An Adaptive Multiscale Strategy to Simulate Fracture of Composite Structures

A. Akbari R.*, P. Kerfriden, S. Bordas

Institute of Mechanics and Advanced Materials, School of Engineering, Cardiff University, Queen's Buildings, The Parade, Cardiff CF24 3AA Wales, UK. akbarirahimabadia@cardiff.ac.uk

In order to simulate fracture in composite structures, one of the most promising approaches is to model the behaviour of the material at the scale of the material heterogeneities, which is usually called micro or meso-modelling. In a second step, these fine-scale features can be transferred to the scale of the structure by averaging techniques (on representative volume element or unit cells) or homogenisation. However, in the case of fracture, these upscaling methods cannot be used in the vicinity of cracks, as the separation of scales necessary for their application is lost.

In the literature, two schools of thought aim at alleviating this problem. The first one tries to extend the applicability of averaging techniques to fracture (e.g. reference [5] for special averaging techniques dedicated to established damage bands). The second one aims at analysing the zones where homogenisation fails directly at the microscopic scale (e.g. [2, 3]), in a concurrent framework (i.e. domain decomposition). Although the latter approach is more general, it is heavier in terms of computations, and requires the development of robust adaptivity procedures [3, 4, 6], which is the topic of this contribution.

We propose to capture the initiation of the damage mechanisms at the macroscale using a classical FE2 approach [1]. In order to control the precision of the simulations, an error estimation for the upscaling strategy is carried out at each step of the time integration algorithm. Based on this estimation, the macro elements are refined hierarchically where needed. When the size of a macro-element becomes of the order of the statistical volume element used in the FE2 method, the homogenisation step is bypassed. Instead, the corresponding process zone is modelled directly at the microscale and coupled to the homogenised region by a mortar-type gluing technique. In the presentation, we will emphasise some key points of the adaptive multiscale method, including:

- the error estimation technique for the chosen upscaling method

- the transfer of internal variables when adapting the macroscopic mesh

- the arc-length method, defined over multiple scales, allowing to regularise softening problems that are treated in quasi-statics.

The efficiency of the method will be demonstrated on examples of fracture in polycrystalline materials, for which the damage mechanisms are represented by intragranular plasticity and intergranular cohesive debonding.

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