Multiscale Ductile Damage Modelling of Heterogeneous Material Using Second-order Homogenization

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ABSTRACT

An efficient modelling of softening phenomena in engineering structures, initiated at their microstructural level, remains an increasing challenge in scientific community. As known, the softening responses yield ill-posedness of boundary value problems which requires various regularization techniques. Besides the implicit gradient formulation usually used, an efficient approach is based on the strain gradient continuum theory, where the strain gradients and their conjugates contribute to the internal energy [1]. Multiscale procedures based on the transition of state variables between different scales have been mostly applied to the analysis of heterogeneous material.

In the present contribution the damage response of ductile material is modelled using a two-scale computational procedure. The damage evolution is considered at microstructural level, represented by a representative sample of heterogeneous material named Representative Volume Element (RVE). The nonlocal implicit ductile damage model derived in [2] together with the gradient-enhanced elastoplasticity is employed. Herein an exponential damage law governed by the nonlocal equivalent plastic strain measure is embedded in the von Mises yield function. The discretization has been performed by the mixed quadrilateral finite elements with the nonlocal equivalent plastic strain as the nodal variable in addition to the standard displacement components. A new scale transition procedure between the micro- and macrolevel is derived, where the second-order computational homogenization scheme [1] is applied. According to the multiscale computation technique, the homogenized first and second order stress tensors, as well as the constitutive tensors, all expressed in terms of damage variable, are mapped to the macrolevel. The regularization at the macrolevel is performed by the strain gradient continuum theory implemented in the C^1 continuous triangular finite element formulation presented in [1]. The element has the fifth order polynomial displacement field and it consists of three nodes, each having 12 degrees of freedom which are the two displacement components with their first- and second-order derivatives. The same element formulation has been applied as the regularization strategy in the modelling of quasi-brittle damage in [3]. All developed algorithms are implemented into the finite element software ABAQUS via user subroutines. The proposed computational model is verified by means of several benchmark examples.

REFERENCES

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