Computation of Configurational Forces for Gradient-Enhanced Inelasticity

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ABSTRACT

Configurational (material) forces in a solid define the energetic driving forces for configurational changes such as the advancement of a crack. It is of engineering interest to compute these configurational forces during (finite element) analysis of inelastic deformations. Most commonly, inelasticity (e.g. plasticity, viscoplasticity) is modelled with so-called local constitutive theory. Moreover, the standard problem is conventionally solved via a displacement-based variational formulation. In the corresponding FE-approximation, the internal variable fields are only computed at discrete points. Thereby, a heuristic nodal smoothing technique is required for the evaluation of the spatial gradient of the internal variables, which enters the computation of material forces. This is shown to result in a pronounced FE-mesh dependent response whenever singularities are present in the solution fields (e.g. due to a crack) [1, 2].

In the present contribution, configurational forces are computed based on gradient-enhanced theory of perfect viscoplasticity, whereby an internal length is introduced. A mixed variational formulation is proposed in terms of displacements and micro-stresses, the latter being represented by a third order tensor which is energy-conjugated to the spatial gradient of the plastic strain. With a continuous approximation of the gradient field, no heuristic post-processing is required for the computation of the material forces, which is a pronounced advantage of the proposed formulation. FE-mesh sensitivity studies on a single edge-cracked specimen show that the proposed gradient-enhanced scheme provides sufficient regularity for the computation of material forces. The rate of convergence with mesh refinement depends strongly on the value of the internal length; however, convergence is indeed obtained even for small values of this length. Moreover, the effective response of the gradient-enhanced model approaches that of purely local theory as the length scale tends to zero. Rate-independent plasticity, as the limit case of viscoplasticity, is also examined, and it is concluded that the convergence behavior is unaffected by the relaxation time parameter.

REFERENCES

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