Flow regime mapping in gas-liquid flow in micro-channels

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Abstract— **Experiments were conducted in a micro-channel with square cross-section with each side being 3 mm. Gas-liquid flow is employed for determining the flow patterns with water being liquid phase and nitrogen being gas phase. Over a wide range of gas and liquid velocities the flow patterns were studied using visual inspection technique. It is found that four types of flow regimes occurred within the range of variables considered in the present study. These are bubble flow, slug flow, channel flow and transient flow. A flow regime map is also constructed.**

***Index Terms*— Two-phase flow, micro-channel, flow regime, flow pattern.**

I. Introduction

Two-phase flow in micro-channels appears quite frequently in many applications in modern process industry and modern electronic industry. Therefore, the study of flow patterns is essential in order to understand the behavior of these systems. Serizawa et al [1] studied two channel flow in a tubular micro-channel of diameters 20, 25 and 100 by employing air-water flow and steam-water flow. The gas velocities are varied from 0.0012 to 295.3 m/s and the liquid velocities from 0.003 to 17.52 m/s. About 8 distinctive flow regimes have been identified: dispersed bubbly flow, gas slug flow, liquid ring flow, liquid lump flow, annular flow, frothy annular flow, rivulet flow, liquids droplet flow and a special type of flow pattern. Kawahara et al [2] also determined flow patterns in a tubular micro-channel of 100 micron diameter with air-water flow over a wide range of flow rates and identified different flow patterns. This behavior is compared with similar studies in 1 mm diameter channel and found good agreement. Tripplett et al [3] conducted experiments in 1.1 and 1.45 mm diameter circular channel and semi-triangular channel. Several discernible flow patterns were observed. The regime transition was verified with various proposed models and found that these models poorly agreed the present test results. A close examination of the literature revealed that the studies on flow pattern transition in two-phase flow in microchannels is mostly limited to circular or near circular cross-section conduits and a rectangular channel was not studied. In view of this the present experiment was taken up.

II. Experimental

The experimental test rig employed for carrying out the present studies has been very carefully fabricated. A schematic sketch of the experimental unit used in the present study has been shown in Fig.1. The unit consisted of a feed tank, a globe valve for regulating the flow rate liquid through the micro-channel, an acrylic square micro-channel test section of 3 mm size, a nitrogen gas cylinder, and a needle valve for regulating the nitrogen flow rate, a pre-calibrated nitrogen gas rotameter of Indus make. The liquid flow rate is estimated by collecting the water in a given time. Water is employed as liquid phase and nitrogen gas is employed as gaseous phase.

