Viscous relaxation of dislocation sub-structure evolution

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Viscous Relaxation of Dislocation Sub-Structure Evolution

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The aim of the project

The aim of the project is to model the plastic anisotropy induced by the strain path changes in BCC metals. We follow three main modeling steps (Figure 1) in order to obtain a physically based multi-scale constitutive model. We started with the

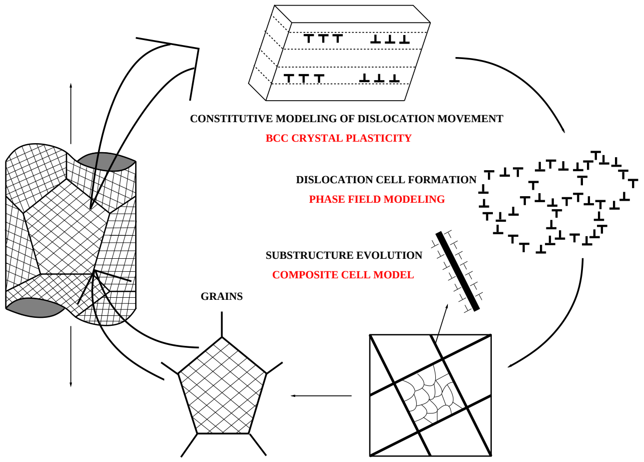
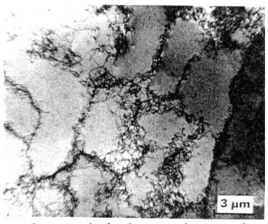


Fig. 1 *Bridging between micro, meso and macro levels.*

implementation of a crystal plasticity framework [1]. Then a composite cell model [2] was developed for the evolution of dislocation cells and the induced anisotropy. Now we are developing a method to predict the dislocation slip patterning.

Dislocation patterning



Dislocation patterning refers to the formation of regions of high and low dislocation densities. It is new a challenge to develop computational tools which can predict the emergence and the evolution of the dislocation sub-structures. Presented model, based on the relaxation of non-convex energies offers a new solution technique.

Field model - Non-convex SGCP

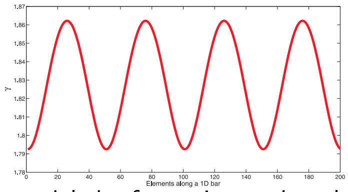
We solve the following system of equations with FEM,

$$\begin{aligned} \frac{\partial \sigma}{\partial x} &= 0 \\ \dot{\gamma} - \dot{\gamma}_0 \left(\frac{\sigma^{\text{dis}}}{s}\right) \text{sign}(\sigma^{\text{dis}}) &= 0 \end{aligned} \qquad (1)$$

where, σ^{dis} consists of stresses which are thermodynamically conjugate to variables γ, $\nabla\gamma$ and ε^e,

$$\sigma^{\text{dis}} = \hat{\sigma}^{\text{dis}} \left(\frac{\partial \psi}{\partial \varepsilon^e}, \frac{\partial \psi}{\partial \gamma}, \frac{\partial \psi}{\partial \nabla\gamma} \right) \qquad (2)$$

Free energy



Additional to convex parts ($\psi_e, \psi_{\nabla\gamma}$), a non-convex ($\psi_\gamma$) contribution of free energy enters the formulation via (2) and results in a rate dependent non convex strain gradient crystal plasticity framework which can model the formation and evolution of dislocation microstructures (right).

Spinodal decomposition of slip

Non-convexity in the free energy (ψ_γ) triggers the patterning between the spinodal points (Figure 2), however causes instability which results in mesh dependent behavior and an ill-posed BVP. The viscous effects and $\psi_{\nabla\gamma}$ part stabilizes the solution.

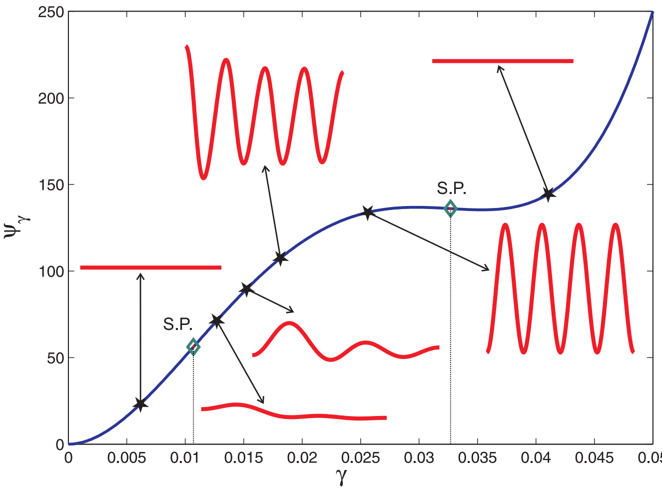
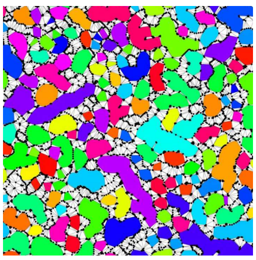


Fig. 2 *Patterning of plastic slip between spinodal points.*

Outlook



The current work is concentrated on the comparison of the presented model with different approaches. The next step is the multi-dimensional implementation of the model in order to have a more physical base for comparisons with experiments.

References:

[1] Yalcinkaya T. , Brekelmans W. A. M. , Geers M. G. D.: *MSMSE. 16 2008 085007*

[2] Yalcinkaya T. , Brekelmans W. A. M. , Geers M. G. D.: *MSMSE. 17 2009 064008*