A 3D-, SGP-Based Model to Study the Effects of Distribution of Particle Size and Spacing on the Plastic Flow Properties of Precipitation-Hardened Materials

M.A. Asgharzadeh* and J. Faleskog

Department of Solid Mechanics
Royal Institute of Technology (KTH)
Teknikringen 8D, 10044 Stockholm, Sweden
Web page: http://www.hallf.kth.se

ABSTRACT

The mechanical behavior of a material on the macroscale depends on its microstructure. In case of precipitation hardening, this behavior is dependent on the particle-matrix interaction, which depends on parameters such as particle size and inter-particle spacing. Here, a 3D model has been developed to study such microstructures. Since conventional continuum theory is not able to capture the effects of scale, a strain gradient plasticity (SGP) theory [1] has been used for the matrix material, and the particle-matrix interaction has been modeled by employing energetic interfaces [2].

The model accommodates eight particles with different sizes in an RVE (figure 1). The edges of the RVE can also change in size, which results in a distribution of inter-particle spacing. The RVE possesses symmetric (and not periodic) boundary conditions. The model is loaded by uniaxial and biaxial straining, and the homogenized, macroscopic behavior of the material is determined.

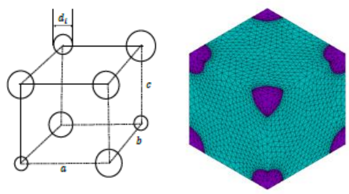

Figure 1-The eight-particle model and its FEM representation

We consider the influence of volume fraction of the particles, intrinsic length scale of the matrix, incoherency between the particle and matrix, plastic flow properties of the matrix, and specific to this study, variation in size and spacing of the particles. Figure 2 depicts the key findings of this study. Starting from left, the overall behavior of the material for different microstructure length scales and particle-matrix coherencies is shown. Decreasing the length scale of the microstructure, and making the interface layer stronger (more incoherent) add to the strengthening effect. Next, the effect of distribution of particle size for a fixed set of other parameters is shown. As the variation in particle sizes becomes bigger (particles tend to have different sizes), the strengthening effects become smaller. Last graph shows the effects of variation in particle spacing for a couple of parameter sets. The trend here, in contrast to the previous one, is that a more varied spacing (rather than a homogeneous distribution of particles) leads to more strengthening in the precipitated material.

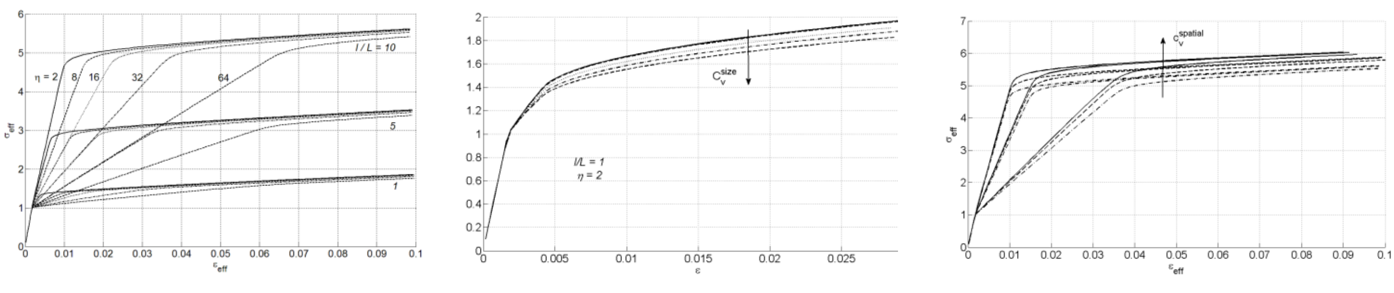

Figure 2-Selected numerical results

REFERENCES

[1] P. Gudmundson, “A unified treatment of strain gradient plasticity”, *J. Mech. Phys. Solids*, **52**, 1379-1406 (2004).

[2] N.A. Fleck and J.R. Willis, “A mathematical basis for strain-gradient plasticity theory. Part II: Tensorial plastic multiplier”, *J. Mech. Phys. Solids*, **57**, 1045-1057 (2009).