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Non-linear boundary element formulation applied to contact analysis using tangent operator

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ABSTRACT

This work presents a non-linear boundary element formulation applied to analysis of contact problems. The boundary element method (BEM) is known as a robust and accurate numerical technique to handle this type of problem, because the contact among the solids occurs along their boundaries. The proposed non-linear formulation is based on the use of singular or hyper-singular integral equations by BEM, for multi-region contact. When the contact occurs between crack surfaces, the formulation adopted is the dual version of BEM, in which singular and hyper-singular integral equations are defined along the opposite sides of the contact boundaries. The structural non-linear behaviour on the contact is considered using Coulomb's friction law. The non-linear formulation is based on the tangent operator in which one uses the derivate of the set of algebraic equations to construct the corrections for the non-linear process. This implicit formulation has shown accurate as the classical approach, however, it is faster to compute the solution. Examples of simple and multi-region contact problems are shown to illustrate the applicability of the proposed scheme.

1. Introduction

Contact mechanics is an important theme in the domain of solid mechanics. During the last few years, this theme has received an enormous attention from the scientific community due to its technological importance and complexity. The knowledge on the contact surface behaviour has great importance in mechanical, aeronautic and ship industry, where several forces are transferred among the solid parts using dents, connections and joints.

The boundary element method (BEM) is particularly suitable to handle this kind of analysis. As the discretization is required only along the boundary and contact surfaces, the number of degrees of freedom tends to be small in comparison with other numerical techniques as finite element method (FEM) and the extended finite element method (XFEM). However, this was not an impeditive to the development of some interesting formulations using these two last numerical methods. Friction and frictionless contact formulations for analysis of multi-bodies, crack surfaces and impact have been successfully developed using FEM [1–3] and XFEM [4,5].

To deal with complex contact problems, especially non-linear contact problems, BEM is recommended because this numerical method is capable to calculate accurately the values on body's boundary, where the contact occurs. In addition, the proposition of new BEM formulations for this problem is straightforward, because it gives explicit equations relating values prescribe and unknown on the boundary, including the surfaces in contact. Considering BEM to analyse contact problems appeared in the work due [6]. A contact BEM formulation based on the sub-region technique was proposed in [7] to analyse slope limit loads in geomechanic problems. They have developed and implemented a non-linear BEM formulation, using only singular integral equations, for which Mohr-Coulomb's criterion was assumed to define the collapse. The sub-region technique was also used by Man [8] and Aliabadi [9] for analysis of several types of contact problems, where linear and quadratic boundary elements were adopted. Coulomb's criterion was considered to model friction contact between cylindrical surfaces and crack lips by Gonzalez and Abascal [10] and Chen and Chen [11], respectively.

An automatic incremental technique was proposed by Huesmann and Kuhn [12], in which contact conditions change at only one node at the end of the increment, for two-dimensional elasto-plastic contact problems including friction. Their algorithm takes into account the elasto-plastic material behaviour over a fast iterative scheme. A BEM formulation applied to solve elastic frictional contact problems, using non-conforming discretization was presented in [13–15]. These formulations use singular and hyper-singular integral equations and the values on the contact surface are determined by enforcing tractions and displacements at every node of the contact zone with points on the opposite

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