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MODIFIED CONTACT SEARCH ALGORITHM FOR SHEET METAL FORMING

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1. Introduction

The presented contribution concerns algorithm for detecting contact in numerical simulations of sheet metal forming. An amendment to a standard contact searching algorithm is proposed that allows to eliminate errors leading to wrong solution results. The considered algorithm is designated for the cases of triangular discretization of contact surfaces. Furthermore, numerical cost of the presented algorithm is discussed.

2. The concept of the proposed algorithm

The standard algorithm for detection of contact between a point and a surface (discretized by finite elements) [1,2] assumes that the contact element (also called contact segment) is one of the elements sharing the node that is the closest to the point considered. For some finite element meshes this assumption may prove false. An example of such a case is shown in figure 1. Here, one can see the surface S discretized by triangular elements and the point P located above or below the surface. Since the closest node of the surface element mesh to the given point P is the node K, the standard procedure will search for the projection point in one of the elements containing this node, although the correct solution is the element N_{min} which is none of them though it actually contains the projection point of P onto S.

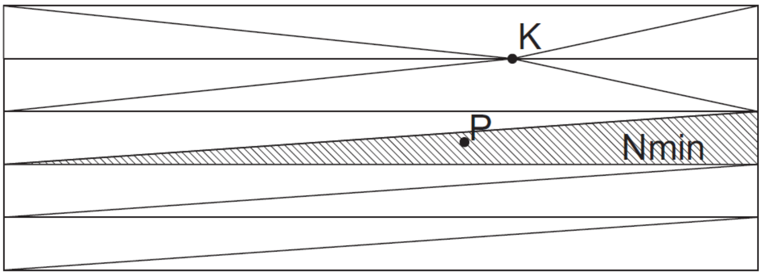

Figure 1. Example discretization of surface.

In order to determine the contact element correctly, an alternative way is proposed. Unlike the standard algorithm, the proposed one consists in finding the closest element for the given point. The procedure is as follows. The point is projected orthogonally onto surfaces of subsequent triangles constituting the finite element mesh of the surface. By solving a 3x3 linear system of equations, the projection distance D and the barycentric coordinates T_1, T_2, $T_3 = 1 - T_1 - T_2$ of the projection point are computed. If $T_1 \geq 0 \wedge T_2 \geq 0 \wedge T_3 \geq 0$ then the projection belongs to this element and the distance between the point and the element is D (figure 2a). Otherwise, the point is projected onto the triangle edges, and, depending on the results, D is assigned the value of distance from the point to one of the edges or vertices of the triangle (figure 2b). Repeating this procedure for all the surface elements and saving the one with the lowest value of D_{min}, the algorithm comes up with the correct contact element (or possibly a set of elements if the projection point is located on an edge or vertex).

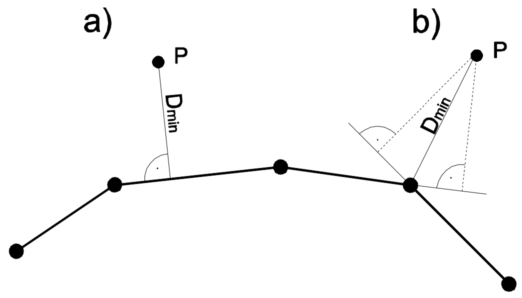

Figure 2. The orthogonal projection.

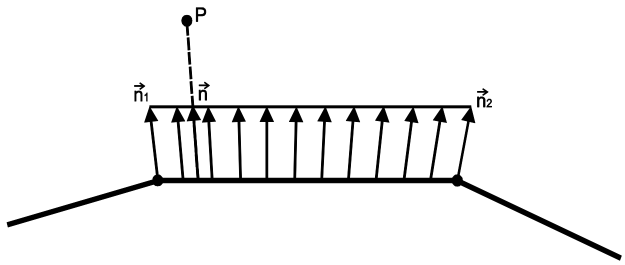

Figure 3. The interpolated projection

The next stage, similarly as in the standard algorithm, is to perform the so-called "interpolated projection", i.e. the projection of a point onto a triangle along an "interpolated normal" vector. This interpolated vector is obtained on the basis of averaged normal vectors computed in each node of the considered element, being the normalized arithmetic average of normal vectors in elements sharing the considered vertex. The idea of interpolated projection is shown in figure 3. The purpose of this action is smoothing the results of the projection procedure as a function of location of the considered point. The interpolated projection of point is done onto the closest contact element (or a number of neighboring elements) indicated in the previous stage of the algorithm.

3. Numerical cost of the algorithm

The numerical cost is defined as the total number of dominating operations that must be performed to obtain the result of analysis. Here, these are operations of multiplication and division, as their execution time is much longer than that of addition and subtraction [3]. Having estimated numerical cost for both the proposed and the standard algorithm, we have found that (1) in both the cases the numerical cost of algorithm is a linear function of the number of rigid surface elements and (2) the numerical cost of the proposed algorithm is significantly higher than that of the standard algorithm. On the other hand, however, the proposed algorithm appears in many cases the only reliable.

4. References

[1] Benson D.J., Hallquist J.O., A single surface contact algorithm for the post-buckling analysis of shell structures. Computer Methods in Applied Mechanics and Engineering, 78:141-163 (1990).

[2] Peter Wriggers, Computational Contact Mechanics, John Wiley & Sons Ltd (2002).

[3] David Kincaid, Ward Cheney; Analiza numeryczna, Wydawnictwa Naukowo-Techniczne Warszawa, 168-169.