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The Observable Method for the Regularization of Shock-Interface Interactions

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Abstract : This paper presents an inviscid regularization technique that is capable of regularizing the shocks and sharp interfaces simultaneously in the shock-interface interaction simulations. The direct numerical simulation of flows involving shocks has been investigated for many years and a lot of numerical methods were developed to capture the shocks. However, most of these methods rely on the numerical dissipation to regularize the shocks. Moreover, in high Reynolds number flows, the nonlinear terms in hyperbolic Partial Differential Equations (PDE) dominates, constantly generating small scale features. This makes direct numerical simulation of shocks even harder. The same difficulty happens in two-phase flow with sharp interfaces where the nonlinear terms in the governing equations keep sharpening the interfaces to discontinuities. The main idea of the proposed technique is to average out the small scales that is below the resolution (observable scale) of the computational grid by filtering the convective velocity in the nonlinear terms in the governing PDE. This technique is named “observable method” and it results in a set of hyperbolic equations called observable equations, namely, observable Navier-Stokes or Euler equations. The observable method has been applied to the flow simulations involving shocks, turbulence, and two-phase flows, and the results are promising. In the current paper, the observable method is examined on the performance of regularizing shocks and interfaces at the same time in shock-interface interaction problems. Bubble-shock interactions and Richtmyer-Meshkov instability are particularly chosen to be studied. Observable Euler equations will be numerically solved with pseudo-spectral discretization in space and third order Total Variation Diminishing (TVD) Runge Kutta method in time. Results are presented and compared with existing publications. The interface acceleration and deformation and shock reflection are particularly examined.

Keywords : compressible flow simulation, inviscid regularization, Richtmyer-Meshkov instability, shock-bubble interactions.
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