High-order Multiphase Flow Numerical Simulation with Pseudo Arc-length Method

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Abstract:

Study of the explosion process of condensed phase explosives has been focused in detonation physics for long. The mechanism of explosion of condensed phase explosives is extremely complicated as a typical multiscale strongly nonlinear problem, including reactive multiphase flow, forming and propagation of strong discontinuity, etc. An appropriate numerical scheme which describes the reaction and strong discontinuity with both enough precision and robustness is required for this problem.

This article studies the numerical simulation of multiphase flow. We build a high-precision finite volume scheme(FVS) with pseudo arc-length method, which helps to catch strong discontinuity and promotes the precision near the wave front. In theory, we extend the unreactive model of multiphase flow to a reactive model by adding reaction source term. In numerical simulation, we consider several popular methods of cell reconstruction and flux computation of FVS. For cell reconstruction, we compare the 2nd order MUSCL and 5th order WENO methods. For flux computation, we study the difference of the ability of keeping flow structures between the Lax-Friedrichs scheme and AUSM-family schemes, part of whose results is shown in Fig.1. Based on the computation results of 1-D and 2-D Riemann problems, we build a multiphase flow FVS in balance between precision and robustness.

Additionally, the pseudo arc-length method(PALM) is utilized in our study of multiphase flow for better simulation of explosion. PALM maps the governing equations in physical space to ones in arc-length space, and simultaneously maps strong discontinuity in physical space to a continuous function, therefore avoids the problem of directly solving strong discontinuity. Based on the arc-length mapping, we can build an appropriate arc-length factor, then solve a moving grid equation by Gauss-Seidel iteration to achieve higher precision near strong discontinuity. Compared to directly refining grid, PALM catches strong discontinuity without much more requirement of storage. We simulate an planar wave generator in practical demand, which validates the ability of catching strong discontinuity of our scheme.

Keywords: multiphase; finite volume method; WENO; numerical flux; pseudo arc-length method