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DISLOCATION DENSITY DISTRIBUTION AROUND AN INDENT IN SINGLE-CRYSTALLINE NICKEL: COMPARING NONLOCAL CRYSTAL PLASTICITY FINITE ELEMENT PREDICTIONS WITH EXPERIMENTS

Franz Roters[1], Christoph Kords[1], Philip Eisenlohr[2] and Dierk Raabe[1]

[1] Max-Planck-Institut für Eisenforschung, Microstructure Physics and Alloy Design, Max-Planck-Straße 1, 40237 Düsseldorf, Germany, f.roters@mpie.de, http://www.mpie.de

[2] Michigan State University, Chemical Engineering and Materials Science, East Lansing, MI 48824, USA, eisenlohr@egr.msu.edu, http://www.chems.msu.edu

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We present a physics-based constitutive model of dislocation glide in metals that explicitly accounts for the redistribution of dislocations due to their motion. The model parametrizes the complex microstructure by dislocation densities of edge and screw character, which either occur with monopolar properties, i.e., a single dislocation with positive or negative line sense, or with dipolar properties, i.e., two dislocations of opposite line sense combined. The advantage of the model lies in the description of the dislocation density evolution, which not only comprises the usual rate equations for dislocation multiplication, annihilation, and formation and dissociation of dislocation dipoles. Additionally, the spatial redistribution of dislocations by slip is explicitly accounted for. This is realized by introducing an advection term for the dislocation density that turns the evolution equations for the dislocation density from ordinary into partial differential equations. The associated spatial gradients of the dislocation slip render the model nonlocal. The model is applied to wedge indentation in single-crystalline nickel. The simulation results are compared to published experiments [1] in terms of the spatial distribution of lattice rotations and geometrically necessary dislocations. In agreement with experiment, the predicted dislocation fluxes lead to accumulation of geometrically necessary dislocations around a vertical geometrical border with a high orientation gradient below the indenter that is decisive for the overall plastic response. A local model variant without dislocation transport is not able to predict the influence of this geometrical transition zone correctly and is shown to behave significantly softer.

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