A Cosserat crystal plasticity and phase field theory for grain boundary migration

Benoît Appolaire*[1], Anna Ask[2], Kais Ammar[3], and Samuel Forest[3]

[1]Institut Jean Lamour (IJL) – Université de Lorraine, CNRS : UMR7198 – France
[2]DMAS – ONERA – France
[3]Centre des Matériaux – MINES ParisTech - École nationale supérieure des mines de Paris, CNRS : UMR7633 – France

Résumé

Elaborating a unified field framework to model concurrent viscoplastic deformation and recrystallization and grain growth in metal polycrystals has remained a formidable issue. In this work, we will present such a unified framework relying on the enhancement of a Cosserat crystal plasticity model with an order parameter to account for diffuse, mobile grain boundaries in analogy with phase field models. The Cosserat directors are taken to represent the lattice orientation of the grains. In order to introduce an evolution law for reorientation during grain boundary migration, the skew-symmetric part of the Cosserat deformation tensor is associated with a dissipative stress. The formulation in terms of the Cosserat deformation provides a natural way to couple reorientation due to deformation and reorientation due to grain boundary migration. In the absence of displacements and for a particular choice of free energy function the model can be considered a generalization to three dimensions of the Kobayashi–Warren–Carter (KWC) orientation phase field model (2000, 2003).

The proposed 3D anisotropic constitutive framework couples the changing orientation at a material point due to migrating grain boundaries (which is essential to the KWC model) to the lattice reorientation due to displacements and plastic slip. Due to the coupling of the Cosserat directors and the elastic reorientation, the bulk rotation of the grains which is inherent to the KWC model (and considered an artefact here although it can nevertheless be desirable in certain cases) can be controlled and even suppressed.

In this contribution, we will explain the main features of this framework and we will illustrate its capabilities with several cases that could not be handled convincingly by other models.

Mots-Clés: Recrystallization, phase field, Cosserat

*Intervenant