

Statistical Underpinning of Continuum Dislocation Dynamics

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ABSTRACT

Understanding the strength of metals has been a scientific challenge for many decades. In recent years, much progress was made toward understanding the plastic strength of metals, thanks to the method of discrete dislocation dynamics (DDD) simulations. This method simulates the evolution of dislocation ensembles in crystals thus revealing how the dislocation mechanisms collectively translate to the observed plastic behavior. The method also has the potential of accounting for alloy strengthening mechanisms caused by solute and particles. However, the DDD method is limited to probing the deformation behavior of metals in the small strain range of only few %. Practical levels of crystal deformation encountered in experiments require the development of dislocation-based models of plasticity that capture the deformation behavior up to higher strain levels. The method of continuum dislocation dynamics (CDD) is believed to meet this objective. This method casts the dislocations dynamics problem in the form of transport-reaction equations for crystal dislocations after expressing them in terms of density fields. Coupled with crystal mechanics, these transport equations provide the plastic closure required solve the crystal deformation problem self-consistently. At present time, however, the method faces theoretical challenges having to do with properly coarse graining the dislocation system, and mathematically expressing their reactions, mobility, and short-range interactions in a density-based framework. Key to resolving these issues is the proper modelling of the spatial and temporal statistics of large dislocation systems and their fields. Accounting for finite deformation kinematics has also been a challenge that was recently addressed. In this presentation, we review the recent progress in the area of continuum modelling of dislocation dynamics, with emphasis on the statistical modelling of internal stress fluctuations and how they influence cross slip and dislocation self-organization.

This work was supported by the National Science Foundation, Division of Civil, Mechanical, and Manufacturing Innovation (CMMI), through award number 1663311 and by the US Department of Energy, Office of Science, Division of Materials Sciences and Engineering, through award number DE-SC0017718 at Purdue University.