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# Homogeneous Gas-Liquid Two-Phase Flow Model and Shock-Cavitation Bubble Interaction Problems

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## ABSTRACT

A numerical method for gas-liquid multi-phase flow such as cavitating flow with variable density is applied to solve shock-bubble interaction problems. Recently, these problems have become an important consideration in the medical field where the application of ultrasound, shock waves. The present method employs a finite-difference Runge-Kutta method and Roe's flux difference splitting approximation with the MUSCL-TVD scheme. A homogeneous equilibrium gas-liquid multi-phase model taken account of the compressibility of mixed media is used. Therefore, the present density-based numerical method permits simple treatment of the whole gas-liquid mixed flow field, including wave propagation, large density changes and incompressible flow characteristics at low Mach number. By applying this method, firstly a Riemann problem for Euler equations of one dimensional shock tube was computed for validation. Then, shock-bubble interaction problems between cylindrical single- or multi-cavitation bubbles located in the liquid with/without solid wall and incident liquid shock wave are computed. Bubble collapsing behavior, shock-bubble and bubble-bubble interaction, shock transmission /reflection pattern are investigated.

Cavitation is a phase change phenomenon accompanying the appearance of vapor bubbles inside a homogeneous liquid medium that occurs in the domain below vapor pressure according to the decrease in local pressure when fluid devices move at high speed in a working fluid in the liquid state. Cavitation takes various forms according to the flow conditions, and causes noise, vibration and damage, as well as reduced performance in hydraulic machine systems [1] when cavitation bubbles unexpectedly attach and collapse on body surfaces. Therefore, in order to reduce these unfavorable effects, technology for accurate prediction and estimation of cavitation are very important in the development of high-speed fluid devices.

In order to clarify and understand the behavior of cavity flow, cavity flow models and analytical methods for numerical simulations have been proposed [2-5], among which, gas-liquid two phase flow approaches that consider homogeneous equilibrium are more advantageous. However, because originally cavity flows have strong unsteady flow phenomena, including phase changes, fluid transients, vortex shedding and turbulence, a numerical method by which to solve these flows has not yet been established. In general, there are few comprehensive applications to the transient flow range from the subcavitation state to the supercavitation state. Recently, present author and co-workers have proposed a mathematical cavity flow model [6-8] based on a homogeneous equilibrium model taking into account the compressibility of the gas-liquid two-phase media. With this model the mechanism of developing cavitation has been investigated through application to cavitating flows around a hydrofoil.

The purpose of this paper is to extend the previous methods [8, 9] to a high-order Runge-Kutta method and MUSCL TVD solution method for stable and accurate treatment of gas-liquid interfaces considered by contact discontinuity, and apply to shock-cavitation bubble interaction problems. As numerical examples, one-dimensional gas-liquid two-phase shock tube problems and two-dimensional shock-bubble interaction problems are computed. Detailed unsteady shock wave phenomena including the propagation of both compression and expansion waves, bubble collapsing behavior, shock-bubble and bubble-bubble interaction, shock transmission/reflection pattern are investigated.

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