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Experimental Observation of Air/Water Multi-Dimensional Flow in a SLAB Geometry Using PIV Technique

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1. Introduction

Multi-dimensional two-phase phenomena occur in many industrial applications, especially in the nuclear reactor during a steady operation or postulated transient conditions which are sometimes considered to significantly affect a reactor safety. In order to validate a newly developed computational safety analysis code, SPACE, a two-dimensional two-phase flow test was performed with a test section having slab geometry with a dimension of 1.43 m × 1.43 m × 0.11 m which is named "DYNAS". Various kinds of two-dimensional flows are simulated with a selection of inlet and outlet nozzles. In this study, visualization was performed by using a digital camera and an image analysis technique, from which detailed information for the two-dimensional movement of the two-phase flow was quantified. Experiments were performed at 130 kPa of pressure and 35°C of temperature based on the flow outlet conditions. Various flow rates of water and air were set in order to take data representing dynamic multi-dimensional two-phase movement. For each selected inlet and outlet nozzle combination, the water flow had from 4 to 20 kg/s and air flow rate were from 2 to 20 g/s.

2. Experiments

2.1 Test Facility

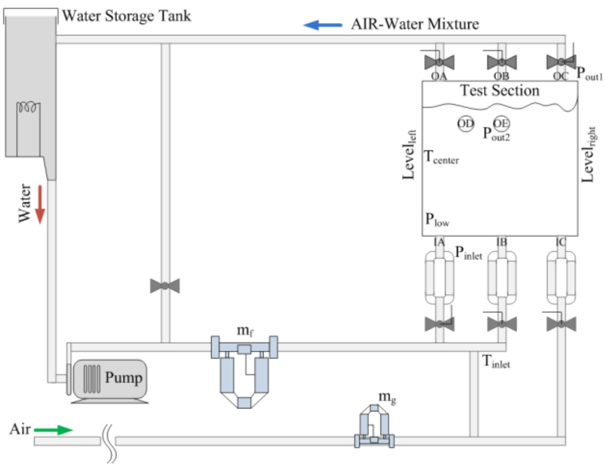

Fig. 1. Schematic diagram of DYNAS test facility.

Figure 1 shows a schematic diagram of the test facility. The test facility consists of a test section, water and air supply systems, a pump and a storage tank including temperature control devices. Air is supplied from the compressor which is maintained at 6 gage bars. The system water temperature is controlled by a cooler and heater imbedded in the storage tank which is installed at the top elevation of the facility. The test section has a dimension of 1.43 m × 1.43 m × 0.11 m based on the internal fluid volume. In order to reduce the wall shear effect induced by a large slug, two transparent acrylic plates were installed with a gap dimension of 0.11 m which corresponds to the maximum stable bubble size at the atmospheric pressure condition. Each acrylic plate has a 25 mm thickness. Support bars were installed on both faces of the acrylic plates to prevent inflation induced by the hydrostatic head of water. A steel frame was designed to support the weight of the fluid and acrylic structure. The test section has three inlet nozzles and five outlet nozzles. All the nozzles have a size of 3" except for the air inlet nozzle which is connected only to the air supply line. Through the other two inlet nozzles, single-phase water or s two-phase mixture flow can be supplied. Three out nozzles were installed on the top face of the steel structure while two outlet nozzles were perpendicularly installed on the face of an acrylic plate. The nozzle corresponds to the broken cold leg. By selecting a combination of inlet and outlet nozzles, various kinds of multi-dimensional flow behavior can be simulated. Figure 2 shows a photograph of the test section and components at the inlet and outlet.

2.2 Instrumentation and Analysis Technique

Several kinds of commercially available instruments were installed in order to measure the boundary conditions. A mass flow rate of injected water is measured by a 3" Micromotion mass flow meter that is installed at the water supply line. The estimated uncertainty for a measured mass flow is 0.1% of its read value. A 1" Micromotion mass flow meter is used to measure air flow at the air supply line of which the accuracy is 0.5%. The system pressure is measured at the top and bottom of the test section by two SMART-type PTs (pressure transmitter). The estimated uncertainty of each PT reading is 0.065% of full scale. To measure the temperature of the fluid, two RTDs are installed at the water supply line and the side of the test section, respectively. The uncertainty of the RTD was expected to be 0.2°C at 35°C of the operation condition.

