Semi-concurrent two-scale model for material failure based on the cohesive crack concept

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Abstract

This work presents a macro-micro semi-concurrent formulation developed to simulate failure in materials with inner heterogeneous structure. The distinctive feature of the present two-scale method is that the irreversible degradation processes are modeled by introducing the cohesive crack mechanical concept, at both scales of analysis. The proposed methodology is based on the notion of *Representative Volume Element* (RVE). It can be considered as a generalization of a previous work of the authors in which failure, at the micro-scale level, was considered through a smeared crack technique within a framework based on strain localization kinematics. As in that work, a well defined axiomatic variational structure is adopted.

The main novelty in this contribution is that failure patterns in the micro-scale can include multiple cohesive cracks, connected or disconnected, with dissimilar orientation, conforming a highly complex tortuous failure path. Tortuosity is a key aspect in the modelling of material degradation due to crack propagation, since the effective dissipated energy strongly depends on this parameter. The tortuosity effect is introduced in the multiscale formulation as a "*kinematical concept*", when the macro-kinematics is transferred into the micro-scale. This is reached through the definition of a novel insertion operator. As a variational consequence, tortuosity affects the homogenized mechanical response for both: (i) the overall stress state in the continuum part of the solid at macro-scale level and (ii) the overall cohesive traction for points belonging to the macro-cohesive crack.

In order to rigorously validate the proposed multiscale methodology, comparisons against the so-called DNS (Direct Numerical Solution) approach are presented. Besides, some practical applications involving a concrete-like material, are also shown.