A novel gradient-extended anisotropic two-surface damage-plasticity model for finite deformations

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ABSTRACT

Modelling as well as simulation of materials behaving both brittle and/or ductile in connection with anisotropic damage is still a challenging task, especially in the case of finite deformations. This has already been intensively discussed in our recently published work of Reese et al. [1], which, however, uses a different kinematic approach than the one that will be presented here. In addition to the formulation of a constitutive law, a mesh-independent formulation in the presence of large deformations is essential from a computational point of view. Therefore, in the presented work, both a thermodynamically consistent elasto-damage-plasticity material formulation and its gradient-extension – based on the invariants of the damage tensor – are discussed, which can be understood as a micromorphic extension following Forest [2]. Thus, although a second order damage tensor is used, only three additional (micromorphic) fields are required to account for the nonlocal nature of damage. Choosing damage itself for the gradient-extension is of course not a unique choice, however, the very good experience of our research group following this approach for different kinds of inelastic and anisotropic material effects (see e.g. [3,4]) motivates this choice.

The coupling of plasticity and damage takes place in the space of logarithmic strains. Both damage and plasticity are treated as independent but indirectly coupled phenomena. This is achieved using a ‘two-surface’ approach. Kinematic as well as isotropic hardening are taken into account in the model. Thereby, the approach of additive plasticity discussed by e.g. Miehe et al. [5] and several others is followed, which is at least *close* to the widely accepted multiplicative decomposition of the deformation gradient in the case of finite elasto-plasticity. Once the material response in the logarithmic space is obtained, it is mapped onto Lagrangian stress and strain measures in order to be applicable in conventional (geometrically nonlinear) finite element simulations. Moreover, the linearization for the Newton-Raphson method requires the transformations of the tangent moduli for the nonlocal damage variables, which is additionally addressed here. Finally, several numerical examples illustrate the behaviour of the presented model and its ability to obtain mesh-independent results.

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