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A mesoscale crystal plasticity framework based on the simplified Continuum Dislocation Dynamics (sCDD) theory

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The motion and interaction of dislocation lines are the physical basis of the plastic deformations of metals. Though Discrete Dislocation Dynamics simulations are able to predict the kinematics (i.e. evolution of dislocations in the given velocity field) of the dislocation microstructure and therefore the plastic behaviour of crystals in small length scales, their computational cost make them less feasible as systems enlarges. In order to overcome this obstacle, the Continuum Dislocation Dynamics (CDD) theory was developed.
The CDD theory is based on higher dimensional generalization of the classical Kröner dislocation density tensor [1, 2]. In this theory, the kinematics of the dislocation system is described based on statistical averaging of observable internal variables. The main advantage of using density like quantities for describing the dislocations is that the number of represented dislocation in a system doesn't have direct effect on computational cost.
In this paper we present a crystal plasticity framework based on the CDD theory. This framework consists of two parts: Finding the stress state of a single crystal which is obtained from the solution of an elastic boundary value problem together with internal stress components of dislocations microstructure and the problem of kinematics of dislocations in the crystal which is solved by Continuum Dislocation dynamics (CDD). Both parts are solved by the finite element method and coupled through eigenstresses due to an inhomogeneous plastic slip [3].

We investigate the ability of the method to capture size effect phenomena in a 3D micro pillar with multiple slip systems under shear load. We compare the evolution and multiplications of dislocations due to the stresses and activation of Frank-Read sources with discrete dislocation dynamics simulations. We will also briefly discuss some numerical and implementation issues, such Discontinuous Galerkin finite element implementation of conservative for of equations, mesh refinement criteria and computation time.

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