Size affected dislocation plasticity in single crystals at small scales

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ABSTRACT

Plasticity at small scales is often affected by a superposition of different strengthening mechanisms. Besides dislocation starvation and source limitation phenomena, other factors may influence the dislocation activities, e.g., in terms of surface effects associated with nanoscale inhomogeneities [1]. In addition to that, strain gradient plasticity can play a crucial role in the deformation behaviour of crystalline materials, for instance in microcompression of single crystals [2] or during testing of nanocomposites in which bending is a predominant deformation mode by which interconnecting solid ligaments deform [3]. In fact, bending represents a typical deformation mode which is exposed extrinsically, leading to the storage of geometrically necessary dislocations (GNDs) within the material. Microbending experiments of single crystals indicate a strong inverse correlation between the thickness of cantilever beam samples and the flow stress. This so-called bending size effect is in the focus of this contribution. A higher-order strain gradient crystal plasticity framework at finite deformations is used to study the extent to which GNDs affect the size dependent bending behaviour [4]. The finite element implementation of the coupled macro-micro mechanical problem is based on a mixed interpolation scheme. The resulting impact on the mechanical bending response as well as on the predicted size effect is analysed. The results are related to experimental findings from the literature.

REFERENCES

[1] E. Husser, C. Soyarslan, S. Bargmann (2017): Size affected dislocation activity in crystals: advanced surface and grain boundary conditions, Extreme Mechanics Letters, accepted for publication.

[2] E. Husser, E. Lilleodden, S. Bargmann (2014): Computational modeling of intrinsically induced strain gradients during compression of c-axis-oriented magnesium single crystal. In: Acta Materialia, 71, 206-219.

[3] S. Bargmann, C. Soyarslan, E. Husser, N. Konchakova (2016): Materials based design of structures: Computational modeling of the mechanical behavior of gold-polymer nanocomposites, Mechanics of Materials, 94: 53–65.

[4] E. Husser and S. Bargmann (2017): The role of geometrically necessary dislocations in cantilever beam bending experiments of single crystals, under review.