Experimental Study on Flow Regime Transition in an Inclined Pipe

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1. Introduction

The identification of flow regime transition is very important part for nuclear safety analysis, improvement and design of mechanical system. There have been many theoretical and experimental attempts to demonstrate flow regime transitions in a horizontal and vertical pipe, on the other hand, research for the inclined pipe has been rare. Taitel and Dukler proposed a theoretical model for predicting flow regime transitions which can be applied to a horizontal and an inclined two-phase flow based on assumptions that flow is steady and equilibrium [1]. Weisman et al. presented correlations for flow regime transition boundary in horizontal pipes based on a number of experimental data, and they added the effect of surface tension [2]. Mishima et al. suggested a theoretical mechanism in order to demonstrate the transition between stratified and intermittent or annular flow in a horizontal pipe based on Kelvin-Helmholtz theory [3]. Bennett et al. presented a mechanism for slug formation in downwardly inclined pipes using Kelvin-Helmholtz analysis [4]. This work has been initiated to investigate flow regime transitions in an inclined pipe as a preparatory research for flow regime identification of APR+ PAFS.

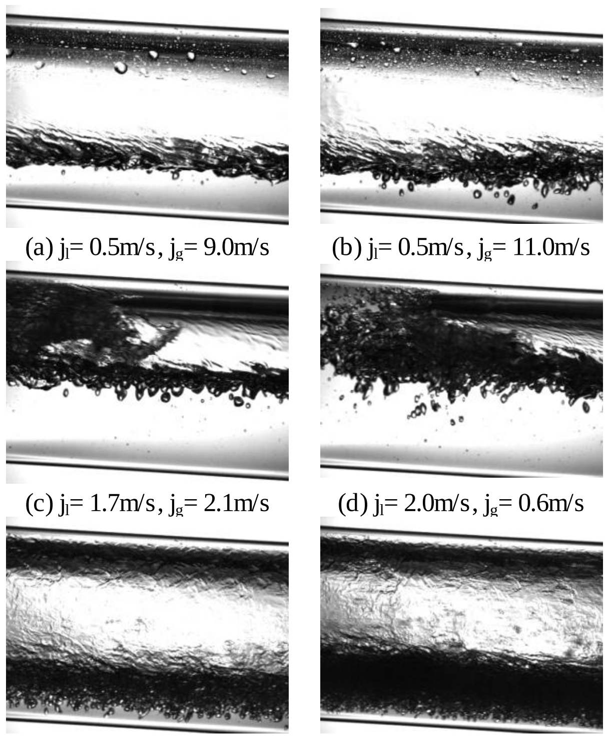
2. Test Section

An inclined test section has been designed for describing two-phase phenomena in APR+ PAFS and for investigating key hydraulic parameters. The inclined test section is made from circular acryl pipe with 45mm inner diameter, and inclination angle is 3°. The inclined section is composed of two inclined pipes with roughly 3500mm length and elbow connecting them, and also contains air and water injector, collection tank, pipe lines and measurement instruments.

The water is supplied into the test section by operation of 5HP pump lifting water in the main collection tank, and the amount of the water is adjusted by the Coriolis mass flow meter whose sensor model is RHM20 and transmitter model is RHE08 and a gate valve. In case of air supply, air compressed by 15HP compressor is injected into the test section and this is controlled by the Coriolis flow meter (CMF100M) and rotameter. The maximum superficial velocity of liquid and gas are approximately 4m/s and 12m/s on a design basis.

3. Experimental Results

For the investigation of flow regime transition in an inclination pipe with 3° inclination angle several experiments have been performed with respect to various liquid and gas superficial velocities under standard temperature and pressure. The water and air have been used as operating fluids. In order to accurately evaluate flow patterns high-speed camera which can monitor two-phase flow in maximum 198,000 fps has been employed. This high-speed camera has been located at the point roughly 3000mm away from the inlet of inclined pipe for describing fully-developed condition. Figure 1 shows some examples for experimental observations obtained from high-speed camera for various liquid and gas superficial velocities.



(a) j_l= 0.5m/s, j_g= 9.0m/s (b) j_l= 0.5m/s, j_g= 11.0m/s
(c) j_l= 1.7m/s, j_g= 2.1m/s (d) j_l= 2.0m/s, j_g= 0.6m/s
(e) j_l= 0.5m/s, j_g= 18.0m/s (f) j_l= 0.9m/s, j_g= 16.0m/s

Figure 1: Flow regimes for given superficial velocities

In Fig. 1, j_l and j_g denote water and gas superficial velocities, and each column shows stratified, intermittent and annular flows, respectively. For the verification of these experimental observations, a comparison with theoretical prediction proposed by Taitel and Dukler [1] has been conducted. Figure 2 illustrates the comparison between observations from high-speed camera and theory.

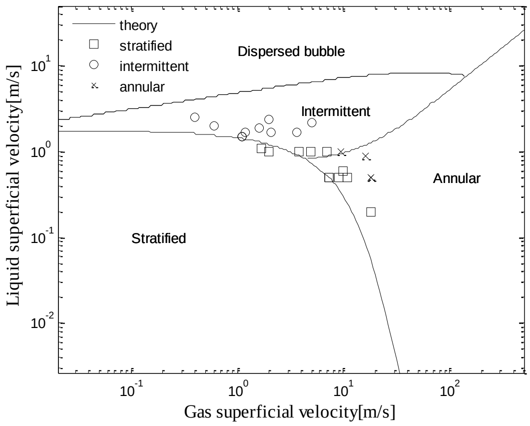


Figure 2: Comparison between experimental results and theory

4. Conclusions

As a preparatory research for identification of flow regime transitions in APR+ PAFS, fundamental experiments have been conducted in an inclined pipe. A high-speed camera has been employed for accurate evaluation of flow regimes and these experimental observations have been compared with theoretical predictions. Some mismatches between theory and experimental results have been observed. These may be due to absence of the effect of wave motion and surface tension in the theoretical model.

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