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Limit analysis and homogenization of nanoporous materials with a general isotropic plastic matrix

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Abstract

In this paper, a closed-form expression of a macroscopic strength criterion for ductile nanoporous materials is established, by considering the local plastic behavior as dependent on all the three isotropic stress invariants and by referring to the case of axisymmetric strain-rate boundary conditions. The proposed criterion also predicts void-size effects on macroscopic strength properties. A homogenization procedure based on a kinematic limit-analysis is performed by addressing a hollow-sphere model comprising a rigid-ideal-plastic solid matrix. Void-size effects are accounted for by introducing an imperfect-coherent interface at the cavity boundary. Both the interface and the solid matrix are assumed to obey to a general isotropic yield function, whose parametric form allows for a significant flexibility in describing effects induced by both stress triaxiality and stress Lode angle. Taking advantage of analytical expressions recently provided by Brach et al. [Int J Plasticity 2017; 89: 1–28] for the corresponding support function and for the exact velocity field under isotropic loadings, a parametric closed-form relationship for the macroscopic strength criterion is obtained as the solution of an inequality-constrained minimization problem, the latter being faced via the Lagrangian method combined with Karush-Kuhn-Tucker conditions. Finally, several comparative illustrations are provided, showing the influence of local-yield-function parameters on the established criterion, as well as the model capability to describe the macroscopic strengthening, typical of nanoporous materials, induced by a void-size reduction for a fixed porosity level.

Keywords: Homogenization, limit analysis, inequality-constrained minimization problem, nanoporous materials, general isotropic yield function, void-size effects

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