Three-Dimensional Crack Propagation in Ductile Media Using the XFEM

M. Holl[1]*, S. Loehnert[2], P. Wriggers[3], M. Nicolaus[4]

[1,2,3] Institute of Continuum Mechanics, Leibniz Universität Hannover,
Appelstraße 11, 30167 Hanover, Germany
[1] holl@ikm.uni-hannover.de, [2] loehnert@ikm.uni-hannover.de, [3] wriggers@ikm.uni-hannover.de
[4] Institute of Material Sciences (Fortis), Leibniz Universität Hannover,
Stockumer Straße 28, 58453 Witten, Germany, nicolaus@iw.uni-hannover.de

This work presents a numerical method to simulate crack propagation in plastic media in three-dimensional space using a damage model to examine crack propagation as well as the direction of growth. Most damage models naturally only induce material softening but no discrete seperation of material yielding extensive straining in case of complete failure. Therefore, a combination of damage and discrete failure is appropriate to model ductile failure, presented in this work.

A widely spread method to model damage is the application of non-local or gradient enhanced damage models introduced by [1]. In contrast to these models, local models suffer from mesh sensitivity and are therefore not applied here. The basic idea of non-local or gradient enhanced models is to take into account the microstructure in average. This averaging can be reformulated into a HELMHOLTZ-type equation leading to additional nodal unknowns, but also to the desired mesh insensitivity. Therefore, non-local procedures are methods of our choice.

Combining non-local damage models with discrete fracture in a standard FE approach under the assumption of elasto-plastic material behavior was introduced by [4] for two-dimensional problems: A new crack segment is inserted once a certain damage threshold value is exceeded. This naturally leads to computationally expensive remeshing for each propagation step.

To avoid remeshing for propagating cracks, the extended finite element method (XFEM) introduced by [2] offers great accuracy and flexibility. Incorporating the level set method to describe crack surfaces as well as enrichment functions depending on level set fields to describe the mechanical behavior of cracks yields the todays XFEM. Thus, advancing crack fronts do not change the FE mesh, but only require a local update of the crack surface, presented in this work. Compared to standard FE approaches, computationally expensive remeshing strategies as well as size differences of finite elements in the vicinity of the crack front and the rest of the domain are avoided.

As the XFEM traditionally was designed for linear elastic fracture mechanics (LEFM) and accordingly for singular stress fields at the crack, elasto-plastic problems require special attention. Stresses are bounded due to the introduction of a yield surface leading to different enrichment functions at the crack front introduced by [3] compared to the XFEM applied to LEFM problems.

The goal of this work is to combine elasto-plasticity, non-local damage mechanics and discrete failure in single computable model using the XFEM. Here, the focus is set to present a robust computational framework for this type of problems. This work offers promising results in terms of modeling ductile failure computationally efficient, without loss of computational stability.

References

[1] R. H. J. Peerlings, R. de Borst, W. A. M. Brekelmans, J. H. P. de Vree, Gradient enhanced damage for quasi-brittle materials, Int J Numer Meth Eng 39 (1996) 3391–3403.

[2] N. Moës, J. Dolbow, T. Belytschko, A finite element method for crack growth without remeshing, Int J Numer Meth Eng 46 (1999) 135–150.

[3] T. Elguedj, A. Gravouil, A. Combescure, Appropriate extended functions for X-FEM simulation of plastic fracture mechanics, Comput Method Appl M 195 (206) 501–515.

[4] J. Mediavilla, R. H. J. Peerlings, M. G. D. Geers, Discrete crack modelling of ductile fracture driven by non-local softening plasticity, Int J Numer Meth Eng 66 (2006) 661–688.