Three-dimensional size-dependent crystal plasticity: Application to mechanical testing of small-scale samples

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ABSTRACT

A finite-deformation strain gradient crystal plasticity model is developed and implemented in a three-dimensional finite element framework in order to study the influence of dislocation pile-ups in micro-mechanical testing of single crystals, for instance in micro-compression experiments [1]. The potential-based and thermodynamically consistent material model is formulated in a non-local and non-linear inelastic context in which dislocation densities are introduced via strain gradients. In the 3D context, the model predicts both, the distribution of edge and screw type dislocations and accounts for, e.g., size effects due to accumulation of GNDs (geometrically necessary dislocations), dislocation interactions in terms of latent hardening, and the Bauschinger effect. The robust solution algorithm is based on a numerically efficient non-standard finite element strategy to solve the highly coupled and highly nonlinear system of equations and it is suitable for parallelization on two different 'levels'.

Presented numerical examples are directly related to experiments. For instance, it is shown that the inclusion of the strain gradient into the free energy enables a reasonable prediction of the deformation behaviour in the case of micro-pillar compression. Here, a typical distinct slip band formation is successfully reproduced by the presented theory. This is experimentally supported by an EBSD analysis of the thinned cross-section of a deformed sample where the correlation between the obtained lattice rotation and calculated GND distributions showed great accordance.

REFERENCES

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