BCC crystal plasticity for multi-stage loading processes

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BCC Crystal Plasticity for Multi-Stage Loading Processes

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Introduction

During sheet metal forming processes material points experience successive different strain paths which results in transient hardening or softening effects due to the induced plastic anisotropy. This anisotropy originates from different sources at different length scales and it has been experimentally observed that dislocation sub-structuring has a dominating effect at moderate strains.

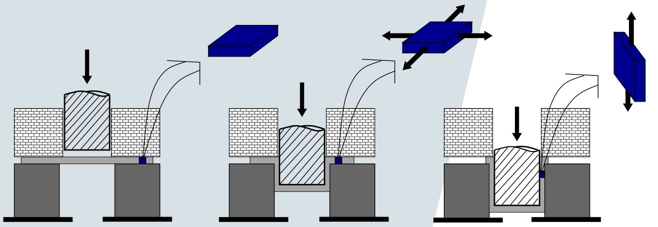

Figure 1 *Strain path change during deep drawing process*

Objective

The aim of the present work is to develop a constitutive model that quantitatively predicts anisotropy produced due to dislocation sub-structuring induced by a strain path change. Figure 2 visualizes the global modeling strategy.

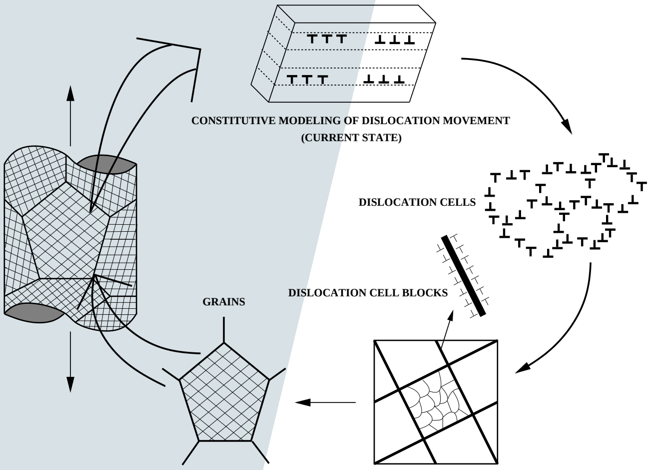

Figure 2 *Global modeling strategy including the bridges between micro, meso and macro levels.*

BCC Crystal Plasticity

In order to model strain path effects within a constitutive model, a proper description of the motion of dislocations is required. A temperature dependent, strain rate sensitive crystal plasticity model at finite strains has been implemented for this purpose. BCC crystals have a number of peculiar features that are not observed in other crystals, which are properly incorporated within the present approach. State of the art knowledge on the activity of slip planes and non-Schmid effects are also integrated in the model.

Model

The essence of the model is in the definition of the plastic deformation where the thermally activated theory of dislocation kinetics is implemented. The slip law:

$$\dot{\gamma}^\alpha = \dot{\gamma}_0^\alpha \exp\left(\frac{-G_0\left[1-\left(\frac{|\tau^\alpha+\eta^\alpha:\tau|-s^\alpha}{s_*^\alpha}\right)^p\right]^q}{k_B T}\right)\operatorname{sign}(\tau^\alpha)$$

includes all the pronounced aspects of BCC crystals such as temperature (T) dependence, thermal and athermal slip resistance (s^α, s_*^α) and the non-Schmid stress terms ($\eta^\alpha{:}\tau$).

Results

The examples in Figure 3 illustrate some intrinsic properties of BCC crystals (left top & bottom: orientation dependence and tension-compression asymmetry, right top & bottom: temperature dependence and strain rate sensitivity).

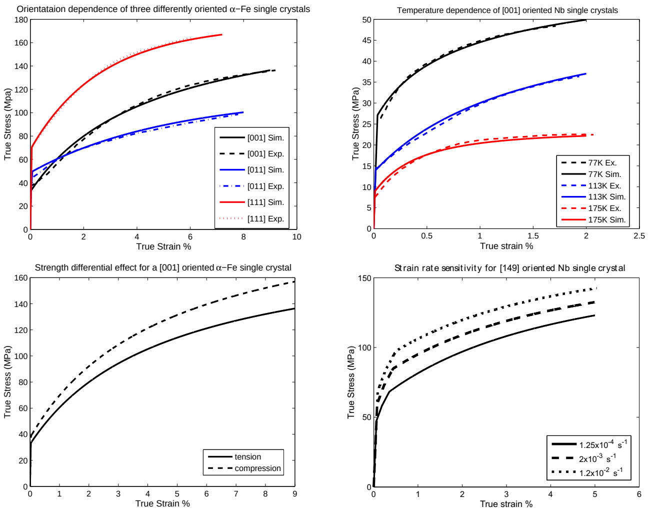

Figure 3 *Simulation of the intrinsic properties.*

Summary

- ☐ The constitutive model has been validated with experimental results and intrinsic properties of BCC crystals have been demonstrated.

Future work

- ☐ Dislocation cell and dislocation sheet forming will be incorporated in the present constitutive model.
- ☐ The evolution of this sub-structure will enable us to simulate the anisotropy induced by strain path change.

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