ON THE INTERPLAY BETWEEN MACROSCOPIC LOCALIZATION AND VOID COALESCENCE FOR STRAIN RATE SENSITIVE MATERIALS

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Abstract

Significant progresses have been made in the last decades on the understanding and modelling of the micromechanics that govern the ductile fracture phenomena in porous metallic materials subjected to complex stress states. Two modes of plastic flow localization commonly occur in the failure of ductile materials. The first is the so-called "macroscopic localization" and occurs when the deformation becomes highly non-uniform and localizes into a thin band. The second one is the so-called coalescence and occurs when nearby microscopic voids interact and merge, leading to the formation of macroscopic cracks.

The question addressed in the present work is whether macroscopic localization occurs prior or after the void coalescence. For that purpose, we have developed an original numerical methodology, based on 3D unitary-cell computations in ABAQUS/Standard [1], to simulate the evolution of a spherical void subjected to complex stress states: predefined triaxiality and Lode parameters which remain fixed during loading. The key and original feature of our investigation, which is based on a previous work of Tekoglu et al. [2], is to consider the strain rate dependence on the flow behavior of the material. We have identified that the viscosity of the material plays a crucial role on both localization modes. Nevertheless, irrespective of the material properties considered, our numerical results have shown that "macroscopic localization" occurs always earlier than "coalescence". The implications and consequences of such behavior will be exposed and discussed.

Numerical results

As is shown in Fig.1, attention is focused to analize a parallelepiped unitary cell that initially contains a spherical void in its center with initial radius R_0.

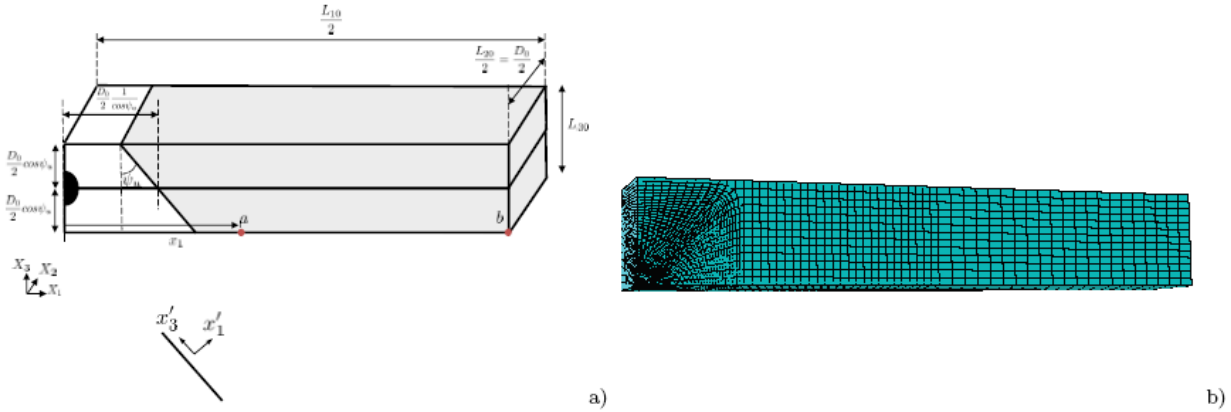

Fig. 1. Squeme of (a fourth) representative volume element used in the simulations. The initial orientation of the voided cell = Ψ^u and his characteristic length = L_0. b) Finite element mesh of the representative element for f0=0.001 and $\Psi u = 0^o$

The representative volume element was numerically analyzed using the finite element software ABAQUS/Standard [1], wich employs a finite strain J_2 flow theory within and updated Lagrangian formulation to account for large deformations. The chosen material for the analysis follows a power-law type rate hardening formulation defined by:

$$\bar{\sigma} = \begin{cases} E\varepsilon & \varepsilon \leq \varepsilon_0 \\ \sigma_0 \left(1 + \left(\frac{\dot{\varepsilon}^p}{\dot{\varepsilon}_0}\right)^m\right) & \varepsilon > \varepsilon_0 \end{cases}$$

where σ_0 represents a reference yield stress, m the strain rate sensitivity parameter of the material, $\dot{\varepsilon_0}$ a reference strain rate, E the Young modulus and $\varepsilon_0 = \sigma_0/E$. The full set of constants employed in the simulations to define material properties are E=167 GPa, ν=0.3, σ_0=418 MPa, $\dot{\varepsilon_0}$ =1s^{-1} and ε_0= 0.0025. In order to study the relative contribution of the strain rate effect in localization and void colescence, numerical simulations are going to be carried out considering the strain rate parameter m varying within the range of values m=0-0.25.

To exemplify the influence of the strain rate parameter on localization and coalescence behavior, the macroscopic strain in the band E_{eq}^{cb} at the onset of localization and coalescence, are plot in Figs. 2 versus triaxiality T for the different m values considered. The prescribed Lode parameter is L = -1 and the initial porosity is f_0 = 0.001. As can be observed, macroscopic localization and coalescence are strongly affected by m parameter promoting, for every T value tested, a delay of the value of E_{eq}^{cb} where localization and coalescence take place.

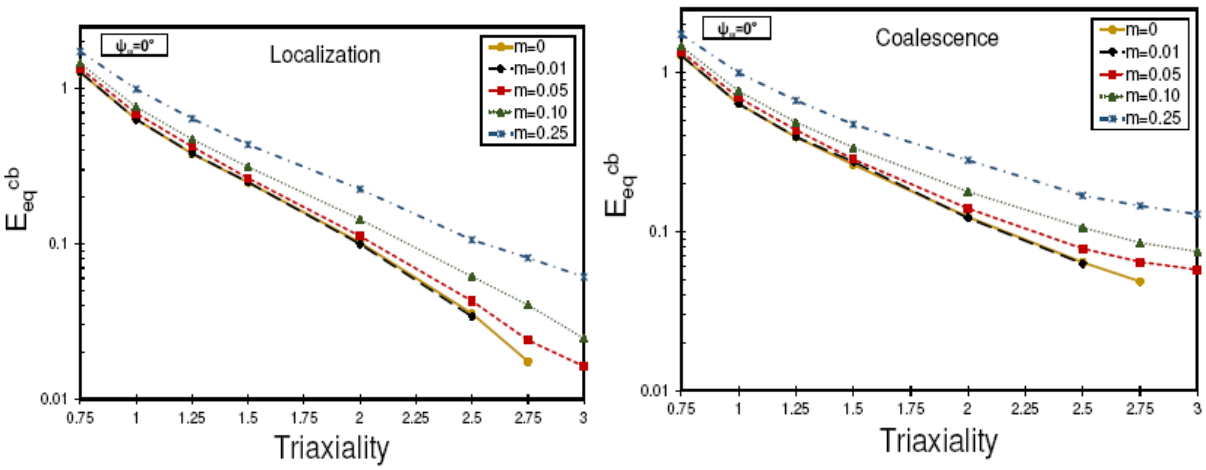

Fig. 2. Critical equivalent strain at the onset of localization and coalescence as a function of triaxiality for strain rate parameters *m* = 0, 0.01,0.05, 0.1 and 0.25.

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