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Phase field approach to interaction of phase transformations and plasticity at large strains

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ABSTRACT

Thermodynamically consistent phase field approach (PFA) for multivariant martensitic phase transformations (PTs) and twinning for large strains is developed [1, 2]. Thermodynamic potential in hyperspherical order parameters is introduced, which allowed us to describe each martensite-martensite (i.e., twin) interface with a single order parameter [3]. These theories are utilized for finite element simulation of various important problems [1-4]. Phase field approach to dislocation evolution was developed during the last decade and it is widely used for the simulation of plasticity at the nanoscale. Despite significant success, there are still a number of points for essential improvement. In our study [5], a new PFA to dislocation evolution is developed. It leads to a well-posed formulation and mesh-independent solutions and is based on fully large-strain formulation. Our local potential is designed to eliminate stress-dependence of the Burgers vector and to reproduce desired local stress-strain curve, as well as to obtain the mesh-independent dislocation height H for any dislocation orientation. The gradient energy contains an additional term, which excludes localization of dislocation within height smaller than H but disappears at the boundary of dislocation and the rest of the crystal; thus, it does not produce interface energy and does not lead to a dislocation widening. Problems for nucleation and evolution of multiple dislocations along the multiple slip systems are studied. The interaction between PT and dislocations is the most basic problem in the study of martensite nucleation and growth. Here, a PFA is developed to a coupled evolution of martensitic PTs and dislocations [6], including inheritance of dislocation during direct and reverse PTs. A complete system of equations, including Ginzburg–Landau equations is presented. It is applied to studying the hysteretic behavior and propagation of an austenite-martensite interface with incoherency dislocations, the growth and arrest of martensitic plate for temperature-induced PTs, the evolution of phase and dislocation structures for stress-induced PTs, and the evolution of dislocations and high pressure phase in a nanograined material under pressure and shear [6, 7].

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