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Dislocation-based Analysis of the Plastic Material Behavior of Heterogeneous Structures

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The great demand for advanced materials and well-defined microstructures has led to an increasing effort towards a proper description of the motion of dislocations as the cause of plastic deformation. In the last few years, several dislocation based continuum theories have been introduced. Only recently rigorous techniques have been developed for performing meaningful averages over systems of moving, curved dislocations, yielding evolution equations for a higher order dislocation density tensor, see [1]. In order to construct a self-consistent implementation, several issues have to be resolved including calculation of the stress field of a system of dislocations, coarse graining, and boundary conditions. A numerical implementation and some simple benchmark tests of a continuum theory for dislocation dynamics (CDD) are discussed in [2].

While accurate solutions have been found for one dimensional systems, fully two- and three-dimensional systems increase the complexity of the system. In order for the behavior of the continuum dislocation density evolution to be accurately predicted, the continuum density must be properly understood as an ensemble average over discrete distributions. In this contribution, an overview of the results for a distribution of one-dimensional glide planes in a two-dimensional elastic medium are presented and several aspects of numerical homogenization are analyzed. Using comparisons with discrete dislocation dynamics calculations in a few simple systems, the multi-component stress field which must be considered for dislocation density motion is derived and discussed. The application to heterogeneous composite materials shows the importance of the correct representation of dislocation pileups for the structural behavior.

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