A Density Field Theory of Plasticity based on the Evolution of the Dislocation Microstructure

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ABSTRACT

The prediction of plastic deformation of metals has a long history and has been conducted from two perspectives. On the one hand, phenomenological approaches (i.e. top-down approaches) can be found, which allow for the predictions of macroscopic material properties using parameters for adaption to experiments. On the other hand there are bottom-up approaches, which are based on the understanding of the underlying physical processes. A central aim is to close the gap between both approaches in order to gain understanding of how the basic physical properties influence the macroscopic material properties.

Discrete dislocation dynamics has shown to be a valuable computational tool which represents a physically motivated description of the evolution of dislocation microstructures causing plastic deformation. The restriction to very small scales due to computational costs leads to the need of an averaged continuum model, which is able to increase the computational efficiency by maintaining the physical representation of dislocation microstructures and their evolution without undefined fitting parameters.

We focus on the continuum dislocation dynamics theory [1], which fulfils the requirements of a density field theory and correctly describes the kinematics of the evolution of the dislocation microstructure in terms of dislocation densities. Here, a continuum descriptions of the physical effects based on the generalization of ensemble averages of discrete dislocation dynamics simulations is derived. We present a continuum method to account for the internal stress fields of a given dislocation microstructure [2] and show the applicability of the formulation by comparing our findings to discrete dislocation ensemble averages and results from 2d statistical physics [3].

REFERENCES

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