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# Stored energy vs dissipation in gradient crystal plasticity: Application to cyclic plasticity and recrystallization

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## Abstract

The dislocation density tensor is treated as a new constitutive variable of crystal plasticity in addition to the usual scalar dislocation densities and kinematic hardening internal variables, within the framework of strain gradient plasticity. It is an argument of the Helmholtz free energy density function since the accumulation of geometrically necessary dislocations leads to the storage of energy which can be released under suitable thermomechanical loading conditions. Comparison with dislocation dynamics simulations of cyclic plasticity on small scales shows that dissipative contributions to the evolution of the dislocation density tensor must also be included (1). Previous contributions were based on an additive decomposition of the higher order stress tensor into reversible and dissipative parts. An alternative is presented here that splits the dislocation density tensor itself into reversible and dissipative contributions.

The energy stored by geometrically necessary dislocations and statistically stored dislocations is the driving force for grain boundary migration phenomena and grain nucleation in recrystallization processes. The gradient plasticity framework is specialized to a Cosserat crystal plasticity theory and coupled with a phase field approach to simulate microstructure evolution in polycrystals. A striking example is the simulation of grain nucleation events during the torsion of a copper single crystal wire (2).

(1) Y.A. Amouzou-Adoun, M. Jebahi, S. Forest and M. Fivel, *Advanced modeling of higher-order kinematic hardening in strain gradient crystal plasticity based on discrete dislocation dynamics*, Journal of the Mechanics and Physics of Solids, vol. 193, pp. 105875, 2024. doi.org/j.jmps.2024.105875

(2) F. Ghiglione, A. Ask, K. Ammar, B. Appolaire and S. Forest, *Cosserat-phase-field modeling of grain nucleation in plastically deformed single crystals*, Journal of the Mechanics and Physics of Solids, vol. 187, pp. 105628, 2024. doi:10.1016/j.jmps.2024.105628

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