Thermodynamic dislocation theory for non-uniform plastic deformations

K.C. Le

PII: S0022-5096(17)30432-5
DOI: 10.1016/j.jmps.2017.10.022
Reference: MPS 3216

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

Received date: 24 May 2017
Revised date: 20 September 2017
Accepted date: 30 October 2017

Thermodynamic dislocation theory for non-uniform plastic deformations

K. C. Le

Lehrstuhl für Mechanik - Materialtheorie, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Abstract

The present paper extends the thermodynamic dislocation theory developed by Langer, Bouchbinder, and Lookman to non-uniform plastic deformations. The free energy density as well as the positive definite dissipation function are proposed. The governing equations are derived from the variational equation. As illustration, the problem of plane strain constrained shear of single crystal deforming in single slip is solved within the proposed theory.

Keywords: dislocations, thermodynamics, configurational temperature, plastic yielding, strain rate.

1. Introduction

Macroscopically observable plastic deformations of single crystals and polycrystalline materials are caused by nucleation, multiplication and motion of dislocations. The interesting question arrises in this connection: is entropy of dislocations relevant to thermodynamics of plasticity and should we take it into account in the continuum dislocation theory? At first glance, since the energy of a single dislocation is so large that ordinary thermal fluctuations cannot create or annihilate it, the kinetic-vibrational temperature of the crystal seems to be irrelevant to the nucleation and motion of dislocations. On the other hand, as the entropy of disorder induced by a dislocation is extremely small compared with the total entropy of the crystal, the standard thermodynamics of crystal plasticity (see, e.g., (Rice, 1971; Halphen and Nguyen, 1975; Lubliner, 2008) and the references therein) have been ignoring the entropy of dislocations completely. A theoretical concept of dislocation entropy was first introduced by Berdichevsky (2008) with a

Preprint submitted to Journal of Mechanics and Physics of Solids *November 3, 2017*