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Advanced Measurement Techniques for a Horizontal Two-Phase Flow

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1. Introduction

The horizontal two-phase flow test loop has been constructed to investigate horizontal flow characteristics in terms of the direct contact condensation heat transfer as well as the interfacial wave characteristics of both condensing and non-condensing fluid. This work presents some of advanced measurement methods applied to measuring water layer thickness, temperate and velocity fields in horizontal flow.

2. Test Facility

The test facility was designed and constructed such that the direct contact condensation of steam and the behavior of water layer along a horizontal channel can be measured in steam-water or air-water flow with co-current or counter-current flow configuration. Fig. 1 shows a schematic of the horizontal two-phase flow test loop. The test loop consists of a test section, an air supply system, a steam supply system, and a water supply system, and a control system and data acquisition system. The test section has a rectangular cross-section with the length of 1850mm, width of 80 mm, and height of 60 mm.

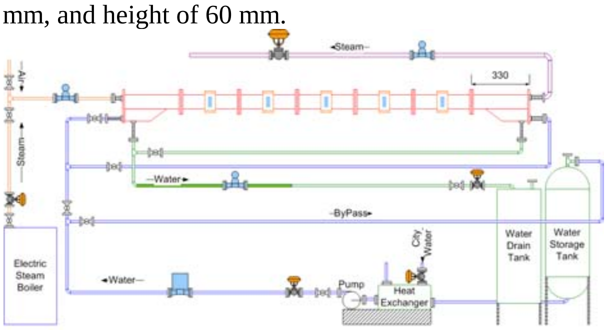

Fig. 1 Schematic of the horizontal two-phase flow test loop

3. Measurement Techniques

In this section some of the measurement techniques applied to the measurement of horizontal flow characteristics are described.

3.1 Ultrasonic method

Ultrasonic measurement technique was applied to the local instantaneous value of water layer thickness. The main components of measurement system are an ultrasonic transducer, a pulser-receiver, a 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 Panametrics 5077PR square wave pulser-receiver was used to provide a high voltage pulse required by the ultrasonic transducer. A National Instruments PCI-5122 digitizer was used for converting the voltage RF signals received from the pulser-receiver into digital data. National Instruments LabVIEW software was used as application software for analyzing the acquired data. The function generator controls the pulse repetition frequency (PRF) of the pulser-receiver and data acquisition frequency of the digitizer. Fig. 2 shows a schematic of the ultrasonic measurement system.

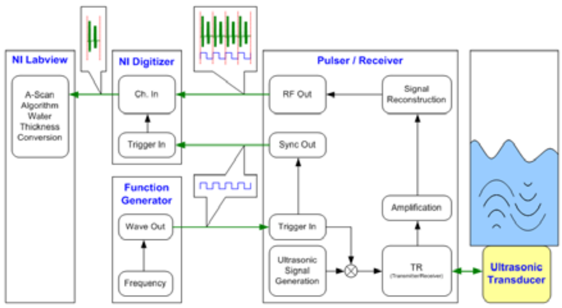

Fig. 2 Schematic diagram of the ultrasonic measurement system

The water layer thickness is calculated by the time-of -flight method. Fig. 3 shows the variation of time-dependent water layer thickness obtained by the ultrasonic measurement system in the air-water co-current flow conditions.

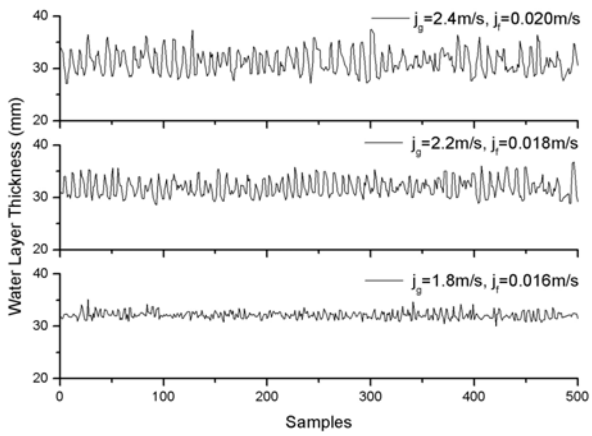

Fig. 3 Time-dependent variation of water layer thickness obtained by the ultrasonic measurement system

3.2 LIF method

The Laser-induced Fluorescence (LIF) technique was applied to the measurement of water layer temperature field. A schematic of the LIF measurement system is shown in Fig. 4. A laser beam emitted from a continuous laser is expanded by a cylindrical lens to form a planar laser sheet in the water layer. The water is mixed with rhodamine B that which is temperature sensitive fluorescence dye. A laser sheet excites the fluorescent dye and fluorescence intensity was measured by the CCD camera with 2x2 K resolution. The fluorescence light from the laser sheet is filtered by 530 nm filter that to eliminate the shorter wavelengths.

