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気泡流における気泡粗密波形成の支配要因
Development process and controlling factors of bubble waves in bubbly flow

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The hydrodynamic behavior of a two-phase system is investigated by an analog experiment. Bubbly flows with spatially periodic distribution of bubbles are sometimes observed in various natural situations such as in the conduit and lava flow. For instance, the early stage of the 1986 fire fountain eruptions of the Izu-Oshima volcano had the continuous magma effusion with a rhythm of mean period about 5s. This suggests the inhomogeneous distribution of bubbles in the conduit. The similar structure of bubble distributions is observed in a glass of Guinness beer. The bubbles are distributed nearly uniformly at the moment Guinness beer is poured, and quickly form layers or waves which appear to propagate downward. Unfortunately, Guinness is not appropriate for scientific experiment because of difficulties to control parameters (e.g. volume fraction and radii of bubbles), formation and dissolution of bubbles, and poor reproducibility of initial conditions such as pouring condition. We therefore conducted an analog experiment using the special liquid and the hollow glass particles as analog materials of a beer liquid and bubbles, respectively, presuming that the bubble waves in Guinness form by the relative motion of bubbles to liquid by buoyancy, but not by the formation and dissolution processes. We mixed the liquid and the particles in cylindrical test tube by gently shaking the test tube. The bubble segregation or relative upward migration of bubbles starts from the homogenous mixture as an initial state just after stopping shaking. We found that under some conditions, the bubble waves form during the upward segregation of bubbles. In order to constrain factors for the formation of bubble waves, we conducted the series of experiments with varying the volume fractions, sizes of bubbles and the inclination of a test tube. We found that the bubble waves formed only when we incline the test tube, and when volume fractions of the particles are less than approximately 30 %. If we settled the test tubes vertically, the bubble waves didn’t form. On the other hand, when we inclined the test tubes, we observed that the circulatory current of the particles directed upwards near the inter surface at higher wall of the test tube and downwards near the lower wall of it. The wave like structure of the particles with the wave length about 10-20 mm and the horizontal width about ˜5 mm developed near the lower wall of the inclined test tube. The wave length and the horizontal width of bubble waves were inversely proportional to the inclined angle of the test tube and the volume fraction of the particles. We propose the formation mechanism of bubble waves on the basis of the Kelvin-Helmholtz instability which develops at the thin boundary layer formed near the lower wall, where the downward bubble-poor and overlaid upward bubble-rich layers contact each other.
Keywords: bubbly flow, inhomogeneous distribution of bubbles, analog experiment