

Ultrasonic Measurement of Water Layer Thickness by Horizontal Flow Pattern Profile in a KAERI HAWL

Kil-Mo KOO¹, Seungtae LEE² and Chul-Hwa Song¹

¹ Korea Atomic Energy Research Institute, Daejeon, Korea

² University of Science & Technology, Daejeon, Korea

Abstract

An ultrasonic measurement technique for determining water layer thickness is presented. The technique can obtain information of the water layer thickness in a tube in the form of a horizontal flow pattern profile through the use of a correct quantitative method. The main objective of the present work is to measure the water layer thickness of the flow using an ultrasonic measurement system. Ultrasonic measurement techniques of water layer thickness are produced to measure the variations in water layer thickness in the horizontal stratified flow and vertical annular flow regimes.

KEYWORDS

Water layer thickness, HAWL (Horizontal Air Water Loop), Horizontal flow patterns profile, PC-based UT special system, Quantitative Method, A-scan, High frequency

Introduction

Ultrasonic methods have the advantage, compared to other water layer thickness measurement techniques, of applicability to large volume objects, since most radiation techniques are limited by the thickness of the pipe & plate walls [1-4]. The 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 [5]. This ultrasonic technique for measuring water layer thickness measurement employ the higher relative acoustic impedance of air with respect to that of liquids. 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. The technique can obtain information of the water layer thickness in a tube in the form of a horizontal flow pattern profile through the use of a correct quantitative method. In this experiment, we also established a special PC-based ultrasonic measurement system through a LabVIEW application that was built as the foundation of an A/D board for data acquisition, including an ultrasonic testing system in a KAERI HAWL (Horizontal Air Water Loop). The main objective of the present work is to measure the water layer thickness of a flow using an ultrasonic measurement system. Ultrasonic measurement techniques are produced to measure the variation of water layer thickness in the horizontal pipe.

1. Experiment

1.1 Ultrasonic measurement system

Figure 1 shows a schematic of the present ultrasonic measurement system. The main components are an ultrasonic transducer, pulser-receiver, digitizer, application software, and a function generator. The ultrasonic transducer is pulsed, sending out an ultrasonic wave. The subsequent echoes generate voltage in the transducer, which is sent back to the pulser-receiver. 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. 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 analog 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 ADC (Analogue-to-Digital Converter). The acquired data were sent to the application software for analysis, and the results were stored and displayed. National Instruments LabVIEW software was used as application software. The application software consisted of acquisition, control, analysis, display, and data storage. The data from the digitizer was processed and analysed according to several defined parameters. Then the A-Scanned data and calculated water layer thickness data were stored. The pulser-receiver, digitizer and application software must operate as one tightly timed unit during the measurement to ensure the accuracy of results and precision of the test time. The function generator acts as the time base (trigger source) of the measurement, and controls the pulse repetition frequency (PRF) of the pulser-receiver and data acquisition frequency of the digitizer.

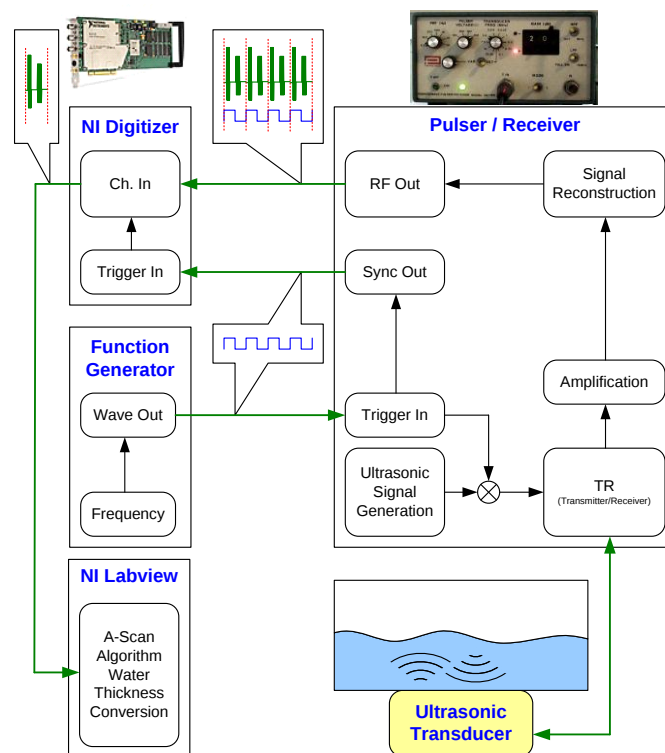


Figure 1 Ultrasonic measurement system

1.2 Methods of water layer thickness calculation

The water layer is sounded by a pulse-periodic signal. During the intervals between the sounding pulses, the ultrasonic converter automatically switched to the echo signal receiving mode. Figure 2 shows an example of echo signals observed on the monitor in the course of the test.