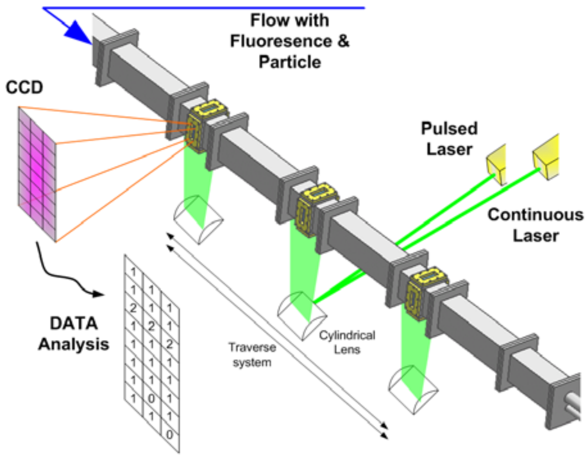

Fig. 4 Schematic diagram of the LIF and PIV measurement systems

To determine the correspondence between water temperature and fluorescence intensity, the fluorescence intensities at each point of the image were calibrated against the water temperature measured by thermocouples. Fig. 5 shows a temperature-dependent variation of the fluorescence intensity at each point of the thermocouple location.

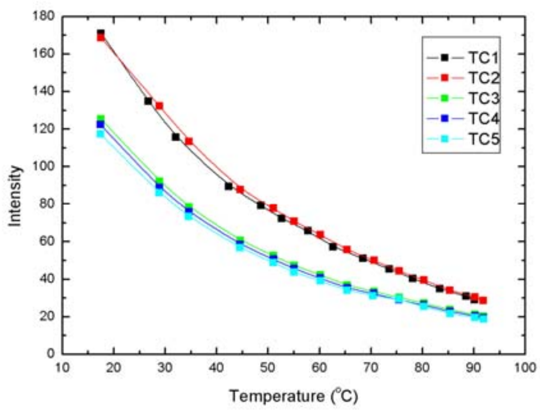

Fig. 5 Fluorescence intensity as a function of temperature

Typical results for temperature field of water layer obtained by the LIF method in the present test facility are shown in Fig. 6. The fluorescence intensity image was translated into temperature by using the calibration curve at each point.

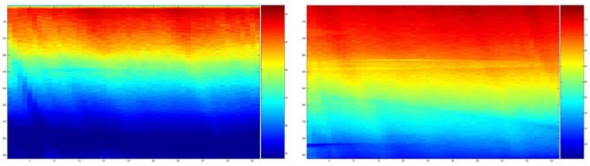

Fig. 6. Temperature field of water layer obtained by the LIF method

3.3 PIV method

The Particle Image Velocimetry (PIV) technique was applied to the measurement of water layer velocity field. A schematic of the PIV measurement system is shown in Fig. 4. A laser beam emitted from a pulsed Nd:YAG laser is expanded by a cylindrical lens to form a planar laser sheet in the water layer. The water is mixed with particle. The PIV image is measured by the CCD camera with 2x2 K resolution.

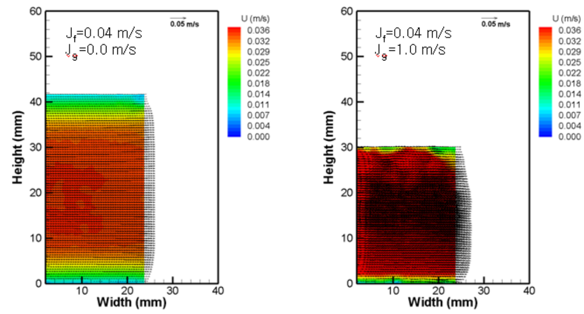

Fig. 7 Velocity field of water layer obtained by the PIV method

Typical results for velocity field of water layer obtained by the PIV method in the air-water co-current flow conditions are shown in Fig. 7

4. Conclusions

Some of advanced measurement methods have been applied to measuring water layer thickness, temperate and velocity fields in horizontal two-phase flow.

They include the ultrasonic measurement system for the measurement of water layer thickness, and the LIF and PIV measurement systems for the temperature and velocity fields of water layer in horizontal two-phase flow.

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