Università degli Studi di Pavia

Dipartimento di Ingegneria Civile e Architettura

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Crystal and phenomenological distortion-gradient plasticity theories

In the first part of this talk, we present a higher-order strain gradient crystal plasticity theory in which, for each glide, three dissipative material length scales enter the model through the definition of an effective slip rate. Such a plasticity measure governs the isotropic hardening function and requires the introduction of length scales for dimensional consistency because it depends also on the crystallographic projections of the plastic slip gradient rate. Two of these projections represent pure edge and screw dislocation densities. Most noticeably, the gradient theory subject of this talk is characterised by a non-standard addition to the free energy called the defect energy, that is a function of Nye's dislocation density tensor and allows for the inclusion of energetic material length scales. By focusing on a crystalline strip sheared between two bodies impenetrable to dislocations, and by resorting to the deformation theory approximation, we show which size effects the model can predict. In particular, we focus on both the strengthening and the increase in strain hardening accompanied with diminishing size, and on their relations with both the material length scales involved in the modelling and the relative orientations of the active slip systems.

By exploiting a Γ-convergence technique, we find an analytic solution in the "isotropic limit" of the crystal model, where any direction is assumed to be a possible slip system. This, supported by many simulations, shows that the phenomenological model of gradient plasticity which better approximates the crystal one is that constitutively involving the dissipation due to the plastic spin, as envisaged by Morton E. Gurtin about ten years ago. Hence, in order to highlight the presence of the plastic spin among the primal kinematic variables of this phenomenological higher-order theory, we call it a distortion -gradient plasticity theory. In such a theory, the material parameter governing the dissipation due to the plastic spin can be estimated by comparison with the analytic integration of the balance equations obtained from the minimisation of the "isotropic" Γ-limit. Appropriate benchmark problems are exploited to illustrate the modelling capability and some peculiarities of the phenomenological distortion-gradient plasticity theory under study.

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