11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

SHARP INTERFACE RESOLUTION IN COMPRESSIBLE TWO-PHASE FLOW BASED ON DISCONTINUOUS GALERKIN SCHEMES

Stefan Fechter[1], Christoph Zeiler[2], Claus-Dieter Munz[3] and Christian Rohde[4]

[1] Institute for Aerodynamics and Gas Dynamics, Pfaffenwaldring 21, 70569 Stuttgart, Germany, www.iag.uni-stuttgart.de, stefan.fechter@iag.uni-stuttgart.de
[2] Institute for Applied Analysis and Numerical Simulation, Pfaffenwaldring 57, 70569 Stuttgart, Germany, www.iag.uni-stuttgart.de, christoph.zeiler@mathematik.uni-stuttgart.de
[3] Institute for Aerodynamics and Gas Dynamics, Pfaffenwaldring 21, 70569 Stuttgart, Germany, www.iag.uni-stuttgart.de, munz@iag.uni-stuttgart.de
[4] Institute for Applied Analysis and Numerical Simulation, Pfaffenwaldring 57, 70569 Stuttgart, Germany, www.iag.uni-stuttgart.de, christian.rohde@mathematik.uni-stuttgart.de

Key words: *CFD, compressible multi-phase flow*

In many scientific and industrial applications the commonly used approximation of an incompressible multi-phase flow field is not longer valid as the flow encounters high temperatures and/or pressures. Examples for such extreme ambient conditions can be found in rocket engines as well as in modern diesel injection systems. However, the simulation of compressible multiphase flows introduces a couple of additional difficulties compared to the incompressible treatment. These difficulties include an accurate description of the equation of state (EOS) for the fluid and the thermodynamic consistent resolution of the interface taking into account surface tension and phase transition.

We describe in this paper the different building blocks in the construction of two-phase flow solver that is based on a discontinuous Galerkin approach. A sharp interface resolution is proposed that allows for a complete separation of both bulk phases. Hence, the building blocks are a compressible flow solver for a real EOS, an interface tracking algorithm, and the coupling of both. The sharp interface resolution is established by tracking the geometry and its temporal evolution by a level-set approach as it is introduced by [1]. Interface jump conditions are provided by a Riemann based solver [2, 3], which takes into account the phase change as well as the interfacial physics. Here, the Riemann solver takes into account information from the micro-scale to define an appropriate solution for the Riemann problem with a phase change. The coupling of the compressible flow solver and the interface treatment is then based on a ghost fluid approach.

For both, the approximation of the level-set equation as well as the fluid variables, we rely on a discontinuous Galerkin spectral element method [4]. We usually use fourth order

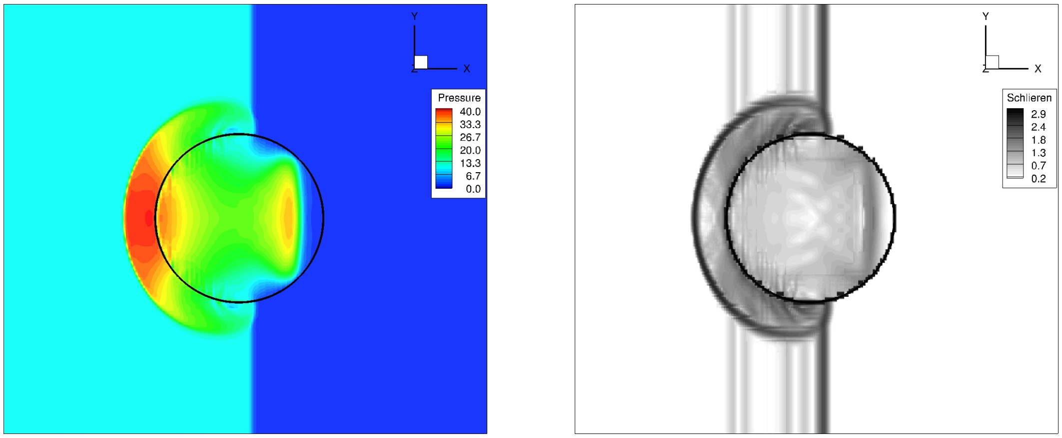

Figure 1: Shock-Droplet interaction with a bubble at $t = 2\mu s$: Left: pressure contours; Right: Schlieren-type image for density.

of accuracy, which allows for the level-set function that the interface curvature can be directly evaluated from the approximation. Near the interface we switch from the coarse grid cell with the high order approximation to a sub-cell arrangement with a piecewise linear approximation. The number of degrees of freedoms remain the same. Within the bulk phases a standard approximate Riemann solver is applied. Due to the ghost fluid method the whole scheme does not guarantee conservativity exactly, but allows the sharp interface resolution on a grid fixed in space and time.

The method has been successfully validated for three-dimensional test cases using the ideal gas law for the gaseous phase and the weakly compressible Tait EOS for the liquid phase. The effects of parasitic currents is assessed simulating a steady bubble at equilibrium with surface tension effects. The transient behavior of the surface tension forces is investigated by a deflected elliptical droplet. In addition, we present a 3D interaction between a planar shock and a spherical droplet, which shows the typical shock reflections and deformations in- and outside the droplet.

REFERENCES

[1] Mark Sussman, Peter Smereka, and Stanley Osher. A Level Set Approach for Computing Solutions to Incompressible Two-Phase Flow. *Journal of Computational Physics*, Vol. 114, 146–159, 1994.

[2] S. Fechter, F. Jaegle, and V. Schleper. Exact and approximate Riemann solvers at phase boundaries. *Computers & Fluids*, Vol. 75, 112–126, 2013.

[3] X. Y. Hu, N. A. Adams, and G. Iaccarino. On the HLLC Riemann solver for interface interaction in compressible multi-fluid flow. *J. Comput. Phys.*, Vol. 228, 6572–6589, 2009.

[4] D. A. Kopriva. *Spectral Element Methods*. Implementing Spectral Methods for Partial Differential Equations, 293–354, 2009.