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New analytic criterion for porous solids with pressure-insensitive matrix

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Abstract

In this paper, we address the question of how the relative weighting of the two invariants of the plastic deformation of the matrix influence the mechanical response of a porous metallic material. To this end, we first propose a new isotropic potential for description of the plastic behavior of the matrix that depends on both invariants of the strain-rate deviator. The relative weight of the two invariants is described by a material parameter β. Depending on the sign of the parameter β, the new plastic potential for the matrix is either interior to von Mises strain-rate potential ($\beta<0$), coincides with it ($\beta=0$) or it is exterior to it. Next, an analytic criterion for a porous solid with matrix governed by the new strain-rate potential is obtained using rigorous upscaling methods. Analysis is conducted for both tensile and compressive axisymmetric loading scenarios and spherical void geometry. No simplifying approximations are considered when estimating the local and overall plastic dissipation, respectively. It is shown that the value of β has a drastic influence on all aspects of the mechanical response. There is a value $\beta=\beta_*<0$ such that there is almost no influence of J_3^Σ on the mechanical response of the porous solid. If the matrix is characterized by $\beta>\beta_*$, the response of the porous material for tensile loadings and $J_3^\Sigma\geq 0$ is softer than that for loadings at $J_3^\Sigma\leq 0$. The reverse holds true for $\beta<\beta_*$. The noteworthy result is that irrespective of the value of the parameter β, the response of the porous solid is harder than that of a porous Tresca material. However, depending on the value of β the rate of void growth or collapse can be either faster or slower than that of a porous Mises material.

Keywords: ductile porous solid; limit analysis; new yield criterion for porous solids, void evolution.

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