Bubble Generation in a Continuous Liquid Flow Under Reduced Gravity Conditions

The present work reports a study of bubble generation under reduced gravity conditions for both co-flow and cross-flow configurations. Experiments were performed aboard the DC-9 Reduced Gravity Aircraft at NASA Glenn Research Center, using an air-water system. Three different flow tube diameters were used: 1.27, 1.9, and 2.54 cm. Two different ratios of air injection nozzle to tube diameters were considered: 0.1 and 0.2. Gas and liquid volumetric flow rates were varied from 10 to 200 ml/s. It was experimentally observed that with increasing superficial liquid velocity, the bubbles generated decreased in size. The bubble diameter was shown to increase with increasing air injection nozzle diameters. As the tube diameter was increased, the size of the detached bubbles increased. Likewise, as the superficial liquid velocity was increased, the frequency of bubble formation increased and thus the time to detach forming bubbles decreased. Independent of the flow configuration (for either single nozzle or multiple nozzle gas injection), void fraction and hence flow regime transition can be controlled in a somewhat precise manner by solely varying the gas and liquid volumetric flow rates. On the other hand, it is observed that uniformity of bubble size can be controlled more accurately by using single nozzle gas injection than by using multiple port injection, since this latter system gives rise to unpredictable coalescence of adjacent bubbles. A theoretical model, based on an overall force balance, is employed to study single bubble generation in the dynamic and bubbly flow regime. Under conditions of reduced gravity, the gas momentum flux enhances bubble detachment; however, the surface tension forces at the nozzle tip inhibits bubble detachment. Liquid drag and inertia can act either as attaching or detaching force, depending on the relative velocity of the bubble with respect to the surrounding liquid. Predictions of the theoretical model compare well with performed experiments. However, at higher superficial,liquid velocities, the bubble neck length begins to significantly deviate from the value of the air injection nozzle diameter and thus the theory no longer predicts the experiment behavior. Effects of fluid properties, injection geometry and flow conditions on generated bubble size are investigated using the theoretical model. It is shown that bubble diameter is larger in a reduced gravity environment than in a normal gravity environment at similar flow condition and flow geometry.

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