Staggered Grid Material Point Method and Its Applications

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Abstract

The material point method (MPM) has demonstrated itself as an effective numerical method to simulate extreme events with large deformations. As a variation of the Particle-In-Cell (PIC) method, the MPM utilizes the advantages of both Lagrangian and Eulerian methods so that mesh distortion and element entanglement can be avoided naturally. However, the original MPM takes the material points as integration points and usually uses piecewise linear grid nodal shape functions whose gradient is discontinuous at the element boundaries. This leads to unphysical oscillations, called "cell crossing noise", while the particle crosses the element boundary. Quite a number of variations based on the MPM have been developed to alleviate the cell crossing noise.

To efficiently eliminate the cell crossing noise, the staggered grid material point (SGMP for short) method was proposed by our group. Two set of background grids were employed with the second grid obtained by shifting the first grid half the length of its cell in each direction. Instead of the particle quadrature, the volume integrals in the weak form were evaluated as the sum of values of the integrand at the cell centers of the first grid multiplied by the cell's volume, which was determined by Shepard interpolation using the particle volumes. The SGMP method is able to eliminate the cell crossing noise with about 10% extra computational effort compared with the original MPM.

In this work, the SGMP method is further improved and investigated. A contact algorithm is introduced into the SGMP to model complex problems with multiple components and interactions. The contact algorithm directly adds the contact force at the nodes where two or more components contact in order to avoid penetration. Numerical studies show that the SGMP method is very efficient and robust. Due to cell crossing, the MPM does not converge and is unstable in some cases, but the SGMP method is not only converged but also stable in all of our test problems, even with a CFL number of 2.5.

Keywords: material point method; staggered grid; grid crossing noise.

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