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# Beyond scale separation – Damage propagation and evolving discontinuities in a multi-scale concept

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## ABSTRACT

Homogenization methods are well established for heterogeneous materials with a periodically or randomly distributed microstructure. It is well known that the approach is applicable only if the assumption of scale separation between small and large scales is valid. This is related not only to the initial situation but also to an advanced loading stage when the character of the microstructure might have completely changed. Typical examples are localization phenomena like shear banding and fracture.

The present contribution addresses this situation where long range material failure mechanism evolve like localized damage zones or even distinct cracks eventually leading to structural failure. The proposed approach is based on a hierarchical two-scale method superimposing the displacement field into a large scale and a small scale solution $u = \bar{u} + u'$ (s-method) within a variational framework [4]. $u'$ is introduced only in areas where a pronounced failure mechanism evolves during loading. The small scale solution is spatially decoupled into several local problems each restricted to a domain of one large scale element saving a considerable amount of computational time. The subsequent assembly of all small scale problems has to satisfy kinematical as well as dynamic continuity requirements and is iteratively carried out utilizing Domain Decomposition schemes (Penalty, Augmented Lagrange, Lagrange methods like FETI etc). It turns out that this procedure is clearly more efficient than the overall complete solution. It should be mentioned that this superposition method in principle also allows using different material models on the large scale and the small scale level.

To verify the described concept an isotropic continuum damage formulation for a one or two phase material is applied first, for the latter one (e.g. fiber and matrix) in addition an interface failure model is introduced. Several two-dimensional numerical examples demonstrate that the method is very promising [4].

Based on a fixed structured mesh, material interfaces as well as matrix and interface cracks can be analysed by the Extended Finite Element Method (X-FEM) utilizing appropriate enrichment functions [1],[3]. For the geometrical description Level Set

functions can be used [2]. In the present contribution fracture is described by a cohesive crack model. The concept is verified by several two-dimensional numerical examples; it is currently extended into the third dimension for which different benchmarks are already tested.

The analysis of material interfaces as well as of matrix and interface cracks applying X-FEM is finally introduced into the above described two scale solution method [5]. For this the small scale solution has to be enhanced by the enriched displacement fields. Special care has been taken to guarantee the continuity of cracks between different small scale domains. It can be shown that the FETI method is best suited to assemble the small scale patches. In the current stage the concept has been investigated in a two-dimensional setting; the extension into three dimensions is planned for future work.

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