Void-fraction, Water Distance & Velocity Measurement of a Gas-Liquid Two-phase Flow in a Complete Test Channel by Ultrasonic Methods

Kil Mo Koo [a]*, Jin-Ho Song [a], Chul-Hwa Song [a], Won-Pil Baek [a]
a Department of Thermal-Hydrauric Safety Research,
KAERI, 150 Dukjin-dong, Yuseong, Daejeon, 305-353, Korea,
**Corresponding author: kmkoo@kaeri.re.kr*

1. Introduction

Ultrasonic methods have the advantage, compared to other void fraction measurement techniques, of applicability to large volume objects, since most radiation techniques are limited by the thickness of the pipe & plate walls [1-4]. This ultrasonic experiment was performed to do an analysis for cooling performance in a complete test channel by the investigation of the two-phase flow that develops in an inclined gap with heating from the top. This ultrasonic technique for measuring void fraction, water distance & velocity measurement employ the higher relative acoustic impedance of air with respect to that of liquids. By the method it is possible to determine both liquid water distance & velocity measurement and void fraction in a gas-liquid two-phase flow.

2. Principle & apparatus for measuring void fraction, water distance & velocity measurement

2.1 Acoustic Principle in the Multi-medium for an Ultrasonic Examination

An ultrasonic pulse is discharged from a transducer and is received by the same type of transducer located on the wall directly opposite the first. Large variations in the instantaneous void fraction measurement are inherent in a bubbly flow. This can be minimized with the oscilloscope using signal averaging mode to capture a large number of traversed sound waveforms and displaying the average of them. From the theoretical model, the relationship between the transmitted ultrasonic signals becomes the equation (1)

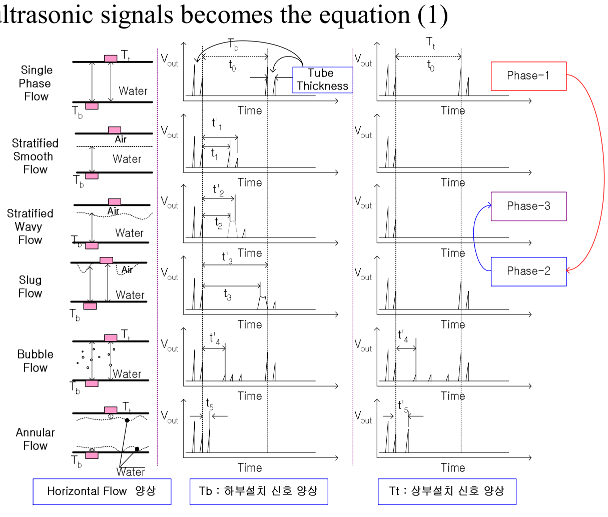

Fig. 1. The different types of flow regimes based on horizontal two-phase flow geometry

$$A = A_0 e^{-k\varepsilon_g} \qquad (1)$$

Where ε_g is the void fraction, and k is a constant depending on the average bubble radius, and then R_B, the channel width, C_W, and the transducer radius, R_U. In this experiment the channel width, C_w has 0.5"width.

For the wave propagation in physics, a plane wave is a constant-frequency wave, and the wave fronts as surfaces of constant phase are infinite parallel planes of constant amplitude to the phase velocity vector. The different types of flow regimes based on horizontal two-phase flow geometry for the wave propagation in physics are shown in figure 1. With this flow geometry, the different flow regimes were observed stratified smooth, stratified wavy, plug and slug flows.

2.2 Apparatus of water distance and void fraction measurement system

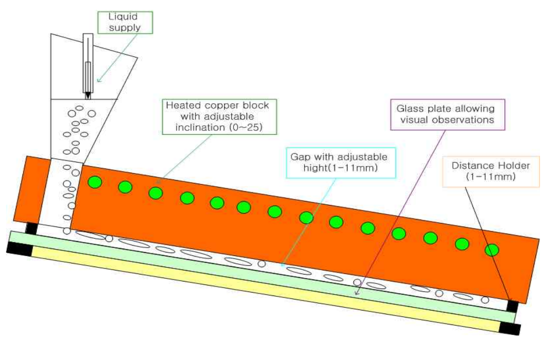

Fig. 2. The complete test channel

For these fundamental experiments the gap is formed by an electrically heated copper block at the top and a glass plate underneath. The gap in between the copper block and the glass plate represents the test channel where the evaporation and two-phase flow are invested. The height of the gap can be adjusted from 1 to 11 mm. The inclination can be varied from 0° to 25° . The complete test channel is shown in figure 2. The test channel is closed at both sides and at the lower end. At the upper end an opening with a funnel to the top allows the vapour to escape and supplies liquid to the gap. The test channel has a size of 0.38m vs, 0.14m. A test series with a shorter gap of o.26m was performed to investigate the influence of the length. The test channel was designed to perform fundamental experiments on the boiling in inclined gaps with heating from the top.

