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Potentials and limitations of equilibrium single-fluid models for prediction of cavitating flows

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Flow-induced evaporation of liquid results in the formation of vapor structures including clusters of vapor bubbles, cavitating vortex cores and clear sheet cavities [1]. Provided that the thermodynamic conditions are sufficiently below critical states, density ratios of $\rho_{liquid}/\rho_{vapor} = 10^2 - 10^5$ occur, thus several flow properties, such as the compressibility and the equilibrium speed of sound, are strongly affected. Furthermore, intense shock waves due to collapse-like recondensation of vapor structures may lead to material damage [2].

In this investigation, we discuss potentials and limitations of two straightforward thermodynamic models for the simulation of cavitating flows including shock formation and wave propagation. Both models are based on the homogeneous mixture assumption and pursue a single-fluid approach. The first model is a barotropic state description, where the energy balance is neglected. The second includes thermal effects by taking the energy balance into account. Both models can be applied via closed-form equations of state or in tabulated form.

We present a series of simulations including hydrofoil-cavitation, prediction of erosion endangered areas in nozzle-target flow, high speed flows in micro-channels, low speed flow in a water tunnel and the collapse of a cluster of vapor bubbles. It is concluded that the overall dynamics of sheet, cloud and vortex cavitation are equally well predictable by both models.

In case of a collapsing cluster of vapor bubbles, we observe nearly grid-independent wall loads, which is a critical feature necessary for predicting erosion endangered areas in engineering applications.

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