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Ultrasonic Water Thickness Measurement at a Gas-Liquid Interface Area in Full-scale Mockup Experiment

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1. Introduction

The ultrasonic pre-examination in the mockup condition was performed to do an analysis for cooling performance in a complete test channel by the investigation of the two-phase flow that will be developed in an inclined gap with heating from the top. This ultrasonic technique for measuring water layer thickness measurement employs the higher relative acoustic impedance of air with respect to that of liquids[1-3]. By this method it is possible to determine both liquid water distance, void fraction in a gas-liquid two-phase flow. Instantaneous measurement of the water layer thickness is useful in understanding heat and mass transfer characteristics in a two-phase separated flow. An ultrasonic measurement technique for determining water layer thickness in the wavy and slug flow regime of horizontal tube flow has been produced as an A-scan mode and B-scan mode.

2. Mock-up Experiment

2.1 Ultrasonic Measurement System

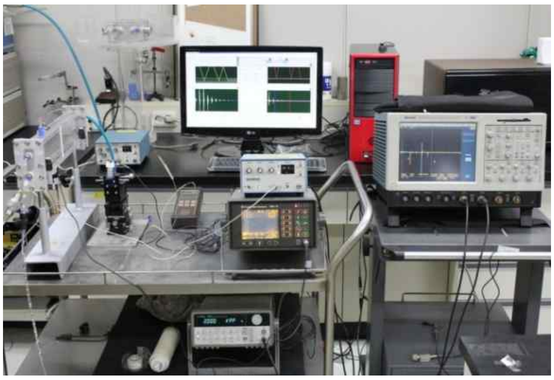

Figure 1 Ultrasonic measurement system in a mock-up experiment

Figure 1 shows a schematic of the present ultrasonic measurement system in a mock-up experiment. The main components are an ultrasonic transducer, pulser-receiver, digitizer, application software, and a function generator which has been generated a pulse of the synchronization for the two ultrasonic measurement systems. The ultrasonic transducer is impulsed, sending out an ultrasonic wave. The subsequent echoes generate some of the operational voltage in the transducer, which is sent back to a pulser-receiver. The pulser-receiver provides a high-voltage pulse required by the ultrasonic transducer. The Panametrics 5077PR square wave pulser-receiver was used. Before beginning the measurement, several parameters such as the pulse voltage level, pulse repetition frequency, damping, band-pass filtering settings, and others were set. The received analogue signal from the ultrasonic transducer was amplified and reconstructed before being sent back to the digitizer. A National Instruments PCI-5122 digitizer was used for converting the voltage RF signals received from the pulser-receiver into digital data using an analogue-to-digital converter. The acquired data were entered in the application software for analysis, and the results were stored and displayed. National Instruments LabVIEW software was used as application software which can be displayed the A-scan and B-scan mode.

2.2 Methods of water layer thickness calculation

A pulse-echo ultrasonic thickness gauge determines the thickness of a material by accurately measuring the time required for a short ultrasonic pulse generated by a transducer. The ultrasonic pulse generated by the transducer travels through the material with velocity of the sound waves in the test material. Then the ultrasonic pulse reflected at the back or inside surface, and finally returned to the transducer. In most applications transit time is only a few microseconds or less. The measured transit time is divided by two to account for the down-and-back travel path, and then multiplied by the velocity of the sound in the test material. This process is expressed by well-known relation equation (1)

$$d = V*t/2 \qquad (1)$$

Where, d is the thickness of the test material, V is the velocity of the sound waves in the test material, t is the measured round-trip transit time. The velocity of the sound in pure water was evaluated from the following 148 point equation [3].

2.3 Analysis of Ultrasonic Transducer Frequency

The frequency of the transducer is chosen based on the required sensitivity and depth of penetration. The higher the frequency, the better the sensitivity but lower the depth of penetration.

Figure 2 shows a frequency characteristic by a FFT (Fast Fourier Transform) for the 3.5MHz transducer at 100MHz sampling, amplitude 20dB of the same instrument. Figure 3 shows a frequency characteristic by a FFT for the 5MHz transducer at 100MHz sampling, amplitude 50dB of the same instrument. Figure 4 shows a frequency characteristic by a FFT for the 10MHz transducer at 100MHz sampling, amplitude 50dB of the same instrument.

