Pile-up studies in dislocation-based single crystal gradient plasticity

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Introduction

In plastic deformations, which arise due to the motion of dislocations in crystalline microstructure, size effects cannot be neglected at a small scales of observation. Within each grain of a polycrystal, the grain boundaries act as natural obstacles to dislocation motion. Due to the stresses dislocations exert onto each other, dislocations will pileup against the grain boundaries as illustrated in Figure 1.

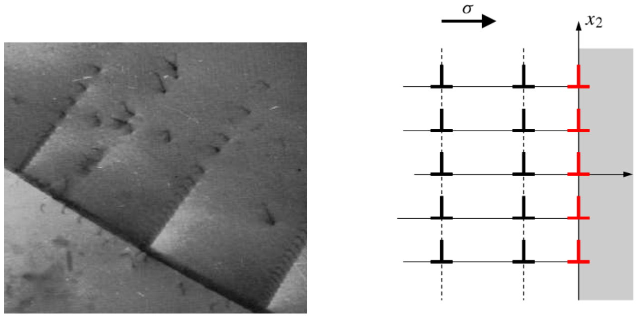

Figure 1: Pile-up against grain boundary [1], Idealized pile-up of edge dislocations against obstacle [2].

Such pile-up behaviour against grain boundaries is governed by the short-range interactions of the dislocations, which are captured through a back-stress term in crystal plasticity theories. We aim at a better understanding of this term.

Modelling

In order to get a clear view on the pile-up mechanism, we restrict ourselves to a simplified problem in which planar glide of edge dislocations against an obstacle perpendicular to the slip planes is considered, which can be modelled in one dimension.
Particularly, we compare two models:

- the strain gradient crystal plasticity of Evers [3],
- the pile-up studies of Kasyanyuk et al. [4].

First, the finite multi-slip framework of [3] is reduced to small strain and a one-dimensional single slip situation. This model uses the balance of the density of geometrically necessary dislocations

$$\rho_{\mathrm{GND}} - \rho_{\mathrm{GND0}} + \frac{1}{b}\frac{\partial \gamma}{\partial x} = 0\,,$$

whereby the evolution of slip is governed by a slip law, e. g.

$$\dot{\gamma} = \dot{\gamma}_0 \frac{\sigma_{12} - \frac{GbR^2}{8[1-\nu]}\frac{\partial \rho_{\mathrm{GND}}}{\partial x}}{Gb\sqrt{A_{11}}\sqrt{\rho_{\mathrm{SSD}} + |\rho_{\mathrm{GND}}|}}\,.$$

and an evolution of the statistically stored dislocation densities. Following the original 3d framework, boundary value problems are solved for the unknown dislocation density ρ_{GND}.
The alternative model of Kasyanyuk et al. [4] (see also [5]), is formulated in terms of a balance both for the total density of dislocations as well as for the density of geometrically necessary dislocations:

$$\begin{aligned} \dot{\rho} + (\rho_{\mathrm{GND}} v)' &= s \\ \dot{\rho}_{\mathrm{GND}} + (\rho v)' &= 0 \end{aligned} \qquad \text{with} \quad v = \frac{b}{B}\left[\sigma_{12} + \frac{1}{\rho}\frac{\partial \tau}{\partial x}\right]$$

Note that in the absence of a source term s, the total number of dislocations is preserved here.

Results

Using a finite-element framework, we model a double pile-up situation within a constrained channel under constant stress, with zero slip at the boundaries.

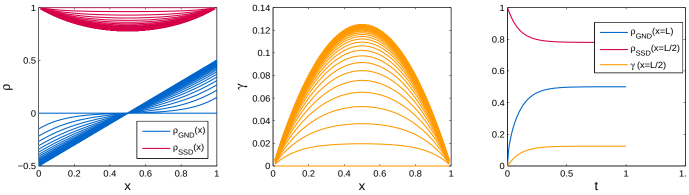

Figure 2: FE solution of double pile-up with ρ_{GND} as primary DOF, using simplified material parameters.

For the first of the two frameworks, Fig. 2 shows the distribution of ρ_{GND}, as well of slip γ over the domain. As time proceeds, both curves approach the steady state solution, which for the simplistic slip law used here obeys a linear relation for the first quantity, and a quadratic function for the slip, as can be shown analytically.

Outlook

The comparison of both frameworks, especially in terms of creation and annihilation of dislocations upon pile-up shall provide further insight into the short-range interactions between dislocations. By also incorporating multi-slip situations later on, we aim at enhanced back stress formulations for crystal plasticity based on a profound physical reasoning.

References:

[1] M. J. Whelan, P. B. Hirsch, R. W. Horne, and W. Bollmann. Dislocations and stacking faults in stainless steel. *Proc. Roy. Soc. Lond. A*, 240:524–538, 1957.

[2] A. Roy, R. H. J. Peerlings, M. G. D. Geers, and Y. Kasyanyuk. Continuum modeling of dislocations interactions: Why discreteness matters? *Mater. Sci. Eng. A*, 486:653–661, 2008.

[3] L. P. Evers. *Strain Gradient Crystal Plasticity Based on Dislocation Densities*. PhD thesis, Eindhoven University of Technology, 2003.

[4] Y. Kasyanyuk, R. H. P. Peerlings, and M. G. D. Geers. Nature of short-range effects and dislocation pile-up, 2008. draft.

[5] S. Yefimov. *Discrete dislocation and nonlocal crystal plasticity modelling*. PhD thesis, University of Groningen, 2004.