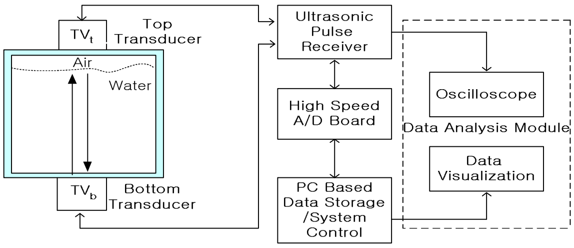

Fig. 3. A schematic of the ultrasonic water distance & void fraction measurement system

A schematic of the ultrasonic water distance & void fraction measurement system is shown in figure 3. In case of a top transducer can be used a low frequency about 150 KHz range that can be measure only air distance. As result it is possible a void fraction measurement by an air distance measurement and a water distance of a bottom transducer.

3. Experimental results and discussions

3.1 Time averaged liquid levels and void fraction

In the complete test channel, the flow regimes of figure 3 consists of air and water of known flow rates through the test channel has a require gap. A piezoelectric type transducer (contact type, 0.5”, 5MHz, Panametrics Model A109R) was mounted from the outside bottom wall, at a section where the flow regime is developed.
In this experiment, measurement conditions of the water distance using a oscilloscope and UT instrument were shown as these values.

- Oscilloscope : time-average traversed waveform
- Ultrasonic Instrument: Gain Control : 28dB, Sampling rate : 5 Ms/s, Amplitude : 188 mV

3.2 Bubble speed and interfacial area

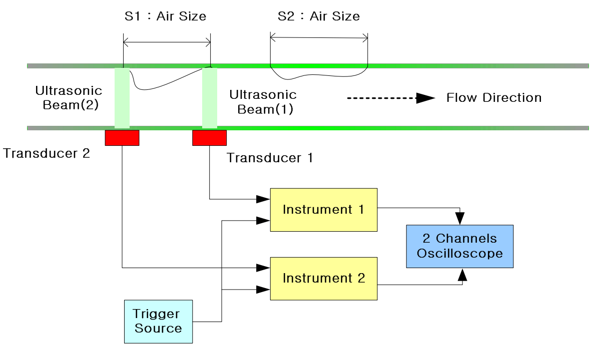

Fig. 5 Experimental system to measure bubble speed and schematics of output

The ultrasonic pulse echo technique may be used to approximately measurement the bubble speed and interfacial area in the two-phase flow system. Figure 5 is a schematic diagram showing the suggested experimental setup to accomplish such a purpose. Figure 6 is water distance signal as an A-scan pattern

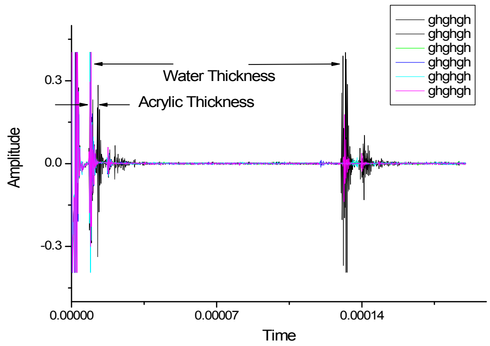

Fig. 6 Water distance signal as A-scan pattern

4. Conclusion

The purpose of this experiment is to understand the operation of the ultrasonic technique for measuring water distance & void fraction of the complete channel in a complete test channel. Therefore there are many kinds of information, including the top transducer in figure 4 can be used a low frequency about 150 KHz range that can be measure only air distance. As result it is possible a void fraction measurement by a water distance and an air distance measurement. It is also possible that the ultrasonic pulse echo technique in figure 5 can be used to approximately measurement the bubble speed and interfacial area in the two-phase flow system.

ACKNOWLEDGMENTS

This study has been carried out under the nuclear R&D program by the Korean Ministry of Education, Science and Technology.

REFERENCES

[1] J. S. Chang and E. C. Morala, Nuclear Engineering and Design 122 143-156, Elsevier Science Publishers B. V. North-Holland (1990).
[2 J. S. Chang, B. Donevski and D. C. Groenevld, Proc. 2nd Int. Symp. Heat Transfer (Hemisphere, New York.) (1989).
[3] J. M. Delhaye and G. Connet Spring-Verlag, Berlin (1984).
[4] K. M. Koo, C. H. Song, and W. P. Baek, The 13th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-13) Kanazawa City, Ishikawa Prefecture, Japan (2009)
[5] K. M. Koo, J. H. Kim, S.B. Kim, H. D. Kim, and D. Y. Ko, Proceeding of the ICEIC 2000, 229(2000)
[6] L. C. Lynnworth, E. P. Papadaskis, D. R. Patch, K.A. Fowler, and R. L. Shepard, IEEE Trans. Nucl. Sci. , NS-18(1), .1 (1971)