# A variational damage-plasticity model depending on hydrostatic stresses

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Ductile fracture is characterised by large plastic strains before a macroscopic crack occurs. Complex processes in the material such as void nucleation, coalescence and growth leading to plastic slip lines and shear bands need to be considered. To capture these characteristics, various local plasticity models have been proposed and extensively used, such as the Gurson-Tvergaard-Needleman (GTN) model.

However, the GTN plasticity model is not well-defined when it comes to the localisation of porosity, as this coincides with the loss of ellipticity of the incremental equilibrium equations. This leads to mesh dependence in FE simulations, which can be eliminated by a non-local regularisation. This has been achieved using an integral condition for the porosity [1], [2] or introducing the gradient of the equivalent plastic strain [3]. The latter method requires an extended associated flow rule since the plastic flow can become singular due to the gradient plasticity term. Alternatively, the coupling of local GTN plasticity with a phase-field model has been proposed [4]. In this case, the phase-field is regularised, but the porosity may still localise and lead to mesh sensitivity, again requiring the introduction of gradient plasticity.

In this work, we suggest a coupled gradient damage (phase-field)-plasticity model that can handle von Mises plasticity as well as more advanced plasticity models to reproduce phenomenological aspects of ductile fracture. The proposed model is variationally consistent, i.e. the equilibrium and damage evolution equations stem from an incremental energy minimisation principle. The plastic dissipation depends on both the deviatoric and the hydrostatic components of the plastic strain tensor. Localisation is prevented by regularisation through the gradient of the damage (phase-field) variable. The resulting model is able to reproduce a material behaviour similar to that of the GTN model with no need of directly introducing the porosity as additional variable and with no need for gradient regularization of the plasticity model.

The behaviour of the proposed model is studied with several benchmark tests. Their results are compared with the results from GTN porous plasticity coupled with a phase-field model.

## References

[1] J. B. Leblond, G. Perrin, and J. Devaux, Bifurcation Effects in Ductile Metals With Nonlocal Damage, ASME. J. Appl. Mech., 61, (1994), 236–242.

[2] V. Tvergaard, and A. Needleman, Effects of nonlocal damage in porous plastic solids, Int. J. Solids. Struct. 32 (1995) 1063–1077.

[3] Y. Zhang, E. Lorentz, and J. Besson, Ductile damage modelling with locking-free regularised GTN model, Int. J. Numer. Methods. Eng. 113 (2018) 1871–1903.

[4] F. Aldakheel, P. Wriggers, and C. Miehe, A modified Gurson-type plasticity model at finite strains: formulation, numerical analysis and phase-field coupling, Comput. Mech. 62 (2018) 815–833.