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Relative Velocity between Micro-Bubbles and Liquid in a Microchannel

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Extended Abstract

Gas-liquid two-phase flows in microchannels are frequently observed in micro-TAS and microreactors. Although many studies have been conducted on Taylor bubble flow and annular flow in microchannels, there are few studies on microbubble flow in the microchannels. Microbubbles are characterized by large specific interfacial area and therefore expected to realize high mass transfer rate between gas and liquid phases. The relative velocity between microbubbles and liquid is, however, quite low and it reduces the mass transfer rate. Kamp et al. [1] and Tomiyama et al. [2] pointed out that the relative velocity occurs due to not only buoyancy force but also pressure gradient. This implies that the relative velocity between microbubbles and liquid in a microchannel might be enhanced by the pressure gradient in the channel. However, there is few studies on the relative velocity between microbubbles and liquid in a microchannel. In this study, we, therefore, experimentally investigated the relative velocity between microbubbles and liquid flow in a microchannel.

The experiments were conducted for microbubbles (diameter: d = 50 – 370 μm) in a horizontal microchannel (inner diameter: D = 500 μm). A PFA tube (refractive index: 1.35) was used for the microchannel and it placed in a rectangular cell filled by water (refractive index: 1.33) to reduce the optical distortion induced by the difference in refractive index. A mirror was placed in the side of the tube to observe the front and side view of the flow simultaneously. The bubble images through a microscope (Nikon, SMZ25) were recorded by a high-speed camera (Photron, FASTCAM Mini WX-100). The bubble position, diameter and velocity were evaluated by an image processing method based on the Hough transfer and the optical flow. The liquid velocity was evaluated based on the theoretical parabolic profile and the volume flow rate measured by using a graduated cylinder and a stopwatch.

The experimental result shows that the relative velocity does not vanish in the microchannel due to the pressure gradient in the microchannel caused by the friction loss at the wall. The magnitude of relative velocity of small microbubbles (d/D < 0.125) is comparable to the value proposed by Tomiyama et al. [2]. The relative velocity of lager microbubbles (d/D > 0.125) decreases as the bubble diameter increases due to bubble-wall interaction [3], and the bubble position locates upper region of the pipe cross-section due to the buoyancy effect in spite of the small Bond number as Cranmer et al. [4] pointed out. The relative velocity of large bubble (d/D > 0.5) reaches to 1.2 times the averaged liquid velocity, which is correspond to the Taylor bubble velocity in a microchannel [5].

References

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