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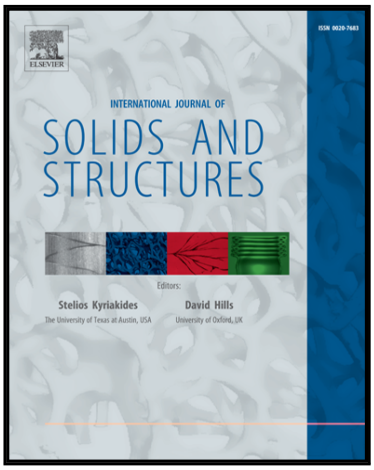

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SMALL SCALE VOLUME FORMULATION BASED ON COUPLED THERMO-MECHANICAL GRADIENT ENHANCED PLASTICITY THEORY

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Abstract:

A coupled thermo-mechanical gradient enhanced continuum plasticity theory is developed within the thermodynamically consistent framework in this work and the corresponding two-dimensional finite element implementation is carried out to examine the micro-mechanical and thermal characteristics of small-scale metallic volumes. The proposed model is conceptually based on the dislocations interaction mechanisms and thermal activation energy. The thermodynamic conjugate microstresses are decomposed into dissipative and energetic components, correspondingly, the dissipative and energetic length scales are incorporated in the proposed model and an additional length scale related to the geometrically necessary dislocations-induced strengthening is also included. Not only the partial heat dissipation caused by the fast transient time, but also the distribution of temperature caused by the transition from the plastic work to the heat, are included into the coupled thermo-mechanical model by deriving a generalized heat equation. The derived constitutive framework and two-dimensional finite element model are validated through the comparison with the experimental observations conducted on micro-scale thin films. The proposed enhanced model is examined by solving the simple shear problem and the square plate problem respectively to explore the thermo-mechanical characteristics of small-scale metallic materials. Finally, some significant conclusions are presented.

Key words: Strain gradient plasticity, Energetic, Dissipative, Thermo-mechanical coupling, 2D FEM

1. Introduction

The conventional continuum plasticity model is characteristically size-independent and is not capable of capturing the size effects, in particular, when the material is subjected to the nonhomogeneous (heterogeneous) plastic deformation under the fast transient time and its size ranges from a few hundreds of nanometers to a few tens of micrometers. The evidence of such a behavior is found in many micro-mechanical experimental observations such as nano/micro-indentation hardness (Kim and Park, 1996; Lim et al., 2017; Park et al., 1996), nano/micro-pillars (Hwang et al., 1995), torsion of micron-

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