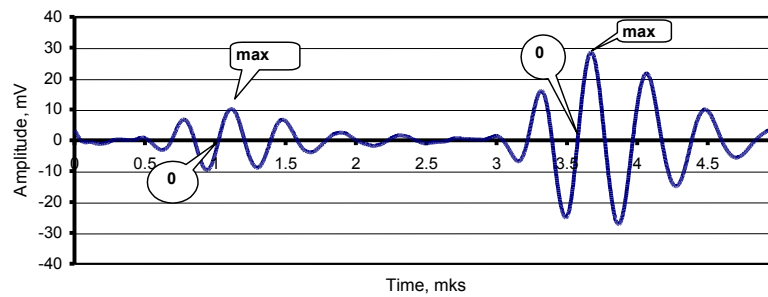


Figure 2 Echo signals observed in the test

The displayed echo signal images represented two groups of oscillations. The left one corresponded to the echo signal from the water bottom, while the right one – to that from the top water surface. The basic frequency of oscillations in both groups coincided with the natural resonance frequency of the ultrasonic converter, but the spectral composition differed between the groups. In-phase half waves were chosen, one per each group. Then, on each half-wave two points were taken – one at the zero line crossing and the other one at an amplitude extreme. Later on, the changes in time delay between the point pairs were followed. These changes, recalculated taking into account the dependence of acoustic speed in material on the temperature, correspond to changes in the water layer thickness due to its surface changing. A regime might be achieved when the useful signal could merge with the noise and data acquisition by the signal peaks might become problematic. In contrast, the zero line crossing can be determined with sufficient accuracy in the absence of the constant component. On the whole, it may be stated that measurements of both types produce similar results and in future one of them can be chosen depending on peculiarities of the test.

For calculation of the water layer thickness, peak detection and computation of the thickness based on water properties were used. In the A-scan (data from the digitizer), the first echo is from the front (or bottom) surface of the water layer, and the second echo is from the rear (or top) surface of the water layer. Using this information, the water layer thickness can be simply calculated by multiplying the speed of sound through the water layer with the time of flight.

1.3 Experimental facility

The HAWL (Horizontal Air-Water Loop) facility is located at the KAERI (Korea Atomic Energy Research Institute), Korea. The HAWL is a test facility to investigate the horizontal air-water flow characteristics. A schematic diagram of HAWL is shown in figure 3. It consists of two circular channels whose inner diameters are 80 and 130 mm. The length-to-diameter ratios of the 80 and 130mm channels are 184 and 99, respectively. The test channels are made of 10 mm thickness

transparent acryl pipes. Air and water injected into the test section through an inlet reservoir and the air and water injection velocity were measured by a vortex flow meter.

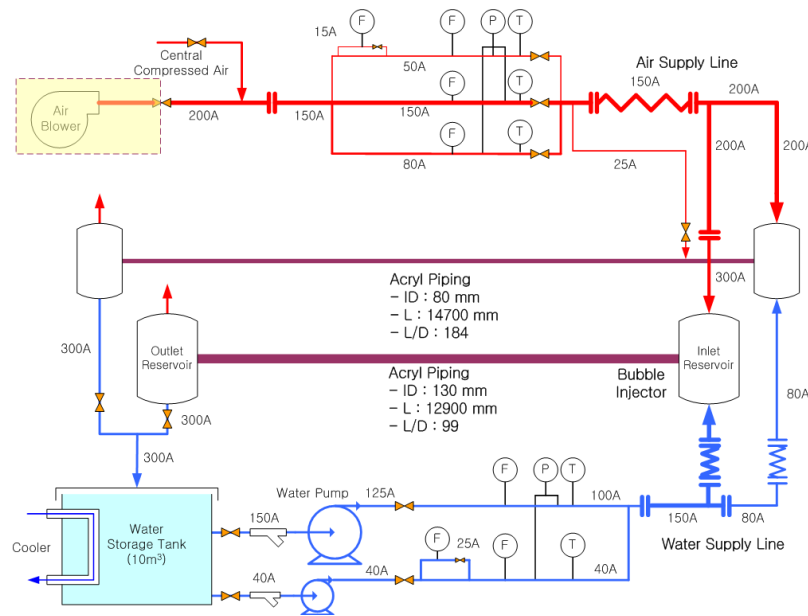


Figure 3 Schematic diagram of the HAWL

2. Test parameters and test results and Horizontal flow pattern profile

2.1 Influence of ultrasonic transducer frequency

To investigate the influence of ultrasonic transducer frequency, water layer thickness was measured using three different ultrasonic transducers with frequencies of 5, 10 and 20 MHz. The data acquisition frequency of the 5, 10 and 20 MHz transducer was 10, 20 and 50 MHz, respectively. Figure 4~6 shows the A-scan graph obtained from the three different ultrasonic transducers directly coupled to a water layer. In the A-scan graph, the first echo is from the bottom surface of the water layer, and the second echo is from the top surface of the water layer. The water layer thickness is can be calculated by distance between first and second echo. As shown in Figure 4~6, higher the ultrasonic transducer frequency results in a lower measurable water layer thickness.

