Multiscale modelling of propagating material fracture.

A continuum approach.

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ABSTRACT

The work presents a new approach for computational multiscale modelling of material failure using finite element analysis at two material scales (FE2). Its goal is beyond the simple computational homogenization, and it aims at inserting the resulting, non-smooth, homogenized constitutive model into a computational scheme for modelling the onset and propagation of the material failure at the structural macro-scale. In this context, the main features of the approach are the following:

- Extends the homogenization paradigms for smooth problems—typically the Hill-Mandel principle and the stress/strain homogenization procedures—to non-smooth problems, with no fundamental changes.
- In both scales, a continuum (stress-strain) constitutive relationship is considered, instead of the most common discrete traction/separation-law, this contributing to provide a unified setting for smooth and non-smooth problems. This is achieved by resorting to the Continuum Strong Discontinuity Approach (CSDA) to material failure [1].
- As for the multiscale modelling issue, it involves a crucial additional entity: an internal (or characteristic) length, which is point wise obtained from the geometrical features of the failure mechanism developed at the lower scale. As a specific feature of the presented approach, for the non-smooth case this internal length is exported, in addition to the homogenized stresses and the tangent constitutive operator, to the macro-scale, and considered the bandwidth of a propagating strain localization band, at that scale.
- Consistently with this internal length, a specific computational procedure, based on the crack-path-field and strain injection techniques, recently developed by the authors [2] is then used for modelling the onset and propagation of this localization band, at the macro-scale.

Representative simulations show that the resulting approach provides mesh objective results with respect to, both, size and bias of the upper-scale mesh, and with respect to the size of the lower-scale RVE/failure cell. The continuum character of the approach confers to the formulation a minimally invasive character, with respect to standard procedures for computational one-scale homogenization and modelling of propagating material failure. The issue of reducing the computational cost using High Performance Reduced Order Modelling (HP-ROM) techniques is also considered.

REFERENCES