Transport Phenomena of the Two-Phase Flow Parameters in Adiabatic Bubbly and Slug Flow Conditions

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1. Introduction

A flow regime map has been utilized for the models related to the energy and momentum transfer of a two-phase flow. Since most of the models are not based on the fundamental phenomenological mechanisms, they sometimes have limitations for an application to the general flow conditions and flow regime transition region. To improve the modeling strategy, studies for the interfacial area transport are being performed to reduce or eliminate the dependency of the flow regime map. A mechanistic study needs a lot of understanding for the particle interactions and propagation phenomena of a flow. The major particle interaction mechanisms can be characterized by coalescence and breakup in adiabatic condition. [1][2] To investigate the fundamental two-phase flow phenomena and to generate an experimental data base for modeling, an air/water test is performed in this study.

2. Experiments and Results

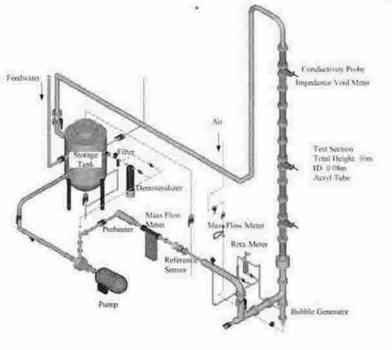
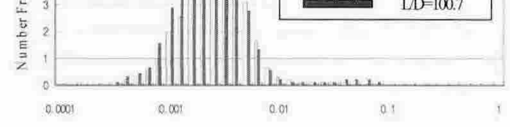


Fig. 1. Air/Water Test Loop

Figure 1 shows the brief configuration of the air/water test facility. The facility has a cylindrical acryl type for the test section of which the diameter and height are 80 mm and 10m, respectively. The local bubble parameters are measured by five-sensor conductivity probes. The main local parameters are void fraction, bubble velocity, bubble frequency, interfacial area concentration and bubble size. To investigate the transport phenomena of the two-phase parameters, the local probe and impedance void meter(IVM) are installed at three axial elevations of the test section. (L/D=12.2, 42.2, 100.7) The test range covers 0.5~2.6 m/s and 0.04~1.2 m/s of the superficial liquid and gas velocity, respectively, which correspond to the bubbly and slug flow regimes. 25 sets of data are generated, which are five void fraction conditions per each of the five liquid mass flow conditions. The local data from the probe are benchmarked by using other instruments for average flow parameters to evaluate the data. The benchmarked parameters are the void fraction, bubble velocity, and superficial gas velocity. The comparisons agreed well within the deviations of 6.1%, 8.1%, and 7.1%. The measured void fractions were also validated with well known drift flux models. The transport phenomena of various channel averaged two-phase parameters, such as the pressure, void fraction and bubble velocity can be analyzed well from the experiment data. The transport of the bubble velocities depends on the buoyancy and drag force. The experimental data shows that the buoyancy force overcomes the drag force as the void fraction increases. The interfacial area concentration can be measured by the five-sensor conductivity probe method for any shape of the interface. The development of the measuring method and its verification are performed by Euh et al.(2004a, b) The bubble size can be obtained from the measured void fraction and the interfacial area concentration by the following formula.

$$D_{sm} = \frac{6\alpha}{a_i} \quad (1)$$

Figure 2 shows the transport of the bubble size distribution for various flow conditions. Although the distribution is not for a bubble diameter but for a chord length, the chord length distribution can approximate that of the bubble size distribution. For low flow conditions, the coalescence phenomenon is expected to be dominant than the breakup since the turbulent intensity is small. However, if the cap bubbles appear, significant turbulence can occur at the rear side of the large bubbles. Since the tail of the cap bubble has a weak surface tension, a lot of small bubbles can be generated from the breakup of the cap bubble. This mechanism can be broadly included into the shearing off phenomena. Figures 2(a) and (b) show the transport of the bubble size distributions for the low flow/low void fraction and low flow/high void fraction conditions, respectively. The figures show that the larger bubbles are generated mainly due to the wakeup entrainment as the flow ascends. However, even in the low flow condition, the bubble number frequency is increased, which illustrates that breakup is also a major interaction mechanism. The fact that the increasing rate of the bubble frequency is larger for the large bubble conditions is evidence that the breakup mechanism is mainly due to the shearing off from the cap bubbles. The wake entrainment effect is also shown in the high void fraction of the high flow conditions although the degree is small. Since the breakup effect is large for the high flow conditions, the bubble number frequency is significantly increased as the flow ascends.(see figure 2(c) and (d)). Most of the generated data consistently shows the above trend.



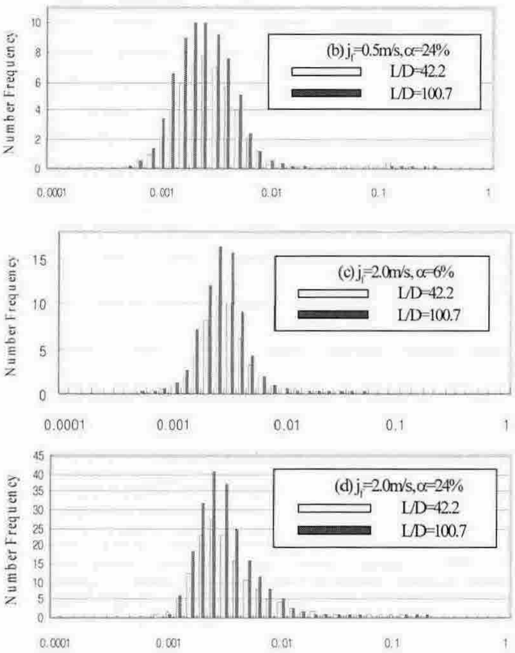


Fig. 2. Transport of Bubble Chord Length Distribution

Figure 3 shows the average bubble size and the cap bubble size for the four test conditions of figure 2. The division criterion of the cap bubble and the small bubble is set to be 7.2mm of the chord length based on the previous study. The figure shows that although the cap bubble size consistently increased for the low flow conditions, the average bubble size of the high void fraction condition is reduced as the flow ascends. This is due to the bubble breakup from the cap bubble. For the high flow conditions, the average bubble size is reduced along the channel due to the breakup effect. The characteristics of average bubble size transport are more explainable if one considers the size distribution function.

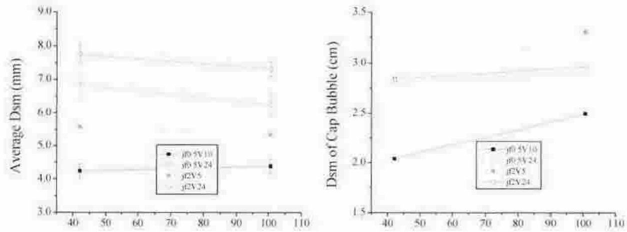


Fig. 3. Transport of Average Bubble Size

3. Conclusion

By using the five-sensor conductivity probe, various local bubble parameters were measured and the local data were benchmarked with the channel averaged data from the other instruments. The transport phenomena of the two-phase flow parameters and the major particle interaction mechanisms were investigated in a long air/water test facility. The data produced in this study could be effectively utilized in the development of the interfacial area transport theory.

Acknowledgement

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