal plasticity is assumed considering different types of yield criteria: Mises, Mises-Schleicher, and Green-type criteria (compressible matrix material). Applying periodic boundary conditions, the REVs are loaded by different stress paths defined by two stress invariants (triaxiality, Lode angle) for determining the corresponding stiffness and maximum load proportional factors. Numerical stability is achieved using the arc-length method.

In the domain of elasticity, the obtained results show a minor influence of the inclusion morphology on the effective behaviour in case of pores, while the shape of particles has a



(a) FE-model: tetrahedral pores.




(b) Yield surfaces in the deviatoric-hydrostatic stress space.

Figure 1: Numerical homogenization of strength properties: Comparison of spherical and tetrahedral inclusions (volume fraction $f_I = 0.1$, Lode angle $L = 60°$, Mises-Schleicher yield criterion).

significant impact. Also in case of plasticity, the effect of morphology is considerable, with morphologies deviating from the spherical shape increasing the weakening or strengthening effect of pores and particles, respectively (as shown by the example in Figure 1). The obtained results allow an assessment, how far well-developed approaches based on spherical inclusions (e.g., [2] and [3]) are still applicable for non-perfect spheres.

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