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Non-instantaneous relaxation procedures with arbitrary equation of state for modeling liquid-vapor flows with phase transition

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We describe liquid-vapor flows by a single-velocity six-equation compressible two-phase flow model, which is composed of the phasic mass and total energy equations for the two phases, one volume fraction equation, and the mixture momentum equation [1]. The model contains relaxation source terms accounting for volume, heat and mass transfer. The system of equations is numerically solved via 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-type finite volume scheme, and the solution of a sequence of three systems of ordinary differential equations for the relaxation source terms driving the flow toward mechanical, thermal and chemical equilibrium. In the literature often relaxation procedures are based on simplifying assumptions, namely simple equations of state, such as the stiffened gas one, and instantaneous relaxation processes. These simplifications of the flow physics, which were also assumed in our previous work [1], are useful to easily conceive efficient and robust numerical methods. Nonetheless, they might be inadequate for a precise description of the thermodynamical processes involved in various flow problems. For instance, in some transient phenomena such as fast depressurizations, the delay of vaporization and the appearance of metastable states are key features for the description of the flow evolution [2, 3]. In the present work we introduce innovative numerical relaxation procedures to integrate phase transfer terms, which are endowed with two significant features: they can describe finite-rate relaxation processes, and they can handle arbitrary equations of state. We present several numerical simulations of evaporation and condensation problems, including tests with the IAPWS-IF97 equation of state, which show the effectiveness of the proposed numerical phase transition model.

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