The Behavior and Characteristics of the Interfacial Waves in Gas–Liquid Two–Phase Separated Flow Through Downward Inclined Rectangular Channel

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An experimental investigation on the behavior and characteristics of interfacial waves in downward inclined rectangular channel was conducted. The interfacial waves were traced and measured by using conductance technique. The wave patterns were distinguished and defined. The characteristics of the interfacial waves, such as time-averaged film thickness, wave height, wave propagation speed, wavelength and wave frequency, were systematically examined in terms of gas and liquid superficial volumetric fluxes. The effect of the inclination and flow channel geometry of the test section on the interfacial wave was also investigated.

Keywords: liquid film thickness, gas–liquid two–phase flow, interfacial waves, experiment study.

INTRODUCTION

In horizontal and slightly inclined gas–liquid two–phase flow, the stratified flow may occur in the case of the low gas and liquid flow rate combinations. In this kind of flow when the gas velocity is increased within the regime of the stratified flow, waves appear on the gas and liquid interface[1,2]. For these stratified wavy flow patterns, the structure and dynamics of the interface greatly influence the rates of mass, momentum and heat transfer as well as the stability of the system[3,4], therefore an accurate knowledge of interfacial wave formation and wave parameters such as wavelength, speed of propagation, amplitude and more detailed wave structures, is essential to the eventual understanding of interfacial transfer mechanisms and two–phase flow pattern transitions in a large number of engineering application.

In contrast to the study of flow and characteristics of the interfacial waves in gas–liquid–two–phase flow through horizontal pipes, which has been summarized in detail in Refs.[5,6], the investigations on the flow and characteristics of the interfacial waves in downward inclined two–phase flow have very few publications. Hanratty and Engen investigated the roll waves in horizontal gas–liquid channel flow[7], Hanratty & Hershman investigated the effect of liquid viscosity on the formation of roll waves in horizontal channel[8]. Cohen and Hanratty reported the studies of the appearances of the interfacial waves[9]. The wave patterns in gas–liquid flow were delineated. Miya et al investigated the formation of roll waves both theoretically and experimentally[10]. Andritsos & Hanratty studied the interfacial stability of gas–liquid two–phase flow in horizontal circular pipes with inner diameters of 25.2 and 95.3 mm respectively[11]. Their researches were focused on the wave pattern transitions and the effect of liquid viscosity on the formation of the interfacial waves. Shi & Kocamustafaogullari reported some experimental results of the interfacial waves of gas–liquid two–phase flow through horizontal circular pipe with an inner diameter of 50.3 mm[12].
They reported the characteristics of interfacial wave parameters and further discussed the relationship between interfacial waves and the interfacial shear stress. Li et al reported their investigations on the interfacial waves in air–water two-phase flow through horizontal rectangular and circular channels [13, 14].

To the authors' knowledge, the wave patterns and characteristics of the interfacial waves in downward rectangular channel are not available in the open literature, yet the experimental data of the interfacial waves in such a channel are highly required in the understanding of the interfacial waves in gas–liquid two-phase flow. The main purpose of this work is to provide a number of background data for the initiation of various interfacial wave patterns and the characteristics of the interfacial waves in downward inclined rectangular channel. The effect of the channel inclination on the flow and the formation of the interfacial waves were examined.

EXPERIMENTAL APPARATUS AND PROCEDURE

Experimental Apparatus

Air and water were used as working fluids in the experiment. Water was pumped by a centrifugal pump and air was supplied by a compressor. The water flow rate was measured by using two LB-type rotameters, and the air flow rate was measured by using three orifices, which were calibrated carefully prior to the experiment. Tests were conducted in a rectangular plexiglass conduit 150 mm in width, 25 mm in height and 6690 in overall length. Fig.1 shows a schematic diagram of the test section. The inclination angle of the test section is 4.55°.

Experimental Technique

Three two-parallel wire conductance probes were used to measure the basic characteristics of the interfacial waves [15]. The distance between the first probe and the second one is 30.0 cm and the third probe is located at 9.7 mm far from the second one. Each of them consists of two parallel platinum wires of 0.1 mm in diameter and 1.5 mm apart. The sensors were aligned perpendicular to the direction of flow.

Data Collection

The input signals to the probes were sine wave signals with the frequency of 100 kHz [16]. The signals across the probes were first converted into voltage signals and next into d.c. voltages through full-wave rectifiers, then the carrier signals were rejected by second-order-low-pass filters set at 5 kHz [17]. The output d.c. signals which were in the range from 0 to 5V were monitored and recorded by: (1) an ADC-35 data acquisition system, in which the sampling rate was chosen as 250 Hz and a sample time of 16s. (2) A XR-5000 Cassette Tape Recorder, in which the tape speed was chosen as 9.5 cm/s and the sample time was chosen as 60s.

In this experiment the conductivity of liquid was measured and monitored by a reference probe located in the downstream liquid line in order to minimize the measurement errors [6].

Experimental Conditions

The experiment was carried out at a location of 5385 mm downstream of the two phase mixture. By varying the air and water flow rates, a wide range of stratified wavy flow pattern regions was covered. The values of liquid superficial velocity \( j_l \) were selected as