Bridging of Material Length Scales and Size Effects

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Abstract
Conventional continuum mechanics models of inelastic deformation processes are size scale independent since they do not possess intrinsic length scales in their constitutive description. In contrast, there is considerable experimental evidence that inelastic flow in crystalline materials is size-dependent. As soon as material failure dominates a deformation process, the material increasingly displays strain softening (localization) and the finite element computation is considerably affected by the mesh size and alignment and gives non-physical descriptions of the localized regions. Gradient-enhanced constitutive viscoplastic and damage equations that include explicit and implicit micro-structural length scale measures are presented in this work. Thermodynamic principles as well as dislocation-based mechanics are used to develop micromechanical constitutive equations that can be used to bridge the material length scales. These equations are validated by conducting various numerical tests in order to predict the size effects at the micron and submicron length scales and to regularize the localization problems for softening media.