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An XFEM approach in solving frictional contact problems based on the penalty formulation

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Abstract

One of the most important issues in solving contact mechanics problems is the numerical instabilities of the solutions. Many different methods have been proposed for stabilizing the numerical quantities. The proposed penalty formulation within the powerful XFEM methodology is capable of treating contact constraint in the whole contact segment, while ensuring the stability of numerical solution. Two types of crack segmentation have been studied. The obtained results illustrate that this formulation yields to stable contact forces on the contacting surfaces. It is shown that many inaccuracies like instabilities and unwanted interpenetrations resulted from the conventional point-to-point contact method can be avoided by the present XFEM formulation. Some examples are provided in order to illustrate the accuracy and efficiency of the proposed approach.

Keywords: extended FEM, frictional contact, penalty method, segment to segment

1. INTRODUCTION

Depending on the type of loading in solids, an existing interface may close partially or completely. As a result, the contact condition must be taken into account in the solution procedure. It is evident that these kind of discontinuous problems can be solved more efficiently by the eXtended Finite Element Method (XFEM). It is known that friction formulation is a nonlinear constitutive law which must be enforced in contacting surfaces in the presence of friction. Modelling of frictional cracks by the XFEM was first performed by Dolbow *et al* (2001using a LATIN formulation in order to impose frictional contact constraints on the surfaces of crack. They imposed contact constraints on some Gauss points on the crack sub-elements. These sub-elements are defined by the intersection of crack geometry and the finite element mesh. But the algorithm was very slow in converging to a suitable tolerance. This work was developed by Liu and Borja (2008) using a coupled penalty-Newton Raphson approach and converged to a better tolerance faster than the LATIN method. Also Geniaut *et al* (2007) proposed a Lagrange's multiplier method for enforcing contact constraints on the general contact problems by XFEM and Elguedj *et al* (2007) used an augmented Lagrangian method to model fatigue crack growth. Recently, Ebrahimi and Mohammadi and Mahmoudzadeh (2013) developed a local PUFEM model of stress singularities in sliding frictional contact problems.

Nevertheless, some improper results were also reported. Such as oscillations in tractions of crack surfaces. These instabilities occurs as a consequence of over-constraining of the system. Many methods have been proposed in order to reduce or diminish these oscillations and instabilities. Nitsche and bubble-stabilization methods were adopted by Sanders *et al* (2009) to impose the constraints and achieve stable solutions. The basic idea of Nitsche's method was to enforce contact constraints (or generally Dirichlete boundary conditions) in a weakly fashion. It was used in combination with the finite element method in applying the Dirichlet boundary conditions by Barbosa(1991). Garcia *et al* coupled Nitsche method with XFEM and discontinuous Galerkin method. Ji & Dolbow(2004) showed that using Lagrangian multipliers could intensify the oscillations and instabilities. Also in the penalty approach, increasing the penalty parameter, oscillation violently affect the oscillations. Moes *et al* (2006) reduced the number of Lagrangian multipliers and stabilized the system and Mourad *et al* (2007) added some bubble degrees of freedom to the enriched elements. By static condensing of these additional degrees a similar formulation to Nitsche's method could be achieved. A mortar-based XFEM in a Lagrangian multiplier space was used by Giner *et al*(2010) to stablilize tractions on the crack faces. They added 2 degrees of freedom to each interface segment that is made from intersection of interface and mesh.