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

AN X-FEM APPROACH FOR MODELING CLOSED DISCONTINUITIES UNDER LARGE SLIDING CONTACT

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Key Words: *X-FEM, hybrid contact formulation, large sliding.*

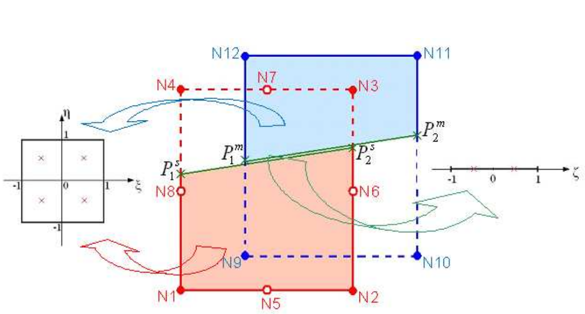
ABSTRACT

The Extended Finite Element Method (X-FEM) developed by Moës et al. in [3] proposes an alternative to re-meshing which relaxes the mesh dependency on discontinuity by enriching the unknown nodal displacement space, thanks to the principle of Partition of Unity Method. Its application to closed discontinuities requires the coupling of X-FEM with a contact algorithm, therefore adding a mechanical interaction between the two sides of the cracks. In this contribution, we present an approach for considering the contact under large displacement on closed discontinuities treated by X-FEM coupled to the hybrid contact formulation developped by Ben Dhia et al. [1]. A first work for coupling X-FEM with the above mentioned algorithm was achieved by Geniaut et al. [2] for small perturbation cases. Our work generalizes this approach to the case of large displacements introducing a new type of contact element, a geometrical update procedure and a contact search algorithm.

The hybrid contact formulation is similar to an Augmented Lagrangian Method with some particularities: the contact conditions are seen as an interface law and not as boundary conditions, the contact non-differentiability is solved with a set of active constraint algorithm and the non-differentiability related to the friction threshold is solved using a fixed point method. This formulation was implemented in Code_Aster, the GPL finite element code developed by EDF (see www.code-aster.org), where a X-FEM module is available too. The crack geometry for X-FEM in this code is introduced using the Level Set Method [4].

Next we present the main steps of our approach. For the contact surfaces of the discontinuities, two series of intersection points are generated, one for each side, denoted as slave and master intersection points. The original intersection points are located at the intersection between the normal level set and the original mesh of the structure. The coordinates of these points are computed before each time step in order to update the contact geometry. So, during the sliding, the contact research algorithm provides the slave-master contact pairs in order to create the hybrid element. An exemple of a such hybrid element

is shown in Figure 1. It is formed by two quadrilateral elements cut by the crack, for which two parts arrive in opposite location during the sliding. The slave element (the bottom one) has middle-edge nodes just for storing the contact unknowns when the crack intersects the corresponding edge.



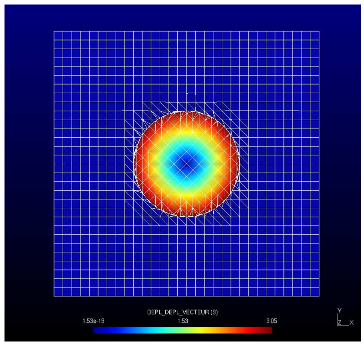


Figure 1. X-FEM hybrid contact element   Figure 2. Final displacement field for a large sliding test

In this example, the slave point P_2^s was projected on the segment created by the master points P_1^m and P_2^m determining a X-FEM hybrid contact element composed of a slave part (the bottom one) and a master part (the top one). The contact points are suported by the slave contact segment $P_1^s P_2^s$ and are located at P_1^s and P_2^s. The numerical integration of the contact contributions needs the evaluation of the gap between the contact point and its projection and the approximation of the contact unknowns over the contact domain. Both calculus are performed on the hybrid contact element using the elementary interpolation domains: the slave one, the master one and the slave contact segment one.

We used several simple models in order to prove the efficiency and stability of this new approach. One of these is a square 2D plate including a circular crack as shown in Figure 2. A spin movement is imposed on the internal circle and the external borders of the plate are subjected to an uniform pressure. The stability of the contact formulation needs the respect of the LBB condition (also called *inf-sup* condition), ensured in our approach by the specified algorithm developed in [2].

During the analysis, the expected pressure value is found on contact points around the circle even if some oscillations were observed when coarse meshes were considered. As the meshes became finer, the oscillation amplitude of the pressure field vanishes and the pressure magnitude converges towards the reference solution.

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