In the present work, the PIV technique was used to measure the velocity field of an air/water flow with a different air/water flow rate. In recent years, the PIV measurement technique has shown very promising results in fluid flow research and has been used very

Fig. 2. Photograph of test facilities and definition of inlet and outlet nozzles.

extensively for velocity field measurements in particular due to its non-intrusive capability. A typical PIV system consisting of two functions, i.e., image capture and image analysis, was used. In the image capture system, the light source was day-light. Sony HDCAM (1920 × 1080 pixels) operated in a continuous mode. The frame rate of the recording device was 30Hz. The field of view was 1,500 mm × 1,800 mm, and the test area was cropped with 400 × 480 pixels. Air bubbles could be incidentally used as tracer particles. It was thought that air bubbles are small enough to follow a multi-dimensional flow with a high momentum.

3. Results

Figure 3 and Figure 4 show instantaneous velocity vector field for AC01-V and AC04-V cases, of which the boundary conditions were summarized at Table 1.

Table 1: Boundary conditions

Case	Value	M_f (kg/s)	M_g (g/s)	TF (°C)	P_{out} (kPa)
AC01-V	Average	4.0	2.1	35.1	124.4
	STD (%)	2.06	4.71	0.18	0.52
AC04-V	Average	20.0	20.4	35.1	147.8
	STD (%)	0.24	0.90	0.29	1.15

4. Conclusions

To identify and generate experimental data for the two-dimensional two-phase flow, an experiment was performed with a large scale of slab geometry. With a various selection of combinations of inlet and outlet nozzles of the test section, various multi-dimensional two-phase flows were visualized. By using a PIV technique, a movement of the gas phase could be quantified. For lower void fraction cases, the image analysis was successful. However, a definite velocity vector could not be obtained for a large air flow condition. The experimental data will be utilized to validate and develop many thermal hydraulic models related to the momentum equation.

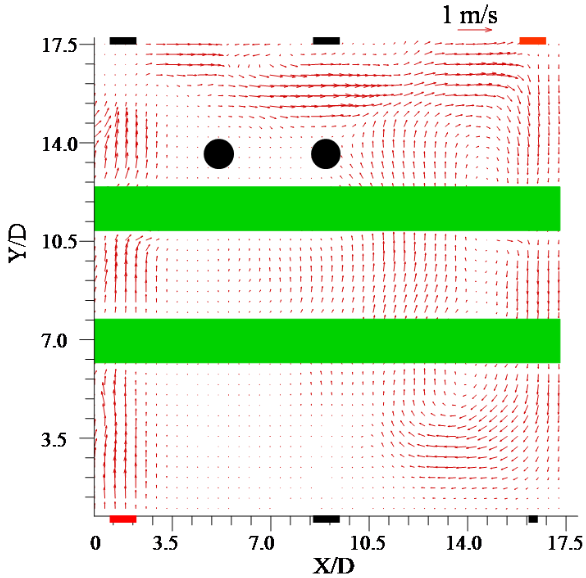

Fig. 3. Instantaneous air velocity field for AC01-V case.

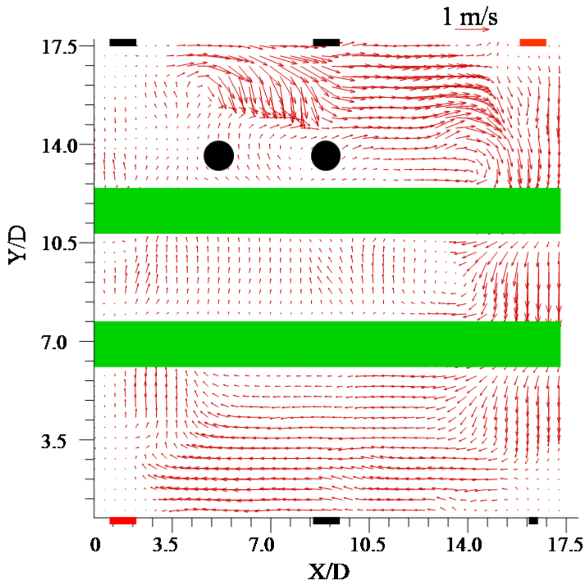

Fig. 4. Instantaneous air velocity field for AC04-V case.

Acknowledgement

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