

# A new coupled X-FEM/ Level-Set strategy to solve contact problem

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When bodies come into contact, the contact surface is a priori unknown. This necessitates the addition of inequality equations to the formulation which are themselves still a challenge to solve efficiently. A lot of numerical approach have been used in the past to solve mechanical problems involving contact between bodies. Most of them rely first on the detection of a discrete interpenetration condition, followed by penalty or Lagrangian methods.

In a contact situation between two bodies, part of their boundary are coincident in the deformed configuration. When following the boundary of one of the bodies, one will cross an interface  $\Gamma$  separating the part of the boundary which is in contact to the one which is not. In general, the solution is not smooth across  $\Gamma$ . Numerically, jumps in the contact pressure are observed. The optimal convergence rate with regard to the mesh size is difficult to obtain and the use of high order methods becomes very problematic. The difficulty mostly arise from the fact that  $\Gamma$  does not coincide with a finite element nodes.

Several cure have been developped to improve the situation. Smoothing the contact surface description using interpolation schemes with continuous derivatives were proposed in [1, 2]. The mortar method, improving the Lagrange multiplier method and allowing a face-to-face approach in place of the usual node-to-face method, was also developped in [3]. More recently, it was proposed in [4] to move the nodes of the mesh in the reference configuration so that the nodes of the deformed mesh coincide with the interface  $\Gamma$ , in a rp-combined mesh refinement approach.

In the present contribution, we propose to transform the inequality problem into a sequence of equality problems with an unknown domain depending on the boundary  $\Gamma$  of the contact zone. This interface is represented implicitly by a level-set function, which move during the iterations, to reach the correct position. The contact problem is now express in term of an evolution problem of the interface  $\Gamma$ . Using a level set function make it easy to track topological change in  $\Gamma$ , such as merging of two separated zone, or splitting a zone in several parts. Furthermore, it allow for the use of enriched displacement field, applying the extended finite-element method (X-FEM) to model field derivative discontinuities around the contact area [5].

The correct shape of  $\Gamma$  is found iteratively by means of configurational mechanics [6]. This shape-optimisation problem is driven by a sensitivity analysis. The same strategy has previously been implemented in [3] to solve volumetric inequalities constrains.

As a first step to more general problems, we have treated simple problems such as a one dimensional medium governed by the rope equation and a two dimensional medium governed by membrane equation. Pressure forces are applied to these media and their displacements is constrained by an undeformable body. The classical Hertz contact problem is also used as a benchmark.

The interest of these methods was highlighted by showing their efficiency using a coarse mesh and

high order elements. In addition, we compared the properties of our method with more classical approaches to contact.

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