8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

MODEL OF CRACK PROPAGATION WITH THE EXTENDED FINITE ELEMENT METHOD

*** N. Chevaugeon[1] and N. Moës[1]**

[1] Institut de Recherche en Génie Civil et Mécanique, UMR CNRS 6183, École Centrale de Nantes, B.P. 92101, 44321 Nantes Cedex 3, France
{nicolas.chevaugeon, nicolas.moes}@ec-nantes.fr

Key Words: *X-FEM, level-set method, crack propagation*

ABSTRACT

In this paper we will first review the combination of the level-sets and Extended Finite Element Method (X-FEM) techniques for the computation of the displacement field in the context of linear elasticity around cracks. Then we will discuss algorithms to extract stress intensity factors and the use of this results for crack propagation algorithm in fatigue context. Finally we will introduce promising techniques for quasi-static crack propagation problems.

The X-FEM and the level-set method constitute a good modeling combination for the simulation of crack problems [1]. The X-FEM allow to enrich the discrete representation of the displacement field with discontinuous and asymptotic solutions near the crack lip, using a partition of unity technique. The geometry of the crack is represented by two level-sets. The first level-set represent the distance to the crack surface. The second level-set has iso-surfaces orthogonal to the iso-surfaces of the first one. The intersection of the zero-level of the two level-sets represent the crack lip. These two level-sets define a coordinate system on the domain that permit to compute at each point, geometrical distance, angle and local basis related to the crack geometry. This data simplify the enrichment procedure of the X-FEM applied to crack and in particular the enrichment with term of the asymptotic expansion of the elastic field around the singularity. It has been shown that with the right enrichment strategy and proper elementary integration, optimal convergence rate can be obtain with the X-FEM/level-set combination ([2], [3], [4]).

Based on G_θ method, an algorithm have been developed to compute J integrals or extract stress intensity factors that take full advantage of the coordinate system defined by the two level set. We show that our implementation give stable and convergent results for three-dimensional cases, with curved crack-lip and non-planar crack surface.

In the context of fatigue analysis, the stress intensity factors are used to compute direction of crack propagation using one of the literature given criteria (maximum hoop stress, maximum energy release ....). These data computed along the crack lip, are then exploited to extend a propagation speed for the level-sets and then update the level-sets representing the crack. The level set update procedure is of crucial importance, since the level-sets are, as was noted before, used for the accurate enrichment

and extraction procedure [5]. We will discuss different algorithms, in term of speed and accuracy. The method is then applied to three dimensional industrials cases to predict the crack propagation path. The results are then related to a number of load cycle using a Paris law.

We then present first step toward the extension of our model to problems of crack propagation under quasi-static loading, using an implicit approach. We recast the model as a minimum principle : for a given dissipation we seek the level-sets representing the crack that minimize the potential energy. The minimization is implemented using a iterative level set propagation technique. Increments of dissipation pilot the global algorithm. the proposed method should be able to reproduce load-displacement curves with snap back behavior typical of the Brazilian test for example.

REFERENCES

[1] N. Sukumar, N. Moës, B. Moran and T. Belytschko. "Extended finite element method for three-dimensional crack modelling". *Int. J. Numer. Meth. Engng.* , Vol **48**, 1549–1570, 2000.

[2] F. L. Stazi, E. Budyn, J. Chessa and T. Belytschko. "An extended finite element method with higher-order elements for curved cracks". *Comput. Mech.* , Vol **31**, 38–48, 2003.

[3] P. Laborde, J. Pommier, Y. Renard and M. Salaün. "High-order extended finite element method for cracked domains". *Int. J. Numer. Meth. Engng.* , Vol **64**, 354–381, 2005.

[4] E. Béchet, H. Minnebo, N. Moës, B. Burgardt. "Improved implementation and robustness study of the X-FEM for stress analysis around cracks". *Int. J. Numer. Meth. Engng.* , Vol **64**, 1033–1056, 2005.

[5] M. Duflot. "A study of the representation of cracks with level sets". *Int. J. Numer. Meth. Engng.* , Vol **70**, 1261–1302, 2006.