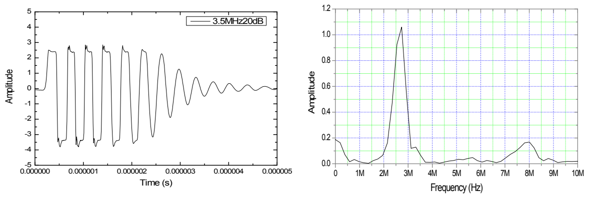

Fig. 2. A frequency characteristic by a FFT of the 3.5MHz RF signal

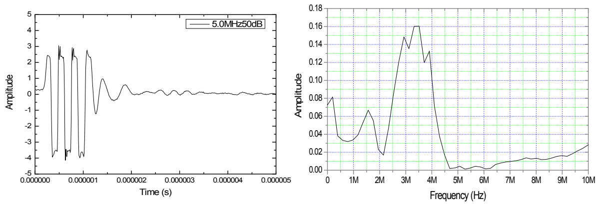

Fig. 3. A frequency characteristic by a FFT of the 5MHz RF signal

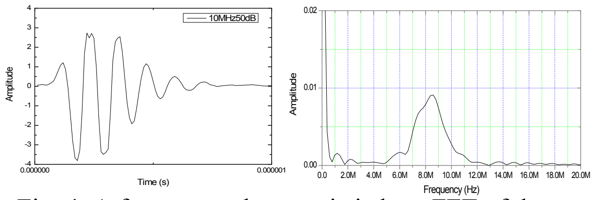

Fig. 4. A frequency characteristic by a FFT of the 10MHz RF signal

2.3 Dimension of the Mockup Facility

In the mockup facility, these fundamental experiments for the gap which is formed between an electrically heated copper block at the top and a glass plate underneath. The gap in between the copper block and the glass plate, which was represented by a test channel invested the evaporation and two-phase flow. The height of the gap can be adjusted from 5 to 15 mm. The inclination can be varied from 0° to 15° . 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 dimension of the test channel has a size of 49 vs, 4cm.

3. Experimental results and discussions

3.1 Time Averaged Liquid Levels

In the complete test channel, the flow regime of consists of air and water of known flow rates through the test channel gap has a requirement. A piezoelectric type transducer (contact type, 0.5", 5MHz) was mounted until inside bottom wall, at a section where the flow regime is developed by the direct contact method of the transducer. In this experiment, a measurement value of the water thickness using an oscilloscope and UT instruments which was shown as this value in the figure 4.

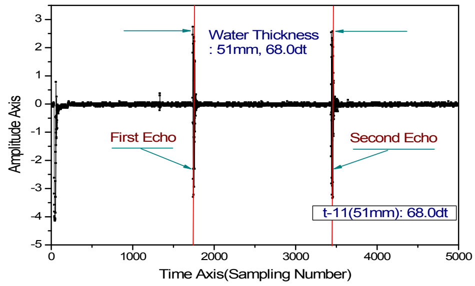

Fig. 4 UT measurement at 51mm water gap in the test channel

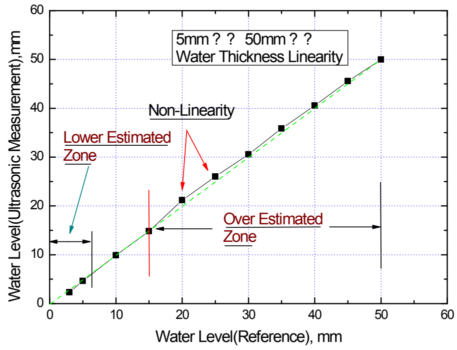

Fig. 5 Comparison UT measurement to water level in the test channel

4. Conclusion

The purpose of this experiment is to obtain for measuring the water distance of the complete channel in a mock-up full scale condition. In this experiment, when the measurement result was compared by the UT measurement value to the real water level, we can get a good linearity characteristic for the all most range of the water levels as shown figure 5. As a result it will be possible that this ultrasonic method can be used to measure the interfacial area in the two-phase flow system.

ACKNOWLEDGMENTS

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