A generalized-secant homogenization scheme for viscoplastic polycrystalline solids under imposed deformations

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ABSTRACT

This work is concerned with homogenization techniques for correlating the macroscopic viscoplastic response of polycrystalline solids with the flow rules governing microscopic viscoplastic slip. Amongst the various quasi-analytical techniques available, the so-called `generalized-secant technique' proposed in [1] seems to deliver the most accurate estimates to date. This technique is based on the concept of `linear-comparison medium' whereby the macroscopic *stress* potential is rewritten in terms of linearized microscopic slip potentials so that linear homogenization techniques, such as the well-known Self-Consistent technique, can be used to approximate the nonlinear macroscopic potential. The resulting estimates are computationally inexpensive relative to full-field simulations, but they still require the numerical resolution of a large set of nonlinear algebraic equations. This fact can become an issue when simulating mechanical processess where deformations are imposed, which require inversion of the constitutive description in order to express stresses in terms of strain rates; this can be particularly crucial in problems where the material exhibits softening.

The purpose of this work is to derive generalized-secant estimates for the macroscopic *strain-rate* potential by applying the strategy of [1] directly to the velocity problem. This problem was not tackle in [1] because the strain-rate potential for crystalline solids does not exhibit the traditional additive form on which the linearization strategy hinges. However, well-known results of convex analysis do permit to write the inverted microscopic flow rule as the minimization of a sum. The accuracy of the resulting estimates is preliminary assessed in the context of a model material system consisting of a single crystal with a random distribution of porosity subjected to anti-plane conditions. Good agreement with previous estimates is found. Moreover, the new estimates agree exactly with those of [1] not only in the case of linearly viscous crystals but also in the extremely nonlinear case of ideal plasticity.

REFERENCES

[1] Y. Liu and P. Ponte Castañeda. “Second-order theory for the effective behavior and field fluctuations in viscoplastic polycrystals”, *J. Mech. Phys. Solids* **52**, 467--495 (2004).