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Two-Phase Flow Analysis on the Occurrence of the Liquid Jet into a Bubble in a Convergent Divergent Channel

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ABSTRACT

Bubble breakup can be observed when a single bubble passes through the throat of a convergent divergent channel, which is used as a device to make micro bubbles. It was found in the experiments that the liquid jet is occurred impulsively and it penetrates a bubble, which results in the bubble breakup.[1] The detailed mechanism why the liquid jet is caused has been not clarified by experimental observations. Numerical analysis for two-phase flow has been conducted in order to explain the bubble breakup phenomena in a convergent divergent channel. In this paper, the results are shown and the mechanism is clearly explained.

The governing equations used in the present work are based on the homogeneous two-phase flow and consist of Navier-Stokes equations in non-conservative form, advection equation of color function for interface tracking and equation of state.

$$\frac{\partial}{\partial t}\rho + \vec{u}\cdot\nabla\rho = -\rho\nabla\cdot\vec{u} \tag{1}$$

$$\rho\frac{\partial}{\partial t}\vec{u} + \rho\vec{u}\cdot\nabla\vec{u} = -\nabla p + \nabla\cdot\boldsymbol{\tau} \tag{2}$$

$$\rho c_v\frac{\partial}{\partial t}T + \rho c_v\vec{u}\cdot\nabla T = -T\left(\frac{\partial p}{\partial T}\right)_\rho \nabla\cdot\vec{u} + \Phi + \nabla\cdot\left(\lambda\nabla T\right) \tag{3}$$

$$\frac{\partial}{\partial t}\phi + \vec{u}\cdot\nabla\phi = 0 \quad (4)$$

$$dp = \left(\frac{\partial p}{\partial \rho}\right)_T d\rho + \left(\frac{\partial p}{\partial T}\right)_\rho dT \quad (5)$$

The equations are split into the three stages of advection phase, diffusion phase and acoustic phase by a time splitting technique. Advection equations are solved firstly by the CIP method[2] which has proven less diffusive and stable. Equations in the acoustic phase are solved by the CUP method[2] at the last stage. In the CUP method the pressure is predicted implicitly and restrictions on the time step attributed to fast acoustic velocity is reduced.

The time evolutions of the numerical results are shown in Fig. 1. The bubble break up phenomena is successfully simulated and results agree well with the experimental one.[1] When a bubble reaches the throat (2.74msec in Fig. 1), the bubble shape becomes like a raindrop which is round at the front and pointed at the backward. Then the liquid jet is generated impulsively from the tail of the bubble. The instantaneous pressure distribution is illustrated in Fig. 2, in which the reason why the liquid jet is occurred is highlighted. It can be seen that the steep gradient of the pressure near the tail of the bubble makes the liquid jet. This results from the concentration of the pressure difference on the backward of the bubble and the convergence of the flow to the tail of the bubble as the bubble shape becomes long in the flow direction.

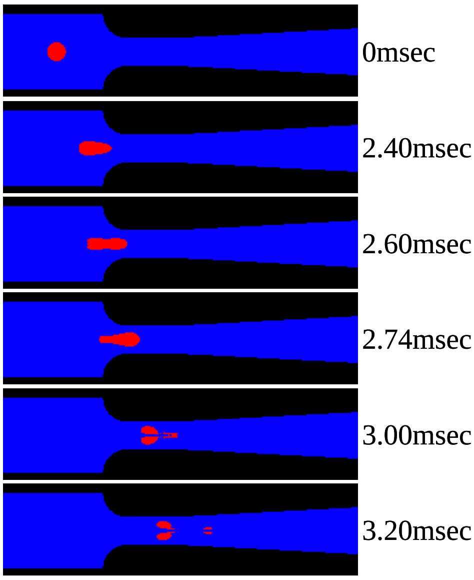

Fig. 1. The time evolution of the bubble breakup.

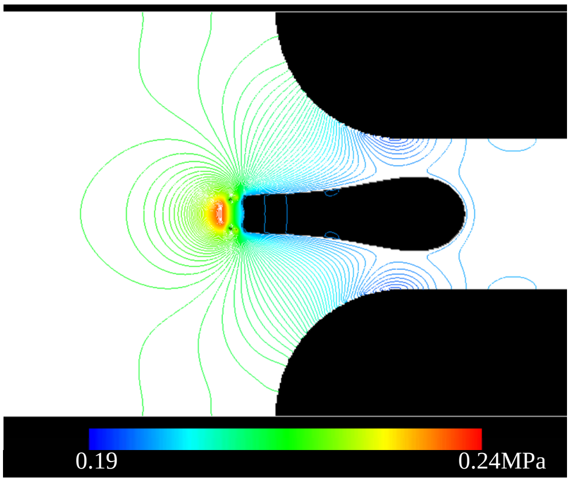

Fig. 2. Instantaneous pressure ditribution at the time of 2.74msec.

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