Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Experimental investigation on characteristics of the interfacial wave for the droplet generation in a horizontal rectangular channel

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1. Introduction

The SPACE code, which is being developed for the safety analysis of Korean nuclear power plant, adopts three governing equations for the gas, continuous liquid, and dispersed droplet fields. Among these, constitutive models for the gas and continuous liquid field equations have been developed by many previous investigators in the numerous literatures. On the contrary, available constitutive relations for the droplet field equations are limited.

Recently, KAERI (Korea Atomic Energy Research Institute) proposed a new mechanistic droplet generation model for the SPACE code [1]. However, it is required to determine three coefficients regarding to the interfacial wave in the stratified flow condition. The main measurement parameters to be needed for the coefficients are the wave slope, liquid fraction, wave hypotenuse length, wave velocity, wave frequency, wavelength, and droplet size. In this study experiments were conducted to measure those parameters with PIV laser system in a horizontal rectangular channel under the air-water flow condition.

2. Experimental facility

2.1 Test Loop

The Test loop consists of a test section, air and water supply systems as shown in Fig. 1. The horizontal rectangular test section was made by transparent Acrylic with the 40 mm x 50 mm x 4 m in width, height and length, respectively. Air and water are supplied into the inlet of the test section by the air blower and the centrifugal pump, respectively. At the outlet plenum of the test section, air and water are separated. And then air is discharged to atmosphere and water is recirculated to the flow loop.

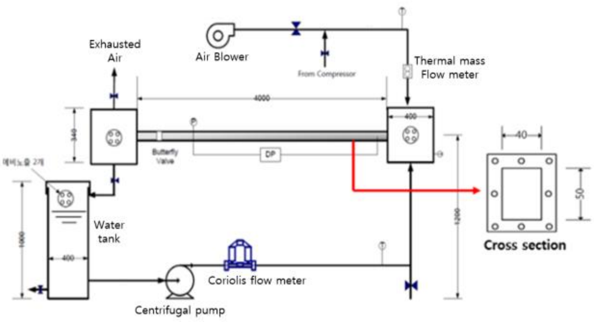


Fig. 1. Schematic diagram of the air-water experiment facility

In the tests, the temperature, pressure, flow rate of the air and water are measured by a thermocouple, pressure transmitter, thermal mass flow meter, and Coriolis flow meter, respectively.

2.2 PIV laser system

Fig. 2 shows the schematic diagram PIV (Particle Image Velocimetry) laser system. The Nd:YLF laser beam which has 527 nm wavelength is converted to the planar laser sheet with 2~3mm thickness through the cylindrical lens. The fluorescent particles of 10 micrometer size were mixed with water to trace the flow illuminated by the laser sheet.

The images are taken by the high speed camera with 1280x800 resolution and 3000 Hz frequency at the side view of the channel, and image processing is conducted by Dynamic Studio software.

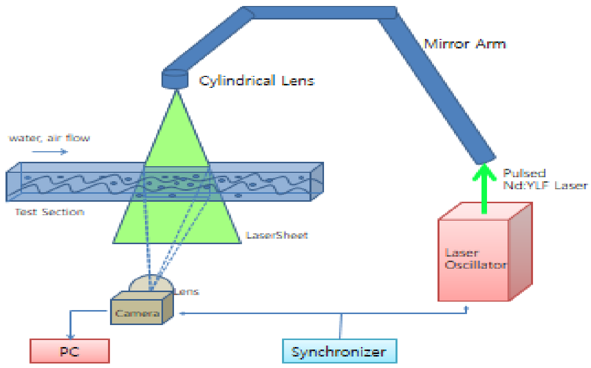


Fig. 2. Schematic diagram of the PIV laser system

3. Methodology of measurement and conditions

The parameters including the wave slope, liquid fraction, wave hypotenuse length, wave frequency, wave velocity, and droplet size were measured with the following methodology.

3.1 Methodology of measurement of parameters

The wave slope was described as the gradient of line AB for horizontal line as shown in Fig. 3. The liquid fraction on the interfacial wave was assumed to be the ratio of the mean wave height to the full height of flow channel. The wave hypotenuse length was obtained from the distance between the crest (point A) and the though (point B) in Fig. 3. The wavelength is defined as the relation between the wave frequency and wave velocity. The wave frequency was calculated from the time between the peak positions of the sequent two waves at the same x position of the acquired images. The mean wave velocity was measured by a PIV algorithm of Dynamic Studio Software. The droplet size was calculated on the basis of 1-pixel size of 76.97 μm in the image.

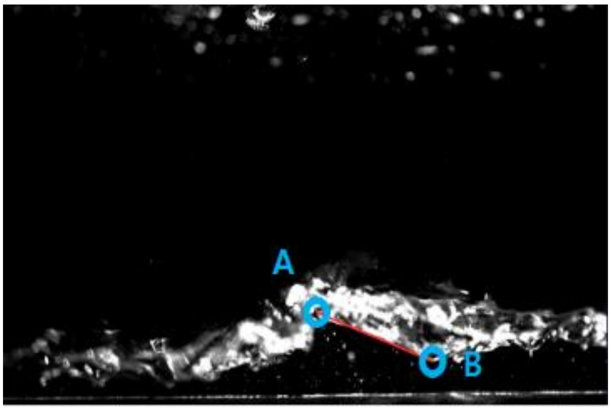


Fig. 3. The image of the interfacial wave

3.2 Experimental conditions

To generate the interfacial wave and droplets in the stratified flow condition, the flow condition was determined on the 12.5 m/s and 0.08 m/s for superficial gas and liquid velocity, respectively. This condition was chosen based on the inception criterion for the droplet generation by Ishii and Grolmes [2] as shown in Fig. 4.