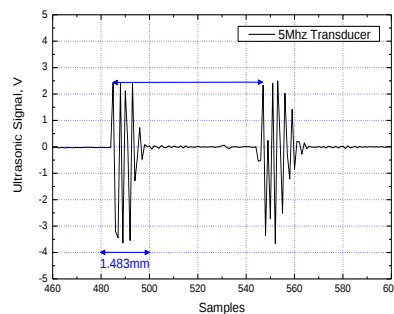


Figure 4 A-Scan Graph using a 5 MHz Ultrasonic Transducer

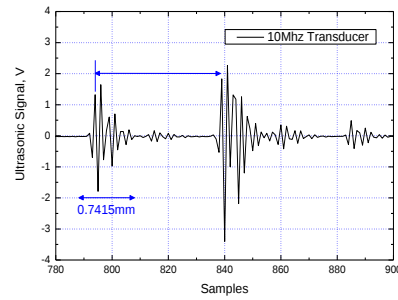


Figure 5 A-Scan Graph using a 10 MHz Ultrasonic Transducer

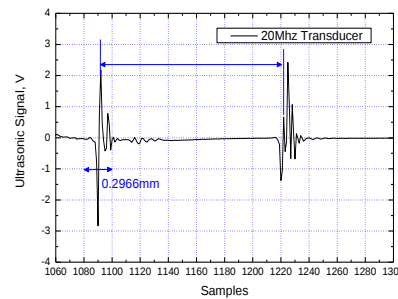


Figure 6 A-Scan Graph using a 20 MHz Ultrasonic Transducer

2.2 Measurement of water layer thickness

The water layer thickness of horizontal flow was measured using 0.5 inch round type ultrasonic transducer with frequency of 5 Mhz. The pulse repetition frequency (PRF) of the pulser-receiver was 80 Hz and data acquisition frequency of the digitizer was 10 MHz. The ultrasonic transducer was mounted at the outer bottom surface of the pipe. The water layer thickness was measured at 11000 mm down stream from the water inlet. All experiments were done at atmospheric pressure and at 10 ± 1 °C. The experimental variables were air injection velocity and water injection velocity. The experiments were carried out at 0.2 degree to the horizontal with 80 mm diameter pipe.

Figure 8 and 9 shows the water layer thickness as a function of time measured by the ultrasonic transducer in the horizontal wavy and slug flow regime, respectively. As shown in Figure 9, the water layer thickness showed that the test section filled with water periodically. The measurement shows an interface shape of slug flow. The ultrasonic measurement technique successfully measured the water layer thickness of horizontal wavy and slug flow.

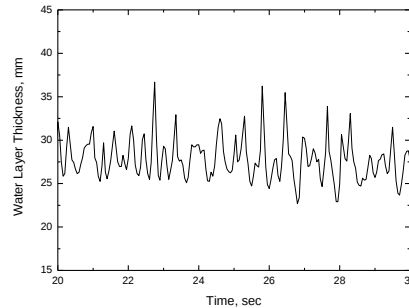


Figure 7 Water layer thicknesses variation of horizontal wavy flow

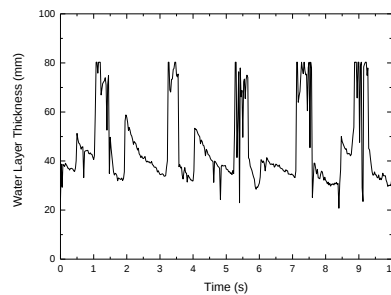


Figure 8 Water layer thicknesses variation of horizontal slug flow

3. Conclusion

The ultrasonic measurement system was established for the measurement of water layer thickness in a KAERI HAWL. To investigate the influence of ultrasonic transducer frequency, the water layer thickness was measured using three different ultrasonic transducers. These results show that a higher ultrasonic transducer frequency results in a less measureable water layer thickness. By using ultrasonic measurement system water layer thickness of horizontal flow was measured. The ultrasonic measurement technique successfully measured the water layer thickness of horizontal wavy and slug flow.

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