Gradient-plasticity vs Gradient-damage for the Modelling and Calibration of Ductile Damage

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Even though damage hides invisibly inside the material, it can notably affect manufacturing processes and the product's lifetime. The modelling and identification of this process-induced damage is conducted by means of a fully coupled plasticity-damage continuum material model at finite strains. For regularisation, we contrast different approaches for gradient-enhancement. This comprises "plasticity – gradient-damage", where the gradient-enhancement is placed on the damage variable, as well as "gradient-plasticity – damage" with a gradient-enhanced plasticity formulation. Further attention is paid to the numerical implementation and identification of the associated internal length.

Based on the gradient-enhancement of the free energy [1], multiple types of localisation, such as damage and softening plasticity, can effectively be eliminated by the introduction of additional internal length scales. Different variables are studied to insert strong non-locality for plasticity and damage. This choice does not only affect the scope of the regularisation [2], but also influences the calibration procedure for the material model. For instance, the gradient-enhancement of the damage variable alters the locally prescribed damage evolution, thus for instance a directly identified failure strain is not accurately reproduced. This can complicate inverse parameter identifications, which are especially tedious when a large number of experiments need to be considered simultaneously, e. g. for coupled stress-state dependent damage models. For damage identification, global force responses together with local deformation measurements are utilised to improve the uniqueness of the optimisation problem, cf. [3].

Experiments and numerical examples, which represent different stress states, demonstrate the regularising capabilities and characteristics of the gradient-plasticity approach and the gradient-damage approach. Moreover, further insights into the regularisation and its requirements are presented, which will become evident in the conducted parameter identification for sheet metal.

References

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