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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. In this paper, an augmented Lagrange formulation for the frictional inequality constraints is introduced. A discretization of the Lagrange multiplier field based on the background grid is proposed to establish the implicit MPM framework with the contact algorithm. To reduce the complexity of the solution, the Uzawa algorithm is employed to decouple the unknown variables and the Lagrange multipliers. Finally, the resulting sequent 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. Numerical studies show that the computational efficiency and accuracy of the implicit MPM with the proposed contact algorithm are much higher than the explicit MPM.

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

1. Introduction

In recent decades, lots of meshfree and particle methods have been proposed to study challenging problems, such as penetration, impact, fluid-structure interaction (FSI) and explosion. The material point method (MPM) is a fully Lagrange particle method developed by Sulsky et al [1,2]. The material domain is discretized by a set of Lagrange particles, which move through a predefined Eulerian background grid. In each time step, the particles are rigidly attached to the background grid and move together with the grid. The solutions are mapped from the grid points to the particles to update their positions and velocities after solving the momentum equations on the background grid. Finally, the deformed grid is discarded and a new regular grid is defined in the next time step. Thus, the mesh distortion is avoided, which often arises in FEM with large

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