X-DMS 2015
eXtended Discretization MethodS
September 9-11, 2015, Ferrara, Italy

Crack propagation by using crack opening displacements in 2D and 3D XFEM

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Key words: XFEM, stress intensity factors, crack propagation

ABSTRACT

Cracks play an important role in engineering, in particular for the safety of the structures. Therefore it is necessary to know their influences and behavior. The large number of books and papers which are available in fracture mechanics represents the importance of this topic. In the 1970s, Irwin developed the stress intensity approach which allows a good description of the crack behavior by using stress intensity factors (SIFs). Since that time many research activities have been invested in the computation of SIFs. Many of these approaches are energy-based such as those based on the J- or interaction integral. But their extension to 3D is quite difficult and several modifications for loaded crack surfaces are needed. Therefore, we prefer techniques which observe the displacement or stress fields in the vicinitity of the crack tip, e.g. displacement extrapolation or fitting approaches. These methods are intuitive and the extension to 3D is often straightforward. A comparison of these methods is given by Muthu [1].

The computed SIFs are used as a criterion for the crack propagation, i.e. for the crack growth rate and the direction of the propagation [5]. The results of a crack propagation simulation are shown in the following figure, where the computed crack path (red line/surface) for a 3-point bend test in 2D and 3D is presented.

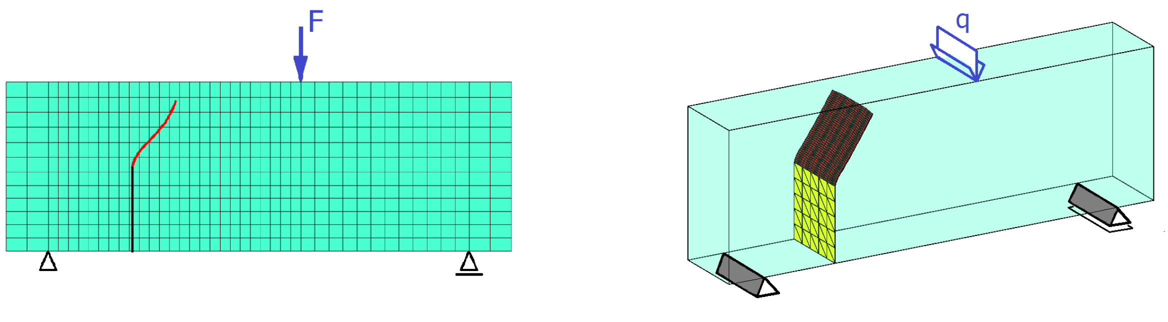

Figure 1: Crack propagation for a 3-point bend test.

Herein, it is shown how the fitting of the CODs is employed in the context of the extended finite element method (XFEM) with a hybrid explicit-implicit description of the crack geometry in two and three spatial dimensions. An explicit crack description by means of straight line segments in two dimensions or flat triangles in three dimensions has the advantage that the update of the crack geometry during crack propagation is quite simple because only new segments have to be added. An implicit crack description is used for calculations with the XFEM wherefore level-set functions are used, which are derived from the explicit master configuration. Then the enrichment functions and coordinate systems, which are needed for the simulation can be extracted. A curved coordinate system is provided by the level-set functions which also allows the representation of curved cracks. This is a useful feature for crack propagations because it is typical that the propagating crack paths are curved. In this reference coordinate system the expected CODs for a pure mode I, II and III are compared with the approximated CODs of the simulation in order to fit SIFs. In this technique there are no differences whether the crack surfaces are stressfree or loaded. That is, the method can straightforwardly be employed in the context of hydraulic fracturing.

The numerical studies show the accuracy of the proposed method for the computation of SIFs for a static crack state and also its robustness for crack propagation simulations. For example, Figure 2 shows the convergence results of the fitted SIFs from CODs for an edge cracked cantilever.

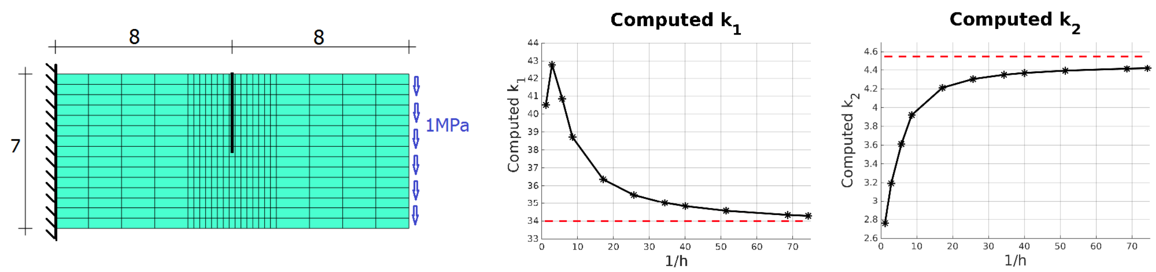

Figure 2: Convergence of computed SIFs for a cantilever.

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