Air-Water Two-phase Vertical Upward Flow Regime Identification with Cross-sectional Phase Distribution

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1. Introduction

To study two-phase flow is so crucial. Since many engineering fields such as the nuclear power plant are related to its safety. In order to understand phenomena of the two-phase flow, identification of two-phase flow regime and characteristics have to be understood.

Flow regime affects the mass transfer such as heat transfer or evaporation/condensation. Therefore it is very useful to predict the flow regimes if flow condition is given. Traditionally, flow regime identification is classified through result of its experiments. Lots of flow regime maps are designed with dimensional coordinate based on superficial velocities.

In this study verify the vertical upward flow regime based on theoretical models [5,6].

2. Experiment

2.1 Vertical Loop

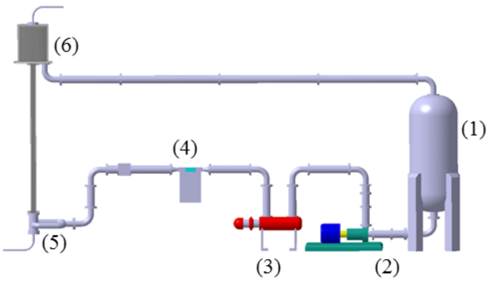

Fig. 3 Vertical test loop

According to the Fig. 3, the water flow (1) to (6) in regular sequence. The inner diameter of the vertical tube is 30 mm and total pipe length is 3360 mm. The shooting section is about 2300 mm from the inlet and wire-mesh sensor locates the 2800 mm from the inlet.

2.2 Description of wire-mesh sensor

The sensor consists of four layers of wire grids with 16 wires each of 0.125 mm diameter. The distance of between wires is 1.875 mm. The distance between the two planes is 1.1 mm. The wire-mesh sensor utilized to obtain cross-sectional phase distribution for slug flow regime. Since the slug flow is one of the stable flow in the vertical regime.

The operating principle is following, briefly. One layer of electrodes is utilized as a transmitter, the other as a receiver layer. Electrical current is applied by the transmitter. The receiver layer measures electrical current. Amplifier changes from current to voltage and sampled in the circuit. Data acquisition computer which is connected to AD converters recorded signal. Final procedure is saved data of the each receiver electrodes [2]. More detailed operating principle of wire-mesh sensor refers Prasser's paper [2,3,4].

2.3 High-speed Camera

For visual observations of flow regimes, a high-speed camera which has been manufactured by Photron, and can monitor two-phase flow in the maximum 500,000 fps has been adopted. This high-speed camera has been located at the point roughly 2300 mm away from the entrance.

3. Results

It could be confirmed during the experiment. Thus, slug (○) flow would be found both of low flow rate. If the superficial gas velocity high, the churn flow (□) take place with flooding. For high superficial velocity of water, dispersed finely bubble (◇) flow occurs in the pipe, if high superficial liquid velocity cause the turbulent force enough to break up the bubbles. The superficial gas velocity is very important parameter determining the onset of annular flow (▽). All of this presented Fig. 6. The continuous line and dotted line constructed by the theoretical models [5,6].

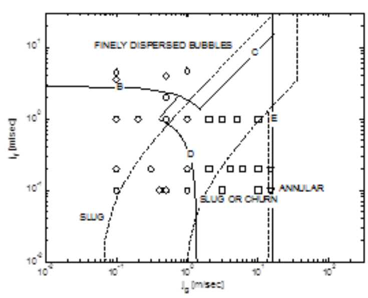

Fig. 6 Test result on the Vertical flow regime

Figs. 7 and 8 presented experimental result. All of them had a same liquid flow condition, but they had a different gas flow condition. It is easily figured out the difference. Figs. 7 showed the Taylor bubble. Fig. 8 could found the chaotic because of flooding condition [1]. Thus, regime of Fig.8 is churn flow. Experimentally, flooding can observed over 2 m/s on superficial gas velocity condition.

Fig. 7 Slug flow for $j_g = 0.2$ m/s, $j_f = 1.0$ m/s

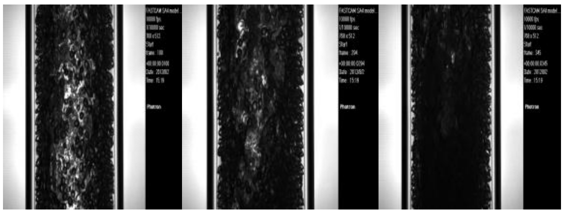

Fig. 8 Churn flow for $j_g = 5.0$ m/s, $j_f = 1.0$ m/s

Figs. 9 and 10 showed experimental results for fixed the superficial gas velocity and changing the superficial liquid velocity. The fixed superficial gas velocity is 0.5 m/s and the superficial liquid velocity increased. The Taylor bubbles of Fig. 9 were very long. They were almost 50 cm long. If the liquid flow rate increases, the bubbles break up due to the turbulent fluctuation. Finally, the pipe was filled with only small bubbles in Fig. 10.

Fig. 9 Slug flow for $j_g = 0.5$ m/s, $j_f = 0.1$ m/s

Fig. 10 Finely bubble flow for $j_g = 0.5$ m/s, $j_f = 4.0$ m/s

Figs. 11 presented the tomographic images of Taylor bubble of each condition. Easily find out the Fig. 16's first image is before pass the Taylor bubble. Second one showed that the Taylor bubble's nose just contacts the wires. The Taylor bubble penetrated the wire-mesh sensor.

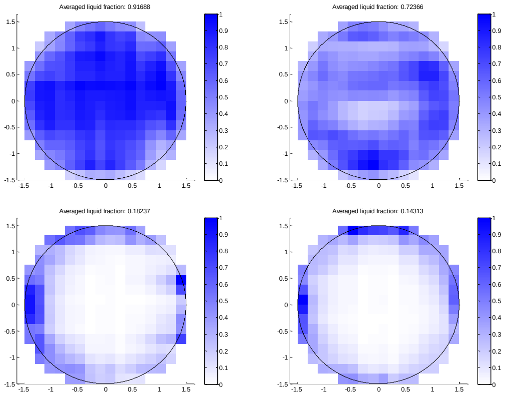

Fig. 11 Cross-sectional phase distribution using wire mesh sensor in vertical pipe, $j_g = 0.1$ m/s, $j_f = 0.1$ m/s

5. Conclusions

For identification of flow regimes in an vertical pipe experimental facility was constructed, and flow regimes for various flow rate conditions was visualized by using high-speed camera recording the two-phase flow in the maximum 500,000 fps. These visual observations were successfully compared with theoretical models on the basis of flow identifications which uses structural characteristics of each flow regimes. Besides the wire-mesh sensor could visualizes the tomographic images of regime of slug flow.

Using the advantage of wire-mesh senor which could contact flows, it would be a basic study for void fraction in the vertical flow regime.

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