A Composite Riemann Solver for Improving Interface Capturing in Multimaterial Calculations

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ABSTRACT

We consider an Eulerian finite-volume method for numerical calculations of multimaterial fluid flows. The medium to be considered consists of several components with different EOS governed by the Euler equations. The mathematical model of a heterogeneous multiphase fluid with the equilibrium in velocity, pressure, and temperature is used to describe multimaterial dynamics.

Our method belongs to the class of interface capturing methods. Once we use the conventional Godunov method for the flux approximation based on the exact or approximate Riemann solver the method looks as a diffuse interface one. It means that the interface between different materials is represented by a set of mixed cells occupied by the heterogeneous mixture of the components. A drawback of the method is that the interface is numerically smeared within from ten to hundreds computational cells, and its exact position in space is lost.

Another drawback is revealed in calculations of the flow of condensed and gaseous materials with rarefaction waves. The problem is that the EOSs in this case are quite different and admit different regions of thermodynamic parameters. Solids admit negative pressure while the gaseous phase not. Because of the equilibrium, the pressure in mixed cells should be always positive. This leads to an artificial numerical effect that we name as pseudo-fracture. It develops as a small region of mixed cells near the pure solid region where the solid volume fraction drastically decreases.

In order to fix these drawbacks one can sharpen smeared interfaces by implementing some techniques commonly referred to as anti-diffusive. We suggest an alternative way that is based on a numerical flux approximation that takes into account the position of the interface in mixed cells or in other words the material sub-cell structure. In doing so, we come to an extended formulation of the Riemann problem that accounts along with the initial discontinuity also the contact one located apart[1]. We name this formulation as Composite Riemann Problem (CRP). The solution of the CRP provides more accurate approximation of the numerical flux in mixed cells. We demonstrate numerical results that show that the CRP technique allows us to reduce the mixed zone to only one computational cell in 1D calculations and a few cells for multidimensional problems.

References

[1] I. Menshov and P. Zakharov, “On the composite Riemann problem for multi-material fluid flows”, *International Journal for Numerical Methods in Fluids*, 76(2), pp. 109-127, 2014.