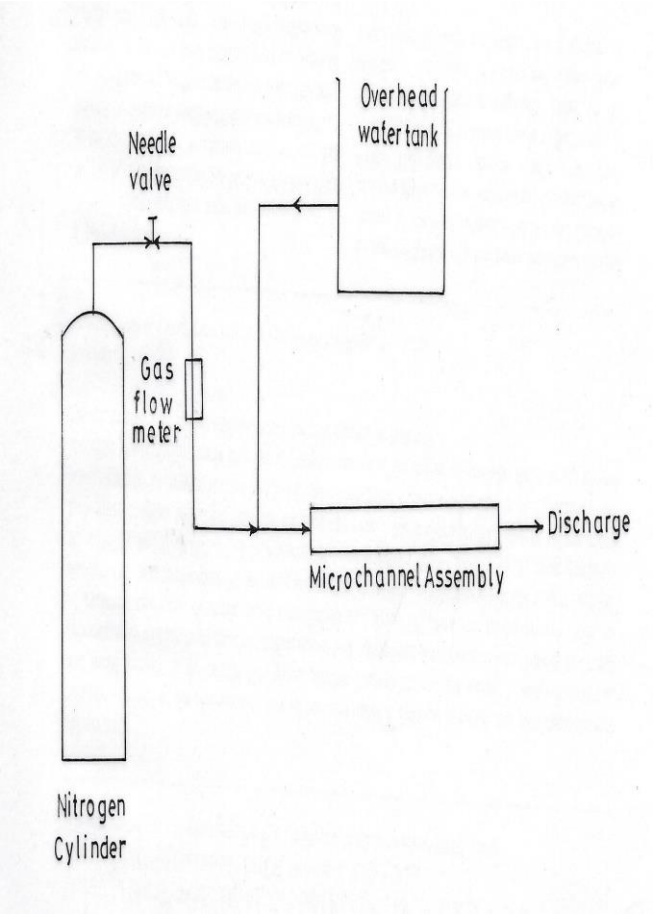

Fig.1. Schematic diagram of the experimental setup

The transparency of the acrylic micro-channel assembly facilitated the visual observations on flow patterns. The flow rate of the liquid was very accurately measured. The liquid flow rate was varied from 0.11 to 1.62 m/s whereas the gas flow rate was changed from 0 to 24 m/s.

III. Results and Discussion

The flow regimes identified in the present experiment in a micro-channel with two-phase flow within the ranges of gas and liquid velocities has been shown in Fig.2.

Manuscript received.

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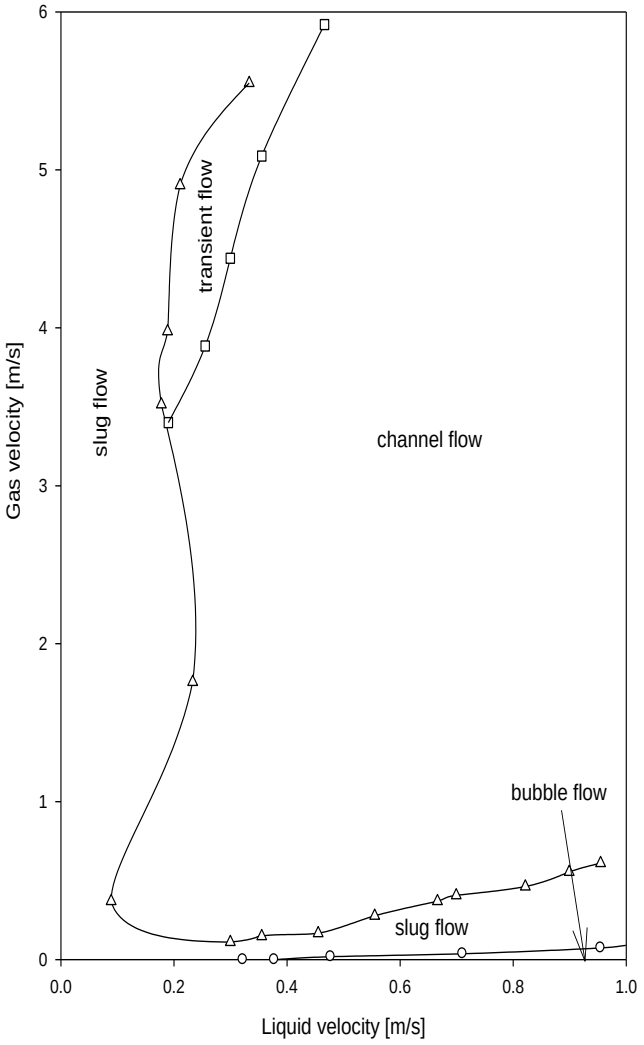

Fig.2. Flow regime mapping in micro-channel with two-phase flow

A close examination of the plots in Fig.2 reveals that there are four types of flow patterns which can be visually identified. These flow patterns are: bubble flow, slug flow, channel flow and transient flow. Bubble flow appeared with liquid being continuous phase and gas forming bubbles, however with in a very narrow range of velocities. Over a wide range of velocities either with high gas flow or liquid flow, slug flow appeared as is evident from the above figure. It is also observed that at a further wider range of velocities gas and liquid formed their favorable channels for flow, because the present flow is concurrent in nature. Further over a narrow range, a mixed flow pattern which cannot be fit into a specific pattern, is termed as transient flow regime is also observed. Identification of the flow patterns is very much helpful in designing equipment for heat and mass transfer operations especially at miniature levels.

IV. CONCLUSIONS

In a square cross-section micro-channel, with gas liquid flow, four types of flow regimes were identified. These are termed as bubble flow, slug flow, channel flow and transient flow. A flow regime map has been constructed for this case. These finding will help engineers working in the relevant fields for the design of equipment.

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