Investigation of a gradient enriched Gurson-Tvergaard model for porous strain hardening materials

Size effects in a strain hardening porous solid are investigated using the Gurson-Tvergaard (GT) model enriched by a constitutive length parameter, as proposed by Niordson and Tvergaard [C.F. Niordson, V. Tvergaard, A homogenised model for size effects in porous metals, J. Mech. Phys. Solids (2019)]. The results are compared with unit cell calculations of regularly distributed voids embedded in a strain gradient enhanced matrix material. The strain gradient plasticity theory proposed by Fleck and Willis [N.A. Fleck, J.R. Willis, A mathematical basis for strain gradient plasticity theory. Part II: tensorial plastic multiplier, J. Mech. Phys. Solids 57 (2009) 1045–1057], extended to finite strains, is adopted for the cell model, consistent with the gradient enriched Gurson model. The gradient model allows for a material length parameter to enter the constitutive framework for dimensional consistency, while the enriched GT model has the same length parameter introduced through prefactors of the usual and factors. The continuum model featuring size-dependent Tvergaard-constants is used to investigate a strain hardening material with the strain gradient plasticity enriched cell model as reference. The two models are compared for three triaxialities, three initial void volume fractions, and three hardening exponents. The enriched GT model captures the effect of elevated yield point and suppressed void growth with increasing length parameter for all the cases investigated. The agreement between the models is good until severe void distortion or plastic flow localisation between neighbouring voids. The response curves and void growth curves for the enriched GT model deviate from those of the cell model at high axial strains. Void shape plots, which are only available for the cell model, show that the length parameter influences the shape of the void which in turn has impact on the material response curves and the void evolution. This is not captured by the enriched GT model as the voids are accounted for solely through a volume fraction parameter.

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