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 (FE^2). 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

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