Thermal and Inertial Equilibrium in Small, High-Speed, Cavitating Nozzle Simulations

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Abstract

The construction of any simulation of cavitating injector nozzles begins with the fundamental assumptions of which phenomena will be included and which will be neglected. To date, there has been no consensus about whether it is acceptable to assume that small, high speed cavitating nozzles are in thermal or inertial equilibrium. This diversity of opinions leads to a variety of modeling approaches. If one assumes that the nozzle is in thermal equilibrium, then there is presumably no significant delay in bubble growth or collapse due to heat transfer. Heat transfer is infinitely fast and phase change is limited by inertial effects. The assumption of inertial equilibrium means that the two phases have negligible slip velocity. Alternatively, on the sub-grid scale level, one may also consider the possibility of small bubbles whose size responds to changes in pressure. The present work uses experimental results collected from the open literature to evaluate assumptions that have been used in previous modeling results. Multidimensional CFD results that assume thermal equilibrium and non-thermal equilibrium are used to further evaluate these particular assumptions with plain orifice injector nozzles. The results indicate that equilibrium assumptions are sufficient to predict mass flow rate and cavitation incidence in small, high-speed nozzle flows. Effects of thermal non-equilibrium are not evident in experimental measurements of mass flow rate.

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