A hyperbolic system for metastable phase transition

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ABSTRACT

A hyperbolic two-phase flow model involving five partial differential equations is built for liquid-gas interface modeling. The model is able to deal with interfaces of simple contact where normal velocity and pressure are continuous as well as transition fronts where heat and mass transfer occur, involving pressure, temperature and velocity jumps. The model involves two temperatures and entropies but a single pressure and a single velocity. The closure is achieved by two equations of state that reproduce the phase diagram when equilibrium is reached. Relaxation toward equilibrium is achieved by temperature and chemical potential relaxation terms whose kinetics is considered infinitely fast only at specific locations, typically at evaporation fronts. Doing so, metastable states are involved for locations far from these fronts. Temperature and chemical potentials relaxation result in appearance of two extra waves, corresponding to phase transition fronts. Thus, the hyperbolic system involves five waves. The two fastest waves correspond to acoustic or shock precursors that produce metastable states. The contact wave plays a conventional role. The two intermediate waves correspond to evaporation or condensation fronts. Their speeds correspond to the eigenvalues of the relaxed system. It follows that the Chapman-Jouguet kinetic relation for evaporation fronts proposed by Moreira and Sheperd (1999) appears as an eigenvalue of the present hyperbolic system. This model thus provides a justification to this kinetic relation and provides an interpretation of the evaporation wave structure in cavitating systems: Evaporation fronts are expansion fans of the relaxed system.

Specific numerical hyperbolic and relaxation solvers are built to solve the non-conservative hyperbolic system (Saurel et al., 2006). Computational tests are done in 1D and 2D and validated against experimental measurements.

Saurel, R., Franquet, E., Daniel, E. and Le Metayer, O. (2006) A relaxation-projection
method for compressible flows. Part 1: The numerical equation of state for the
Euler equations. Journal of Computational Physics, in revision

Simões-Moreira, J.R. and Shepherd, J.E. (1999) Evaporation waves in superheated dodecane. Journal of Fluid Mechanics, 382, pp 63-86