Anisotropic Strain-Gradient Plasticity of Porous Metals

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ABSTRACT

A gradient version of the anisotropic model for porous metals presented by Ponte Castañeda and co-workers [1] is developed. The model takes into account the evolution of porosity and the development of anisotropy due to changes in the shape and the orientation of the voids during deformation. At every material point a "representative" ellipsoid is considered. The basic "internal variables" are the local equivalent plastic strain $\bar{\varepsilon}^{p}$, the local porosity f_{loc}, the aspect ratios $\left(w_1 = a_3/a_1, w_2 = a_3/a_2\right)$ and the orientation of the principal axes $\left(\mathbf{n}^{(1)}, \mathbf{n}^{(2)}, \mathbf{n}^{(3)} = \mathbf{n}^{(1)} \times \mathbf{n}^{(2)}\right)$ of the ellipsoid. The gradient version of the model is based on a "non-local" porosity variable f and introduces a "material length" ℓ to the constitutive equations. We follow Peerlings et al. [4] and Engelen et al. [2] and define the "non-local" porosity field $f\left(\mathbf{x}\right)$ in terms of the "local" porosity field $f_{\mathrm{loc}}\left(\mathbf{x}\right)$ from the solution of an additional boundary value problem (BVP). It is shown that the non-local porosity f at a material point P can be identified with the average value of the local porosity f_{loc} over a sphere centered at P and of radius approximately equal to 3ℓ. The present paper focusses on important issues associated with the numerical implementation of the non-local model in a finite element code. These include the finite element formulation of the non-local boundary value problem and the numerical integration of the constitutive equations. The model is implemented in the ABAQUS general-purpose finite element program and both quasi-static and dynamic problems are solved. Two possible ABAQUS implementations are discussed. First, "user elements" are developed, which can be used for the solution of both quasi-static and dynamic problems. An 8-node hexahedral element with reduced 1-point Gauss integration is developed and the "physical stabilization" method of Puso [5] is used to remove the resulting numerical singularities (hourglass control). Second, the implementation of the model via "user material" subroutines is discussed.

REFERENCES

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