A frictional contact algorithm for implicit material point method

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Abstract

The explicit material point method (MPM) works successfully in modeling high frequency problems, but it is very computationally expensive in simulating low frequency with small time steps or quasi-static problems. Thus, several groups have developed an implicit MPM for modeling low frequency problems. Recently, a few attempts were undertaken to investigate the contact problems using the implicit MPM but the accuracy was dissatisfactory. The contact problem is one of the saddle point problems, which are usually indefinite and highly ill-conditioned. These features bring great challenges to the Newton-like methods, which require the Hessen matrix to be positive definite.

An easy-implementing frictional contact algorithm is proposed for the implicit MPM, which is based on an augmented Lagrange formulation. By employing the Uzawa algorithm, the condition number of the original problem is dramatically improved and the positive definiteness of the effective stiffness matrix can be reserved. In addition, the Uzawa algorithm decouples the unknown variables and the multipliers, which simplifies the solving process. The resulting nonlinear equations are solved by the Newton method, in which the tangential matrix is assembled explicitly. By using the compressed sparse row (CSR) technique, the total storage of the matrix can be greatly reduced.

The accuracy, efficiency and robustness of the contact algorithm have been validated by the numerical studies. The results obtained by the implicit MPM with the proposed contact algorithm agree well with the analytical solution. The computational accuracy and efficiency are much higher than the explicit MPM. The cutting simulation demonstrates the competitive advantages of the implicit MPM over the FEM and the robustness of the contact algorithm.

Keywords: Implicit, material point method, frictional contact, augmented Lagrange method

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