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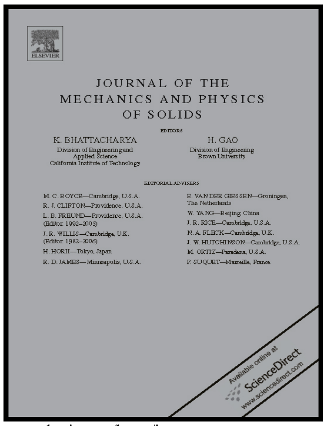

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S.M. Keralavarma, A.A. Benzerga

PII: S0022-5096(15)00108-8
DOI: http://dx.doi.org/10.1016/j.jmps.2015.05.003
Reference: MPS2643

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 19 September 2014
Revised date: 19 February 2015
Accepted date: 12 May 2015

Cite this article as: S.M. Keralavarma and A.A. Benzerga, High-Temperature Discrete Dislocation Plasticity, *Journal of the Mechanics and Physics of Solids,* http://dx.doi.org/10.1016/j.jmps.2015.05.003

High-Temperature Discrete Dislocation Plasticity

S. M. Keralavarma[1*] and A. A. Benzerga[1,2]

[1] *Department of Aerospace Engineering, Texas A&M University, College Station, TX 77843*

[2] *Department of Materials Science & Engineering, Texas A&M University, College Station, TX 77843*

May 13, 2015

Abstract

A framework for solving problems of dislocation-mediated plasticity coupled with point-defect diffusion is presented. The dislocations are modeled as line singularities embedded in a linear elastic medium while the point defects are represented by a concentration field as in continuum diffusion theory. Plastic flow arises due to the collective motion of a large number of dislocations. Both conservative (glide) and nonconservative (diffusion-mediated climb) motions are accounted for. Time scale separation is contingent upon the existence of quasi-equilibrium dislocation configurations. A variational principle is used to derive the coupled governing equations for point-defect diffusion and dislocation climb. Superposition is used to obtain the mechanical fields in terms of the infinite-medium discrete dislocation fields and an image field that enforces the boundary conditions while the point-defect concentration is obtained by solving the stress-dependent diffusion equations on the same finite-element grid. Core-level boundary conditions for the concentration field are avoided by invoking an approximate, yet robust kinetic law. Aspects of the formulation are general but its implementation in a simple plane strain model enables the modeling of high-temperature phenomena such as creep, recovery and relaxation in crystalline materials. With emphasis laid on lattice vacancies, the creep response of planar single crystals in simple tension emerges as a natural outcome in the simulations. A large number of boundary-value problem solutions are obtained which depict transitions from diffusional to power-law creep, in keeping with long-standing phenomenological theories of creep. In addition, some unique experimental aspects of creep in small scale specimens are also reproduced in the simulations.

*Presently at Indian Institute of Technology Madras, Chennai, India