STRAIN GRADIENT AND COSSERAT CRYSTAL PLASTICITY WITH APPLICATION TO GRAIN BOUNDARY MIGRATION

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1. Stored energy by means of the dislocation density tensor in crystals

Internal stresses in crystalline solids are often induced by the development of non-homogeneous plastic deformation inside the grains of metallic polycrystals. The latter can be accounted for by means of the dislocation density tensor defined as the rotational part of the plastic deformation field. Energy is stored in that way and represented by appropriate terms in the Helmholtz free energy density function. Different forms of this potential will be discussed highlighting the various types of single crystal constitutive behaviour, especially under cyclic loading [6, 9].

Fig. 1 shows the response of a single crystal under shear with microhard boundary conditions inducing the pile-up of dislocations at grain boundaries. These non convex loops are obtained when the free energy density is proportional to the norm of the dislocation density tensor or to its logarithm. They correspond to the concept *first in–last out* for dislocations at grain boundaries [3].

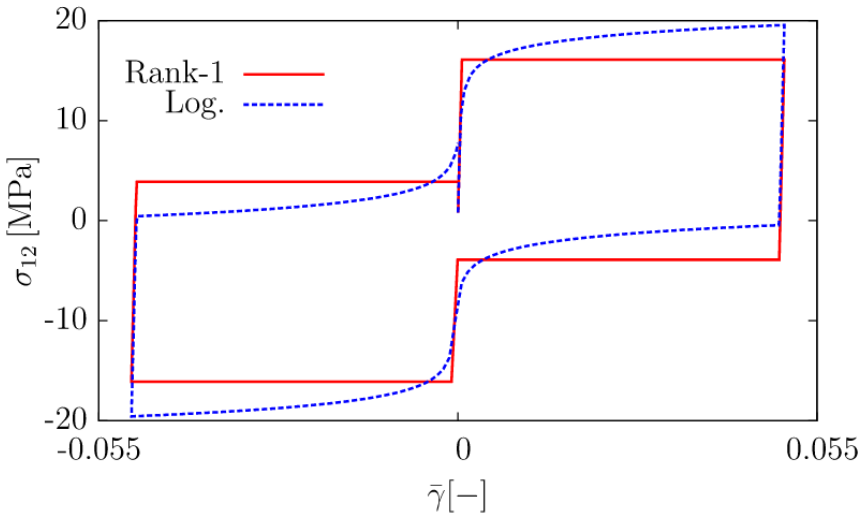

Figure 1: Non-convex cyclic loops in simple shear using two different free energy functions depending on the dislocation density tensor, after [9].

2. Cosserat crystal plasticity

The lattice curvature tensor can be seen as an approximation of the full dislocation density tensor. It has the advantage that it can be measured in a standard way by means of Electron Back-Scatter Diffraction, thus allowing for direct comparison between experiment and computations. The previous strain gradient plasticity model can be reduced to a Cosserat theory of crystal plasticity [5, 7]. Finite element simulations of the deformation of Cosserat and strain gradient polycrystalline aggregates will be presented.

3. Phase field modelling of grain boundary motion

This Cosserat theory of crystal plasticity is finally coupled to the phase field appoach to simulate the evolution of the polycrystalline microstructure. For that purpose, a phase field variable representing the crystal order is introduced, having minimal values inside diffuse grain boundaries of the polycrystal [1, 2, 8]. The gradient of stored energy serves as a driving force for grain boundary migration. Lattice rotation then has two origins: plasticity driven lattice rotation in the bulk of the grain, and lattice reorientation inside moving grain boundaries. The fully coupled Cosserat mechanical and phase field framework is used to simulate dynamic recrystallization at the mesoscale [4].

Fig. 2 shows the field of lattice orientation, cristallinity parameter and stored energy in deformed aluminium. The sweeping of some grain areas by grain boundaries is clearly visible on the right. Dynamic and static dislocation recovery takes place in the diffuse boundary.

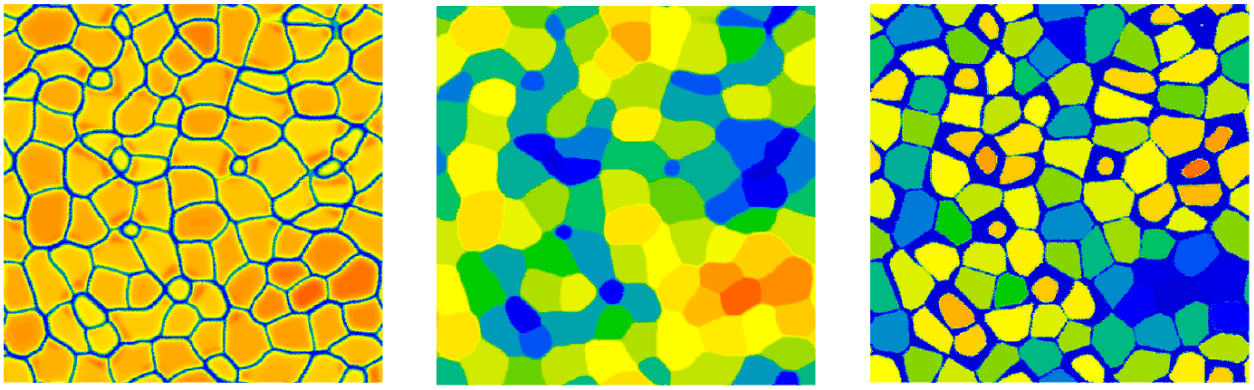

Figure 2: Phase field simulation of grain boundary migration in a deformed polycrystal, after [2]

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