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Mechanics of dislocation pile-ups: A unification of scaling regimes

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Abstract

This paper unravels the problem of an idealised pile-up of n infinite, equi-spaced walls of edge dislocations at equilibrium. We define a dimensionless parameter that depends on the geometric, constitutive and loading parameters of the problem, and we identify five different scaling regimes corresponding to different values of that parameter for large n. For each of the cases we perform a micro-to-meso upscaling, and we obtain five expressions for the mesoscopic (continuum) internal stress. The upscaling method we illustrate here can be made mathematically rigorous, as we show in the companion paper (Geers et al. Asymptotic behaviour of a pile-up of infinite walls of edge dislocations, *Arch. Ration. Mech. Anal.*, **209** (2013), 495–539). The focus of the present paper is on the mechanical interpretation of the resulting internal stresses. In the continuum limit we recover some expressions for the internal stress that are already in use in the mechanical community, as well as some new models. The results in this paper offer a unifying approach to such models, since they can be viewed as the outcome of the same discrete dislocation setup, for different values of the dimensionless parameter (i.e., for different local dislocations arrangements). In addition, the rigorous nature of the upscaling removes the need for ad hoc assumptions.

Keywords: Dislocations, pile-up, internal stress, plasticity.

1. Introduction

Dislocations occupy a central position in discussions of the permanent deformation of metals because of their role as the main carriers of plastic deformation. Therefore it is necessary to incorporate their presence, or the main effect of their presence, in a plasticity model that aims for a predictive power. However, since the typical number of dislocations even in a small sample of the material is very high, formulating a model that keeps track of every single dislocation is out of reach except for very small-scale problems. This explains the interest in describing the collective behaviour of dislocations in terms of a continuum quantity: the dislocation density.

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