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SURFACE-TO-SURFACE PENALTY CONTACT FOR QUADRATIC ELEMENTS

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In former days industrial Finite Element calculations were usually limited to just one component. Nowadays, complete assemblies are being analyzed involving quite complicated contact conditions. Therefore, fast and stable contact algorithms are of enormous value in industry.

Over the years a lot of contact algorithms have been developed [1]. Among these, the penalty method is especially attractive because of its ease of programming and straightforward physical interpretation. One of its common implementations is in the form of nonlinear contact spring elements connecting a node on the slave side with a face on the master side, a so-called node-to-face formulation (Fig. 1). Application to real life applications, however, has shown that frequently problems arise when a node is slipping across an external edge. Furthermore, the concentrated force in the slave node leads to difficulties for quadratic faces, for which a constant pressure yields tensile forces in the vertex nodes.

Therefore, a surface-to-surface formulation was devised by creating spring elements between the Gauss integrations points of the slave faces and the master faces (Fig 2). The force arising in the slave integration points is redistributed among the nodes belonging to the face. In that way, contact between two 8-node faces leads to a 16-node contact spring element. The location of each slave integration point in relation to the master faces determines which faces are being connected. The forces consist of a normal component, which is a linear function of the penetration, and a tangential component, determined by Coulomb friction. For reduced integration 20-node brick elements four integration points are used per slave face, leading to four contact elements.

In order to improve the continuity and robustness of the contact formulation, a second integration scheme was analyzed based on a triangulation of the common areas between

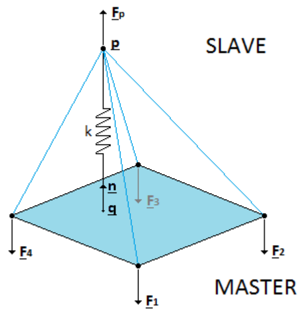

Figure 1: node-to-face contact

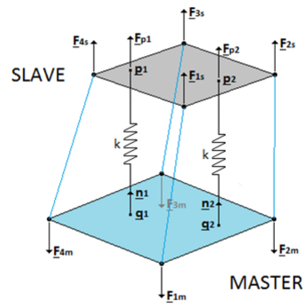

Figure 2: face-to-face contact

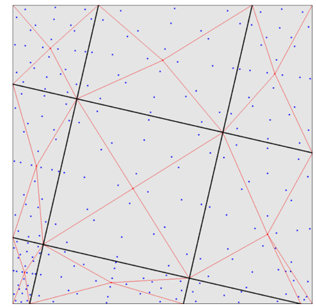

Figure 3: triangulation

Table 1: Iterations for selected engine component contact calculations

example	Abaqus® face-to-face	Gauss	Triangulation
disk-blade	26	7	9
vane-casing	18	18	24
casing-bolt	89	117	63

slave and master faces. Fig. 3 shows one slave face with the opposite square master faces and the triangulation. In this way the choice of slave and master face becomes irrelevant, since the same triangulation results. For the integration of each triangle a 7-point scheme was used (dots in Fig. 3). The number of integration points is about 10 times the amount in the ordinary slave integration scheme. Although the number of contact elements clearly increases significantly, a very smooth contact state is expected.

Both methods were implemented in CalculiX® and applied to 15 complicated aero engine component calculations using quadratic hexahedral and tetrahedral elements. Typical assemblies were analyzed such as disk-blade, vane-casing and casing-bolt arrangements. Both the number of iterations needed to finish the calculation and the computation time were monitored, and compared with the commercial Finite Element Solver Abaqus®.

Table 1 shows the number of iterations for three selected examples. Both schemes seem to be competitive and frequently faster than the Abaqus® solutions. The contact stresses of all methods were comparable. The stability of the scheme based on the triangulation of the slave-master contact area, however, was superior (all 15 examples converged) to the one based on the Gauss integration points (20 % did not converge). The computation times were in most cases within a factor of two (either way).

REFERENCES

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