Numerical modeling of strain, strain rate hardening, and viscous effects on viscoplastic behavior of metallic materials

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ABSTRACT

The main goal of the present work is to provide a finite strain elastic-viscoplastic framework to numerically account for strain, strain rate hardening, and viscous effects in cold deformation of metallic materials. Aiming at contributing to the constant search for models combining both constitutive adequacy and computational efficiency, the present work provides a simple and efficient numerical framework capable of modeling the main macroscopic behavior associated with high strain rate plastic deformation of metals at room temperature. The work concerns numerical formulation and simulations where advantage is taken of a constitutive model previously presented [1], which proved to be suitable for this task. Adopting a simplified semi-physical approach allows to maintain the corresponding computational efficiency associated with phenomenological models while incorporating adequate constitutive capabilities, such as strain rate hardening behavior, in simulations where high velocity plastic features have to be taken into account. Numerical procedure to solve nonlinear equilibrium problem follows an implicit incremental finite element formulation. At local level, an implicit integration scheme based on an exponential mapping [2, 3] is adopted. An analytical consistent tangent modulus is obtained. Classical problems are simulated: compression test involving homogeneous deformation and compression test involving contact and frictional conditions. Numerical simulations demonstrate the constitutive capabilities associated with the proposed model when predicting material and structural behavior at high strain rates. Numerical efficiency related to the present procedure is assessed by means of global convergence analysis. The numerical results have demonstrated the overall framework can be an efficient numerical tool for simulation of plastic deformation processes where high strain rate effects have to be accounted for.

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