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Modelling of dislocation mediated plasticity across the scales

M.M.W. Dogge[1,2], R.H.J. Peerlings[2,*], M.G.D. Geers[2]

[1]Materials innovation institute M2i
PO Box 5008, 2600 GA Delft, Netherlands
[2]Department of Mechanical Engineering, Eindhoven University of Technology
PO Box 513, 5600 MB Eindhoven, Netherlands

*Corresponding author: R.H.J.Peerlings@tue.nl

Glide of dislocations is an important mechanism underlying plasticity of crystalline materials. The behaviour of individual dislocations in a perfect crystal is quite well understood. Plasticity at a larger scale, however, is the result of a massive number of dislocations. Our work is aimed at understanding how the collective response of large numbers of individual dislocations, embedded in a crystalline microstructure at an intermediate scale, ultimately determines the macroscopic response of the material. We therefore eliminate the smallest scale, i.e. that of individual dislocations, by a homogenisation approach and formulate continuum transport equations for the total dislocation density as well as the excess density at the scale of the microstructure. Short-range interactions between the dislocations are accounted for by gradients of these densities along the slip system. This results in nonstandard, nonlocal governing equations. The equations are solved numerically by the finite element method. Results are discussed for a uniform medium with constrained boundaries, as well as for a heterogeneous, two-phase material. These results demonstrate how the nonlocal transport character influences the material's plastic response.

Keywords: Dislocations, Continuum Modelling, Nonlocal Continua, Finite Element Simulation