Micromorphic and gradient crystal plasticity: theory and applications

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Eringen's micromorphic approach for materials with microstructure is applied to the plasticity and damage of single crystals. A plastic microdeformation variable and its rotational part are introduced in a standard crystal plasticity model in order to predict size effects in the overall stress response of crystalline solids. The dislocation density tensor computed as the curl of plastic distortion is regarded as a new constitutive variable in crystal plasticity. The dependence of the free energy function on the dislocation density tensor is explored starting from a quadratic ansatz. Rank one and logarithmic dependencies are then envisaged based on considerations from the statistical theory of dislocations. The relevance of the presented free energy potentials is evaluated from the corresponding analytical solutions of the periodic two-phase laminate problem under shear where one layer is a single crystal material undergoing single slip and the second one remains purely elastic. In the case of an ideal laminate microstructure including a purely elastic layer and a plastic layer undergoing single slip, the model, called microcurl, is shown to produce a kinematic hardening component that depends on the size of the layers.
In a last part, a microdamage variable is introduced that accounts for cleavage or plasticity induced pseudo-cleavage phenomena in single crystals. The formulation accounts for straight crack paths but also allows for crack branching and bifurcation.

References.

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