A robust meshing algorithm for complex 3D crack growth simulations

V. Chiaruttini, F. Feyel, J.-L. Chaboche

1 Onera, DMSM/CEMN, Châtillon, France, {vincent.chiaruttini, frederic.feyel, jean-louis.chaboche}@onera.fr

Robust and efficient strategies for simulation of cracked structures are of great interest for a wide range of industrial applications. However, the usual finite element method, which is one of most popular tool for computational mechanics is suffering many limitations that prevent its use to robustly and accurately predict critical damage tolerance analysis of 3D structures where crack propagation occurs. One of the main drawback is related to the specific remeshing effort required to properly model an evolving crack geometry and the singular phenomena arising in the front vicinity.

To tackle those difficulties, the computational mechanics community has developed various new methods in order to deliver strategies able to simulate crack growth on complex industrial structures. Thus, new promising techniques, such as meshless methods, boundary element methods, or partition of unity derived methods have been highly investigated. One of them, the extended finite element method (X-FEM) [1, 2] is certainly one of the most popular, both in academic and industrial areas. Based one the introduction of enriched finite element shape functions (which could represent a crack discontinuity, for instance), this technique avoids some of the drawbacks of the usual finite element method. Associated to a level-set crack localization, its advantages are numerous: easy to insert crack on a given finite element mesh, ability to deal with complex crack and structure geometries, possibility for crack front to collapse in different parts, etc. However, in large or complex structures, mesh adaptation can be required since elements of a reasonable size are needed in the crack area, inserting new functions and the accurate integration rule considerably increases the computational time and required memory and robust level-sets update during out-plane propagation can be difficult.

Concerning the standard finite element approach, recent improvements of meshing and remeshing techniques allow the generation of complex 3D meshes [3] that could be refined in local areas of interest where a crack could propagate. Thus, inserting the discontinuity surface in those refined uncracked meshes became one of the last drawback of those methods. Traditional approaches, usually based on a cracked CSG model, or mesh generation with boolean operations, generally lack of robustness which makes it difficult to deal with complex geometries.

In order to fundamentally push the lines of remeshing based techniques, a new algorithm as been developed to bring them some of the best X-FEM advantages. Our approach is mostly based on a new fast and efficient crack insertion algorithm. The robustness and quickness of this method is obtained by the way the output cracked mesh is represented (linked to element mesh size near the surface of discontinuity). In fact, each volume element of the input mesh that crosses the crack surface is cut. An important assumption is that the generated surface can be approximate by the polygonal elements built on the input element edges intersection points. Some special treatments are also performed on element faces to carry out the crack front intersection and some topological difficulties that could arise for highly curved cracks. This obtained mesh is finally rebuilt using an adaptive remeshing strategy in order to eliminate bad quality elements and provide a suitable discretization for accurate finite element solution and stress identity factors computation.
This approach has been implemented in the Z-Set [4] finite element software co-developed by the École des Mines de Paris, NW Numerics and Onera. This technique has already been applied to some complex 3D cracked structures mesh generation (cf. figure 1) and used to treat various 3D crack growth simulations, in order to validate its accuracy, robustness and computational cost.

![Complex cracked mesh generation: intersection between a part of a turbine disk and an arbitrary surface.](image)

**Figure 1:** Complex cracked mesh generation: intersection between a part of a turbine disk and an arbitrary surface.

**References**


