A NON-LOCAL DUCTILE FAILURE MODEL ACCOUNTING FOR VOID GROWTH AND COALESCEENCE AT LOW AND HIGH STRESS TRIAXIALITY

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ABSTRACT

A micromechanics-based numerical model of ductile material failure is developed, in which the void growth, necking coalescence and shearing coalescence phases are competing. This combination allows accounting for the triaxiality, Lode variable and shear effects. In order to avoid loss of solution uniqueness during the coalescence stages, a multiple-variable nonlocal implicit formulation regularizes the problem. This model allows reproducing cup-cone and slant fracture modes for round and plane strain specimens.

Keywords: ductile failure, nonlocal, void coalescence, necking, shearing.

INTRODUCTION

Ductile failure is controlled by the nucleation, growth, and coalescence of voids combined with an extensive plastic dissipation accumulating before failure. Although the Gurson-Tvergaard-Needleman (Tvergaard and Needleman, 1984) model, which is the most popular model of the ductile failure, gives a complete computational methodology for all stages of void evolution, the framework remains phenomenological and does not provide a realistic description of the physics of the void coalescence.

In this work, a hyperelastic finite strain multi-surface constitutive model with multiple nonlocal variables is developed for predicting the failure of ductile materials (Nguyen \textit{et al.}, submitted). This model is based on the combination of the three distinct nonlocal solutions of expansion of voids embedded in an elastoplastic matrix. The void growth phase governed by the GTN model considers the diffusion of the plastic deformation around voids. The first coalescence mode considered is by void necking and is governed by a heuristic extension of the Thomason model based on the maximal principle stress. The second coalescence mode considered is by void shearing triggered by the maximal shear stress. In order to avoid the loss of solution uniqueness when material softening occurs whatever the localization mechanism is, an implicit nonlocal formulation with multiple nonlocal variables, including the volumetric and deviatoric parts of the plastic deformation, and the mean plastic deformation of the matrix, regularises the problem.

RESULTS AND CONCLUSIONS

The competition between the three modes of porosity evolution by diffuse void growth, internal necking coalescence, and shear driven void coalescence respectively governed by the GTN yield surface $\Phi_G$, the maximum principal stress-based Thomason yield surface $\Phi_T$, and maximum shear stress-based yield surface $\Phi_S$ is modelled by an effective yield surface $\Phi_e$ as:

$$\Phi_e = \max(\Phi_G, \Phi_T, \Phi_S)$$

(1)
While the failure at high-triaxiality is governed by the maximum principal stress (Figure 1-left), thought the yield surface $\Phi_T$, the failure at low triaxiality depends on the Lode variable and is governed by the maximum shear stress (Figure 1-centre) through the yield surface $\Phi_S$. The effective yield surface (1) captures the different coalescence modes (Figure 1-right).

Macro-scale numerical tests show that the current approach allows capturing complex failure modes such as slant failure for specimens in plane strain (Figure 2 - left) and cup-cone failure for cylindrical specimens (Figure 2 - right).

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**REFERENCES**
