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0155 A multi-mechanism non-local porosity model for high-ductile materials; application to high entropy alloys

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High ductility materials are characterized by high failure strains and high toughness properties. As a result, modelling their response up to failure requires the development of robust constitutive models able to represent both the hardening phase during which large deformation gradients of several tens of percent arise in combination with nucleation and growth of micro-voids, as well as the softening phase characterized by high critical energy release rate and during which coalescence of micro-voids develops.

The most popular model of the ductile failure is the Gurson- Tvergaard- Needleman (so-called GTN) model, which provides a complete computational methodology for all stages of void evolution with a limited number of material parameters that can be identified based on macroscopic mechanical tests. However, the underlying phenomenological concept of void coalescence does not provide a realistic description of the void coalescence physics. Instead, the micro-mechanical-based coalescence model pioneered by Thomason provides a more physical basis under the assumption that the coalescence starts when the localization of the plastic deformation occurs in the ligaments between neighbouring voids.

In this work a coupled finite-strain Gurson Thomason model is completed by a set of appropriate evolution laws governing the internal variables. The void growth phase is governed by the GTN plasticity solution and the Thomason model is used as a closed form of the plasticity problem during the coalescence stage. This provides a physically based numerical framework to represent the hardening, damage nucleation and growth, and localization stages of ductile materials. In order to avoid the loss of solution uniqueness, the damage model is formulated within an implicit gradient enhancement in which length scale effects are considered to take into account the influence of the neighbouring material points. Since the combined Gurson/Thomason model developed herein is driven by multiple softening mechanisms, it is formulated in a nonlocal setting using multiple nonlocal variables. It is shown that this approach allows recovering complex failure patterns such as slant and cup-cone of respectively plane strain and axisymmetric samples tests.

Besides, the formulation is calibrated considering experimental tests performed on High Entropy Alloys (HEAs). HEAs form a new material family characterized by a combination of high strength and high toughness properties. Because of these exceptional properties, modelling their response up to failure requires the development of robust constitutive models and it is shown that the developed multi-mechanism nonlocal Gurson Thomason model provides such a framework able to reproduce the failure of HEA samples of different geometries.

[1] Torki, M.; Tekoglu, C. T.; Leblond, J.-B. and Benzerga, A., International Journal of Plasticity, 2017, 91, 160 - 181.