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A boundary elements formulation for 3D fretting-wear problems

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ABSTRACT

Computational wear modeling is an extremely time-consuming problem, especially the 3D cases. In this work, a 3D boundary element method (BEM) formulation for wear modeling is proposed and applied to simulate 3D fretting-wear problems under gross sliding and partial slip conditions. The present formulation applies the BEM to approximate the elastic response of solids, and an *augmented Lagrangian formulation* to solve the contact problem. Contact restrictions fulfilment is established by a set of projection functions, and wear on contact surfaces is computed using the Archard wear law. The BEM proves to be a very suitable numerical method for this kind of mechanical interaction problems, considering only the boundary degrees of freedom involved in the problem and obtaining a very good approximation of contact tractions with a low number of elements. This is very interesting in terms of computational cost reductions of wear modeling, specially in 3D problems. In that regard, an acceleration strategy is applied to the proposed algorithm. It allows to obtain very important reductions on wear simulation times. The proposed methodology is therefore an efficient numerical tool for 3D fretting-wear problems modeling.

1. Introduction

Wear is present in the mechanical interaction of solids. This phenomenon has been studied indepth since the end of the first half of the twentieth century. Worthy of emphasis are the important works of Holm [1] and Archard [2], who converged to the same model: the *Holm–Archard wear law*, which is very extended in engineering applications. The works of Rabinowicz, which are collected in his book [3], together with the main research works on friction and wear, should also be mentioned.

The theoretical analysis of contact and fretting was first studied by Cattaneo [4] and also independently by Mindlin [5]. Both authors provided the analytical solution for two spheres under partial slip. Hills and Nowell [6] extended that work to different contact geometries and loading conditions. More recently, Goryacheva et al. [7] developed a 2D analytical model for computing the tractions and profiles of solids in fretting-wear problems, showing that there exists an asymptote in the contact pressure solution.

In the area of numerical formulations and simulations, several different formulations, using different methodologies and algorithms, have been proposed for wear prediction. The fundamental works of Klarbring [8,9], Johansson [10], Strömbeg et al. [11] and Strömbeg [12,13], which present the formulation and fundamentals for contact–wear simulations, and more recently Ireman et al. [14,15], should be mentioned. McColl et al. [16] present a 2D finite element-based method for simulating fretting wear compared with experimental measurements, and Madge et al. [17] propose a 2D finite element model for fretting fatigue. In the area of boundary elements, there are not many works about wear. The main ones belong to Sfantos and Aliabadi [18–21], who present a sliding wear BEM-based formulation, and to Lee et al. [22], who use a 2D model to study fretting wear of tube-to-plate contact.

The BEM proves to be a suitable numerical formulation for this kind of mechanical interaction problems, in which it is necessary to reduce the CPU times and obtain good accuracy of the contact variables, such as contact tractions.

This work presents a boundary element formulation for 3D fretting problems. The methodology for contact modeling suggested in this work is based on the preceding works on augmented Lagrangian contact formulation by Alart and Curnier [23], Klarbring [8,9], Laursen [24] and Wriggers [25], and continues the BEM contact works presented by the authors: [26–31]. Boundary elements compute the elastic influence coefficients, and the projection functions acting over the augmented Lagrangian guarantee the fulfilment of contact restrictions. The Holm–Archard wear law is considered to compute material loss on solid surfaces. Changes in the geometry of solid due to wear processes are taken into account by means of a gap variable. The non-linear system of

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