Diffuse interfaces and nucleate boiling flows

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Abstract

Diffuse interfaces are a consequence of numerical diffusion at contact discontinuities separating various materials. They appear with any Eulerian hyperbolic solver and result in computational mixture cells. This has serious consequences on the thermodynamic state computation as the equations of state of the fluids in contact are discontinuous. To circumvent this difficulty artificial mixture cells were considered as true multiphase mixtures with stiff mechanical relaxation effects (Saurel and Abgrall, 1999). This method was simplified by Kapila et al. (2001) with the help of asymptotic analysis, resulting in a single velocity, single pressure but multi-temperature flow model. This model present serious difficulties for its numerical resolution, as one of the equations is non-conservative, but is an excellent candidate to solve mixture cells as well as pure fluids.

In the present talk, modeling extensions with capillary (Perigaud and Saurel, 2005) and phase transition effects (Saurel et al., 2008) are addressed. With this approach, capillary effects are modeled through a conservative formulation that avoids to resolve spatially the interface, the jump conditions being inherent features of the model. Numerical issues in the frame of explicit hyperbolic solvers are addressed and solved with the help of an extended over determined system (Saurel et al., 2009).

This method is then extended to low Mach number flow conditions following Turkel (1987) and Guillard and Viozat (1999) approaches. The accuracy of corresponding method is demonstrated on two-phase nozzle flows problems having exact solutions. Then, multidimensional computations are compared under experiments of cavitating flows in Venturi nozzles, showing excellent agreement, without having recourse to any model parameter (Le Martelot et al., 2013).

Last, the various modeling ingredients (capillarity, heat conduction and Gibbs free energy relaxation) as well as low Mach preconditioning are coupled to deal with the direct numerical simulation of boiling flows. Multidimensional computations are shown, showing method capabilities.

Guillard, H. and Viozat, C. (1999) On the behaviour of upwind schemes in the low Mach number limit., Computers and Fluids 28, 63-86.

Kapila A., Menikoff R., Bdzil J., Son S., Stewart D. (2001) Two-phase modeling of DDT in granular materials: reduced equations, Physics of Fluids, 13, pp. 3002-3024

Le Martelot, S., Nkonga, B. and Saurel, R. (2013) Liquid and liquid-gas flows at all speeds. Journal of Computational Physics, in revision

Perigaud G., Saurel R. (2005) A compressible flow model with capillary effects. Journal of Computational Physics, 209, pp. 139-178

Saurel R. and Abgrall R. (1999) A multiphase Godunov method for compressible multifluid and multiphase flows. Journal of Computational Physics, 150, pp 425-467

Saurel R., Petitpas F., Abgrall R. (2008), Modelling phase transition in metastable liquids. Application to cavitating and flashing flows, Journal of Fluid Mechanics, 607: 313-350

Saurel R., Petitpas F. and Berry R.A. (2009) Simple and efficient relaxation methods for interfaces separating compressible fluids, cavitating flows and shocks in multiphase mixtures. Journal of Computational Physics 228, pp 1678-1712

Turkel, E. (1987) Preconditioned methods for solving the incompressible and low speed compressible equations. Journal of Computational Physics 72 (2), 277-298.