Dynamic flow surface of porous materials containing spheroidal void shape.

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From recent works of the literature, there is now clear evidence that the fracture of ductile materials may be strongly affected by inertial effects when dynamic loading is considered. Under loadings with different stress triaxialities, void shape may evolve from oblate to prolate or vice versa. So we propose to model the mechanical behavior of porous materials accounting for spheroidal void shape. To investigate this issue we propose to extend the multi-scale model proposed for the behavior of porous ductile materials accounting for micro inertia and spherical voids, see Molinari and Mercier (2001).

The dynamic of bubble in water is governed by the Rayleigh Plesset equation, where an inertia related term is present. Such a relationship has already been adopted in solid mechanics, see for instance the pioneering work of Carroll and Holt (1972).

A general framework has been proposed in Molinari and Mercier (2001) where the macroscopic stress is decomposed into a quasistatic part and a dynamic part. The quasistatic component is described by the Gologanu et al (1997) approach valid from any spheroidal voids. The dynamic part will be evaluated by considering the velocity fields proposed in these approaches.

Axisymmetric loadings are considered and the void axes are assumed to be aligned with principal directions of the loading. The mathematical expression of the dynamic part of the macro-stress involves the void morphology (aspect ratio, volume fraction), a quadratic dependency with respect to the macroscopic strain rate and a linear dependency with respect to the time derivative of the strain rate (see Sartori et al, 2015, Sartori et al, 2016).

For particular loading conditions (at constant strain rate), the dynamic flow surface is no more convex. Nevertheless, the direction of the flow (linked to the strain rate) is still perpendicular to the static yield surface at the point corresponding to the quasistatic stress. As a consequence, micro-inertia provides a non-associated flow rule plasticity. It will be shown that the non-convexity is mostly present for large triaxiality loading. This feature is linked to a kinetic energy transfer that we have demonstrated in the particular case of material containing spherical void.

Finally, we will discuss the case of penny shape voids. This particular void shape is really important in fracture mechanics. From our modeling, we have observed, that for penny shaped cracks, the volume fraction of voids is zero but micro-inertia effects are still existing.

Finite element simulations were performed to validate the model. The analytical results were confirmed by the numerical computations.

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