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Numerical approaches have been extensively developed to predict the mechanical behavior of polycrystalline metals and alloys. In particular, micro-mechanical approaches have been used to take into account the physical mechanisms of deformation at different scales. Self-consistent approaches are common mean-field homogenization methods used to link crystal deformation mechanisms to the overall behavior of heterogeneous materials.

Many approaches have been developed in the case of elastic-plastic or viscoplastic behavior. The linearization of the macroscopic behavior has been classically carried out by using thermoelastic [1], incremental [2] or secant [3] approaches in elastic-plasticity and incremental [4] or tangent/secant [5] in viscoplasticity.

Such approaches are easy to implement numerically but cannot be developed out as easily in the framework of elasto-viscoplasticity because of the existence of two potentials, the free-energy density and the dissipation potential [6]. Lahellec and Suquet developped recently a variationnal approach to the effective response of elastic-plastic heterogeneous materials [6]. Moreover, Mareau *et al.* [7] proposed an alternative approximation based on translated fields to solve the elastic-viscoplastic heterogeneous problem. Although these mean-field approaches have been partly validated with respect to full-field FFT results, their numerical implementation is not straightforward.

Mercier *et al.* [8] proposed earlier a generalization of Molinari's model [5] to predict the elasto-viscoplastic behavior of heterogeneous materials. In the initial stage of loading (low stress but high stress rate), the grain/matrix interaction is assumed to be mainly thermo-elastic, turning out to be viscoplastic after the transient regime. The localization rule is then defined by an additive law including a thermoelastic term based on Kröner's localization rule and a viscoplastic term based on Molinari's localization rule. This model should be therefore able to predict the material behavior under low and high strain rates. Unfortunately, the use of the tangent modulus for the viscoplastic part leads to large underestimations of the macroscopic stress magnitude as already noticed in case of pure viscoplastic flow for high Norton law exponents [9].

In this work, a similar scale transition law as the Mercier-Molinari one, called Kroner-Secant, is applied. The macroscopic behavior is assumed to be isotropic. This model uses the secant modulus for linearizing the macroscopic viscoplastic behaviour. The secant modulus allow indeed a more accurate prediction in case of pure viscoplasticity and then enhancements may be expected in the elastic-viscoplastic framework. This new localization rule is as easy to implement as the Mercier-Molinari one.

The predictions of the self-consistent models proposed by Kroner [1], Hill-Hutchinson [2,4], Molinari [5] and Mercier-Molinari [8] are compared with the ones of the Kroner-Secant transition rule. Since these models assume different grain-matrix interactions, their global response under elasto-plastic and elasto-viscoplastic conditions is assessed. The predictions of these models are then compared to the results of full-field finite element (FE) computations carried out on a large aggregate which are considered as reference results.

In the elasto-plastic regime, the Kroner-Secant model leads to a macroscopic curve differing by less than 10% with respect to the one provide by the FE computations. Moreover, the Kroner-Secant formulation results to softer predictions compared to Kroner's model in the elasto-viscoplastic regime. The macroscopic response of the Kroner-Secant model under uniaxial loading is in a better agreement with the FE one, since it takes into account the elastic-viscoplastic interactions between each grain and the surrounding matrix. Additionally, cyclic deformation, creep and stress relaxation are rather well predicted by this mean-field model.

The mean grain equivalent viscoplastic strain distribution is evaluated under uniaxial tensile loading. Whatever the model used, a more scattered distribution is found at lower strain rate and for higher viscosity. Increasing the plastic strain, the width of the strain distribution curve decreases, but the width of the mean grain stress distribution curve increases. The difference between the homogenization schemes and the FE increases as plastic strain increases. Even so, the distribution computed using the Kroner-Secant approach is the closest to the FE one. The local mean grain stress and viscoplastic strain distributions computed during the relaxation phase are also analyzed. Once more, the Kroner-Secant model predicts more accurately the mean grain distributions than the other mean-fields models.

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