A coupled Eulerian-Lagrangian algorithm for explosion and shock problems

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Abstract

In recent decades, significant effort had been directed toward computations for intense impulse loading due to high-velocity impact and explosive detonation. This type of dynamic problem has extreme conditions, including a high temperature, pressure, and strain rate, which often involve localized extreme deformations and failure such as high-speed penetration and explosion driven problems. Considering the special difficulties associated with computer simulation, such as large deformations, interface tracking for multi-materials, and failure or fracture of materials, it is a common concern to develop efficient algorithms with wide applications. Both the Lagrangian and Eulerian methods are well-established techniques for simulating problems of shock hydrodynamics. Lagrangian methods are often implemented in a remap framework to maintain mesh robustness during extreme fluid distortion, whereas Eulerian methods use a fixed mesh and can eliminate distorted meshes caused by interfaces. Lagrangian methods can accurately track the material interface and the algorithm programming implementation is easy. However, the discrete particles will cause numerical oscillation of physical quantities in the process of numerical calculation with large memory and long time consumption.

In this paper, a coupled Eulerian-Lagrangian method is proposed to solve the three-dimensional (3D) numerical analysis of explosion and shock problem. In this method, the Lagrangian particles with a certain volume and influence domain are added to the Eulerian background grids to simulate real material flow, and the bidirectional mapping of physical quantities are achieved by the influence domain-weighted average based on the topological relationship between grids and particles. Consequently, the method can overcomes the Lagrangian particle method numerical fluctuation due to the limited number of particles, and the different materials will not embed because joining the fixed grid and single-valued mapping. The coupled Eulerian-Lagrangian algorithm effectively avoids the defects of Lagrangian method, and maintains its original advantages, thus solving the problem that Euler method is difficult to track the deformation process of multi-material interface accurately. Numerical simulations of typical explosion and impact problems are carried out, and then the numerical results are compared to the corresponding experimental data to verify the effectiveness of the present method. Numerical results show that the coupled method combines the advantages of both Lagrangian and Eulerian method and can efficiently calculate the process of large deformation and dynamic damage of the material.

Keywords: coupled Eulerian-Lagrangian algorithm; explosion and shock; multi-material interface; numerical simulation;

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