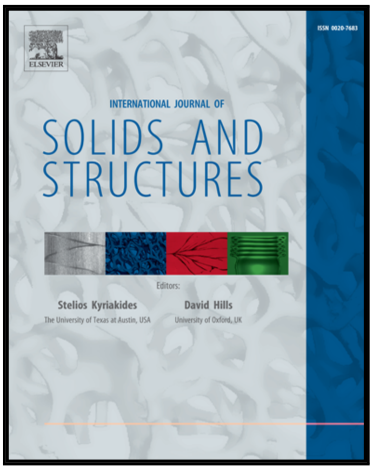

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# A reduced micromorphic single crystal plasticity model at finite deformations. Application to strain localization and void growth in ductile metals

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## Abstract

A micromorphic single crystal plasticity model is formulated at finite deformations as an extension of Mandel's classical theory based on a multiplicative decomposition of the deformation gradient. It involves a single *microslip* degree of freedom in addition to the usual displacement components. Two main variants of the constitutive equations are proposed. The first one relies on a Lagrangian microslip gradient and leads to a Laplace term in the isotropic hardening law. In contrast, the second formulation, based on a generalized strain measure defined with respect to the intermediate configuration, is shown to induce both isotropic and kinematic enhanced hardening. The first formulation is implemented in a 3D finite element code. The model is applied first to strain localization phenomena in a single crystal in tension undergoing single slip. The regularization power of the model is illustrated by mesh-independent simulations of the competition between kink and slip bands. The model is then used to investigate void growth and coalescence in FCC single crystals. Cylindrical and spherical voids are considered successively. The simulations show, for the first time in the case of spherical voids embedded in a single crystal matrix, that smaller voids grow slower than bigger ones, and that the onset of void coalescence is delayed for smaller voids. These results are related to the fact that the field of plastic slip is found to be more diffuse around smaller voids.

*Keywords:* Micromorphic model, Strain gradient plasticity, Ductile single crystal, Strain localization, Slip band, Kink band, Regularization, Void growth, Void coalescence, Size effect

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## 1. Introduction

The intrinsically heterogeneous nature of plastic slip in metals results in a non-homogeneous deformation of single crystals. With increasing straining, the deformation of single crystals is usually accompanied with diffused necking or/and localized shearing (Peirce et al., 1982a), which has been observed in experimental studies such as in (Simoto et al., 1965; Chang and Asaro, 1981). Localized shear banding in single crystals has been analyzed by means of bifurcation analysis of the classical crystal plasticity constitutive equations (see, e.g., Asaro and Rice (1977); Forest and Cailletaud (1995); Forest (1998)) and finite element simulations (see, e.g., Peirce et al. (1982a); Forest (1998)). However, the post-localization behavior and the size–dependence of localization modes require enhanced crystal plasticity models accounting for a more accurate description of