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SIMULATION OF LARGE INELASTIC DEFORMATIONS INCLUDING DAMAGE-INDUCED POROSITY WITHIN ANISOTROPIC VISCOPLASTICITY

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This study is devoted to the prediction of ductile damage and plastic anisotropy accumulated in metallic materials during forming operations. A new macroscopic model of metal plasticity is suggested, which accounts for the isotropic/kinematic hardening, the strain-induced damage, and the rate-dependence of the material response. The strain hardening and the damage are fully coupled. The resulting material model is an extension of the finite-strain viscoplasticity model previously proposed by the authors [4]. For the extended model, existing efficient and robust numerical algorithms can be used (cf. [4, 5]).

The description of the nonlinear kinematic hardening is based on the double multiplicative decomposition of the deformation gradient suggested by Lion [2]. An additional multiplicative decomposition is introduced in order to account for the damage-induced porosity of the material. This modification is needed to ensure the correct prediction of the hydrostatic stress component.

The model is formulated in a thermodynamically admissible way as an open framework, suitable for further extension. In particular, the case of distortional hardening can be covered as well [3]. Appropriate variants of constitutive relations for void nucleation, growth, and coalescence can be implemented in a straightforward manner. The restrictions imposed on these relations by the second law of thermodynamics are obtained in an explicit form. As a simple example of the suggested framework, the material porosity is adopted as a rough measure of damage. A new law of void nucleation is formulated for porous ductile metals with second phases. This nucleation rule includes dependencies on the eigenvalues of the effective stress tensor.

The material model is validated using the experimental data on void nucleation in A356-T6 aluminum alloy [1]. The constitutive equations are implemented into the FEM code Abaqus and a simulation of a deep drawing process is presented to demonstrate the robustness of the proposed numerical algorithm.

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