

A nonlocal approach of ductile failure incorporating void growth, internal necking, and shear dominated coalescence mechanisms



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ABSTRACT

An advanced modeling framework is developed for predicting the failure of ductile materials relying on micromechanics, physical ingredients, and robust numerical methods. The approach is based on a hyperelastic finite strain multi-surface constitutive model with multiple nonlocal variables. The three distinct nonlocal solutions for the expansion of voids embedded in an elastoplastic matrix are considered: a void growth phase governed by the Gurson–Tvergaard–Needleman yield surface, a void necking coalescence phase governed by a heuristic extension of the Thomason yield surface based on the maximum principal stress, and a competing void shearing coalescence phase triggered by the maximum shear stress. The first solution considers the diffused plastic deformation around the voids while the last two solutions correspond to a state of plastic localization between neighboring voids. This combination captures the Lode variable and shear effects, which play important roles in dictating the damage evolution rates. The implicit nonlocal formulation with multiple nonlocal variables, including the volumetric and deviatoric parts of the plastic strain, and the mean equivalent plastic strain of the matrix, regularizes the problem of the loss of solution uniqueness when material softening occurs whatever the localization mechanism. The predictive capability of the proposed model is demonstrated through different numerical simulations in which complex failure patterns such as slant and cup-cone of respectively plane strain and axisymmetric samples under tensile loading conditions develop.