The experiments for fully developed flow were conducted at 3.5 m from the inlet of the test section. The number of pictures taken from the test was 31, and the temperature of air and water were maintained 25℃ and 19℃, respectively. The differential pressure along the test section was negligible.

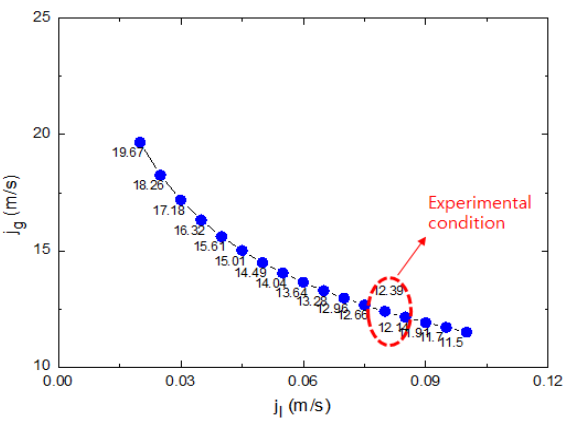
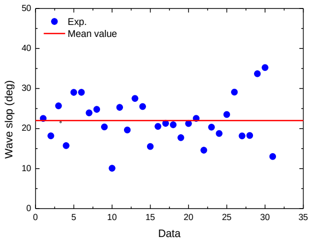


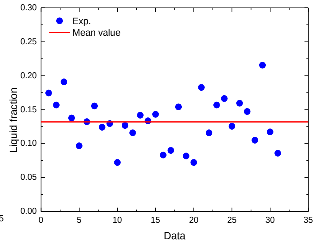
Fig. 4. The inception of the droplet generation by Ishii and Grolmes [2]

4. Results

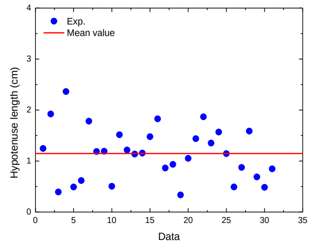
The measured parameters regarding to the interfacial wave in air-water stratified flow are shown in Fig. 5. The wave slope was 22° in Fig. 5(a), the mean liquid fraction in the wave was 0.13 in Fig. 5(b). The wave hypotenuse length was 1.15 cm in Fig. 5(c), the wave velocity was 1.13 m/s and the wave frequency was 7 Hz. As shown in Fig. 5(d), the experimental wave velocity was similar to the wave velocity of Paras et al. [3] correlation. The wave frequency of Swant et al. [4] correlation was lower than that of the present experiments as shown in Fig. 5(e). The mean wavelength was 16.13 cm in Fig. 5(f). Lastly, Fig. 5(g) shows that the droplet size was mainly distributed in 100~200 μm about the 60 data points.



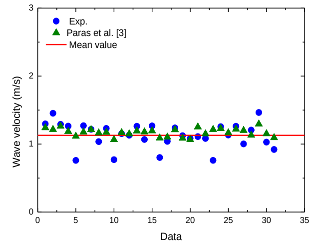
(a) Wave slop



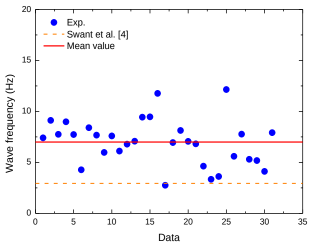
(b) Liquid fraction



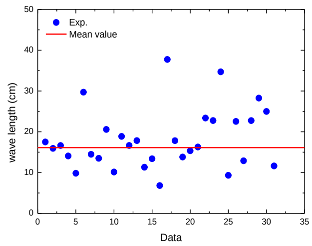
(c) Wave hypotenuse length



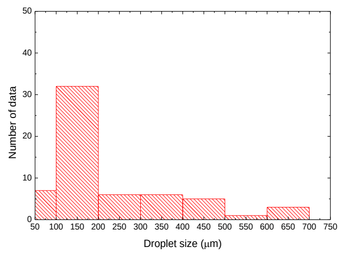
(d) Wave velocity



(e) Wave frequency



(f) Wave length



(g) Droplet size distribution

Fig. 5. Major measurement parameters

5. Conclusions

Experimental investigation was performed for the measurement of parameters related to the interfacial wave when droplets were generated in the air-water stratified flow condition.

From the tests, wave slope, liquid fraction, wave hypotenuse length, wave frequency, wave velocity, and droplet size were measured. Finally, we determined three coefficients for the mechanistic droplet generation model which was proposed by KAERI.

An additional study will be performed for the extension of database and model coefficients for the droplet generation in the future.

ACKNOWLEDGMENTS

This work was supported by Nuclear Research & Development Program of the NRF (National Research Foundation of Korea) grant funded by the MSIP(Ministry of Science, ICT and Future Planning) and by the Nuclear Safety Research Center Program of the KORSAFe grant funded by Nuclear Safety and Security Commission (NSSC) of the Korean government (Grant code: NRF-2012M2A8A4055548, 1305011).

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