Level-set based numerical simulation of vapor bubble motion in acoustic fields

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Abstract

Vapor bubble motion in acoustic fields is an important phenomenon in various medical diagnostic and therapeutic applications. However, its general predictive model has not yet been developed due to the complexity of the liquid-vapor interfacial phenomena including the effects of compressibility and phase change.

Recently, numerical simulations of compressible bubble motion were performed using a level-set (LS) method, a front-tracking method and the volume-of-fluid method. However, the numerical methods were limited to the bubble motion without phase change. Computations were also reported for bubble motion with phase change, but they were not extended to the compressible cases.

In this work, the LS method for tracking incompressible two-phase flows is extended to include the effects of compressibility and phase change by incorporating the ghost fluid method to efficiently implement the matching conditions of velocity, stress and temperature at the interface. The semi-implicit pressure correction formulation is implemented into the LS method to avoid the serous time step restriction in compressible flows.

The present numerical method is validated through computations of one-dimensional compressible single-phase and two-phase flows, whose analytical solutions are available. The bubble motion under a periodic pressure wave condition is observed to be significantly amplified in the compressible liquid condition. Computations are extended for bubble growth in acoustic droplet vaporization (ADV) including two LS functions for the liquid-vapor and liquid-liquid interfaces. The effects of acoustic wave and ambient temperature on the vaporization of a volatile droplet immersed in liquid water are investigated.

Keywords: Acoustic, Bubble, Level-set method, Phase change.