ON THE IMPLEMENTATION OF A GRADIENT ENHANCED NONLINEAR PLASTICITY MODEL

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An overview of the formulation and numerical implementation of a gradient enhanced continuum plasticity model as a constitutive framework to model the nonlocal response of materials is presented. The main objective of this work is to model the localization behavior using a gradient enhanced nonlocal continuum theory. The gradient enhancements are investigated as powerful tools for modeling observations at the microscale that are not possible to interpret with classical deformation models. By the introduction of higher order gradients, our model will be able to predict the size of localized zones based on material constants, as opposed to local models where the loss of ellipticity causes the localized zones to be mesh dependent. Justification for the gradient theory is given by approximating nonlocal theory through a truncated Taylor expansion. The gradients are incorporated in the constitutive model by the introduction of nonlocal measures in the plasticity potential function and yield criterion. The formulation uses a thermodynamically consistent framework to introduce a microstructural characteristic material length scale through gradient enhancements of the hardening variables.

By following a mathematically consistent formulation in the expansion of Laplacians of hardening variables, first order gradients as well as the Laplacians of several variables are incorporated into the model. As opposed to previous theories in the literature with linear hardening, the gradient model used here consistently expands the Laplacian evolution equations to allow different nonlinear material models. The gradients of hardening terms are found directly by operating on the respective hardening term. Numerical methods are used to compute these gradients of the hardening terms. Thus, the two terms are considered to be dependent, and no additional internal state variables are introduced into the Helmholtz free energy for the gradient terms. Due to the gradients of the anisotropic hardening in plasticity, additional equations have to be introduced for the evolution of the gradients of the plastic normal, the plastic strains, the damage normal, and the damage tensor.

The numerical implementation uses a small deformation finite element formulation and includes the displacements and the plastic multiplier as nodal degrees of freedom, thus allowing the two fields to have different interpolation functions. Higher order elements are used for the plastic multiplier to enforce continuity of the second gradients, which requires the introduction of additional boundary conditions.

Keywords: Gradient, Localization, Finite Element