A two-phase numerical model for liquid-vapor flows with arbitrary heat and mass transfer relaxation times

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We describe liquid-vapor flows by a hyperbolic single-velocity six-equation two-phase compressible flow model with relaxation source terms accounting for volume, heat and mass transfer [2]. The system of equations is numerically solved by a classical fractional step algorithm, where we alternate between the solution of the homogeneous hyperbolic portion of the model system via a second-order accurate HLLC/Suliciu-type finite volume scheme, and the solution of a sequence of systems of ordinary differential equations for the relaxation source terms driving the flow toward mechanical, thermal and chemical equilibrium. For an accurate description of the thermodynamical processes involved in transient liquid-vapor flow problems it is often important to be able to simulate both instantaneous and finite-rate relaxation processes. For instance, in some phenomena such as fast depressurizations the delay of vaporization and the appearance of metastable states are key features in the flow dynamics [1]. In the present work we present new numerical relaxation procedures to integrate interphase transfer terms with two significant properties : the capability to describe heat and mass transfer processes with arbitrary relaxation time, and the applicability to a general equation of state. The main idea is to describe relaxation processes by systems of ordinary differential equations that admit analytical semi-exact exponential solutions. For instantaneous processes we show the capability of the numerical model to approximate efficiently solutions to the relaxed two-phase flow models that can be established theoretically from the parent six-equation model in the limit of instantaneous equilibria. Several numerical tests are then presented to show the effectiveness in modeling finite-rate heat and mass transfer, including simulations of depressurizations leading to metastable superheated liquid.

[1] M. De Lorenzo, P. Lafon, M. D. Matteo, M. Pelanti, J.-M. Seynhaeve, Y. Bartosiewicz. *Homogeneous two-phase flow models and accurate steam-water table look-up method for fast transient simulations.* Int. J. Multiphase Flow, **95**, 199–219, 2017.

[2] M. Pelanti, K.-M. Shyue. *A mixture-energy-consistent six-equation two-phase numerical model for fluids with interfaces, cavitation and evaporation waves.* J. Comput. Phys., **259**, 331–357, 2014.

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