Measurements of Bubbly Flow in a Subchannel by using Optical Sensor Probe

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1. Introduction

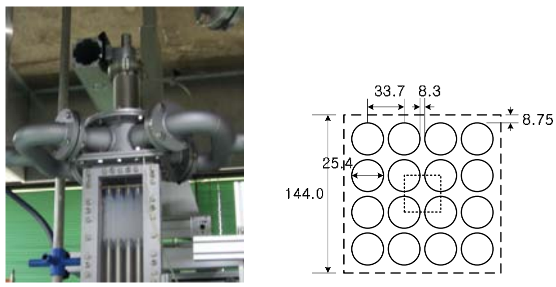
Understanding of the two-phase flow structure in a subchannel is extremely important in a view point of the safety analysis in nuclear power plants. The basic characteristic of a two-phase flow is clarified by two parameters such as void fraction and interfacial area concentration. So, extensive analytical and experimental studies have been performed on basic flow channels such as round tube and annulus. But studies on subchannels were very limited because of the geometrical complexity. Recently, experimental studies on a rod bundle have been published. Yun et. al.[1] have been presented the interfacial flow structure of subcooled water boiling flow in a subchannel of a 3x3 rod bundle. Paranjape et. al.[2] have been obtained a flow regime maps for an adiabatic air-water two-phase flow through a flow channel with 8x8 rod bundle. In spite of various experimental efforts to understand the flow structure in a subchannel, there were still coarse and insufficient experimental data. From this circumstance, this study presents precise measurements in a subchannel with a 4x4 rod bundle by using a two-sensor optical probe.

2. Experimental Works

In this section the test facility and the measurement methods are described. The test facility which is called MATiS-V (Measurements and Analysis of Turbulence in Subchannels–Vertical) includes a cold loop and the test rig which was newly constructed to simulate the air/water two-phase flow in a rod bundle. The test rig has a 4x4 rod bundle. An optical sensor probe can be installed to measure void fraction in a center subchannel.

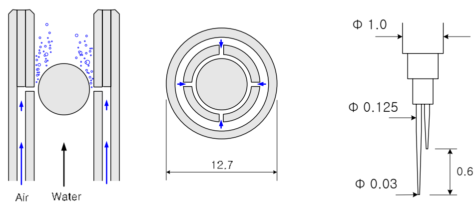
2.1 Test Rig

The experimental loop (MATiS-V) consists of a water storage tank (0.9 m^3) with a heater and a cooler, a circulation pump (2 m^3/min max.) and a test rig which includes a 1.427 m long 4x4 rod bundle. Fig. 1 shows an upper part of the test rig and the probe traverse system in (a) and the dimensions of a rod bundle test section in (b). The rod diameter and the rod pitch are 25.4mm and 33.7mm, respectively. These dimensions are 2.6 times larger than the real PWR rod bundle size. Measurement resolutions are highly improved with this enlarged rod bundle. A 3x3 nozzle-type air/water injection unit was installed at the inlet of the rod bundle (bottom side). Each air/water injectors are located at the center of the subchannel. Fig. 2 (a) shows an air/water injection unit which was designed to inject finely dispersed bubbly flow into the bottom of the test section with bubbles of approximately uniform diameter of 0.5~8 mm by adjusting the air /water flow rate. For the measurement of the void fraction and the bubble velocities in a subchannel, an optical two-sensor probe was adopted. As shown in Fig. 2 (b), two optical fibers are located at the center of a metal tube of 1.0mm diameter. The tips of optical fibers are apart 0.6mm to get a bubble velocity as well as a void fraction when a bubble goes upward along the subchannel. The optical probe is connected to the traverse system which can move accurately in x, y and z directions according to the pre-determined coordinate. The optical probe is inserted 100mm depth from the top end of a rod bundle and is enveloped with a flexible tube so as to move any directions in a subchannel.



(a) (b)

Fig. 1 Photo of the test rig (a) and the dimensions of a bundle test section (b)



(a) (b)

Fig. 2 A nozzle-type air/water injector (a) and a two-sensor optical probe (b)

2.2 Measurements

For a full measurement of a subchannel, the coordinate of measurement locations was generated as shown in Fig. 3. Total 1,321 locations were selected to measure the void fraction and the bubble velocities in a center subchannel. Every points were measure with 40K sampling rate and 60 repeats. The VXI equipment was used as a data acquisition system.

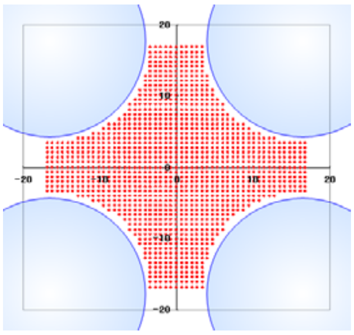


Fig. 3 Coordinate of the measurement locations

Experiments were performed at the conditions of *Re* = 49,000 (equivalent to W_{avg} = 1.60 m/s), 25 ºC and 1.5 bar in the test section. Air was injected into five subchannels (center and its neighbor four subchannels) and its flow rate was controlled at j_g = 0.13. The generated bubbles from a center air injector were almost confined in a center subchannel.

3. Experimental Results

Local void fractions, bubble velocities and Sauter mean diameters were obtained from the precise measurements using an optical two-sensor probe in a subchannel. Generated bubbles from the air/water injector were controlled to make bubble sizes of approximately 2.3 mm diameter. These bubbles less than 5 mm diameter make peaking at rod walls and Fig. 4 shows this well-known phenomena.[3] Local void fraction at rod wall is about 10% while about 2% in a subchannel center. Fig. 5 shows the bubble velocity distribution obtained from separate two sensors. Fig. 6 shows the distribution of Sauter mean diameters. From this result, bubble sizes are uniformly distributed and it was inferred that there was no vital coalescence between bubbles.

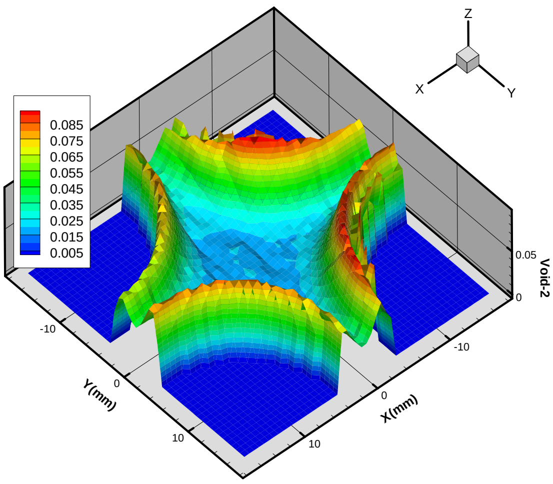


Fig. 4 Distribution of void fraction in a subchannel

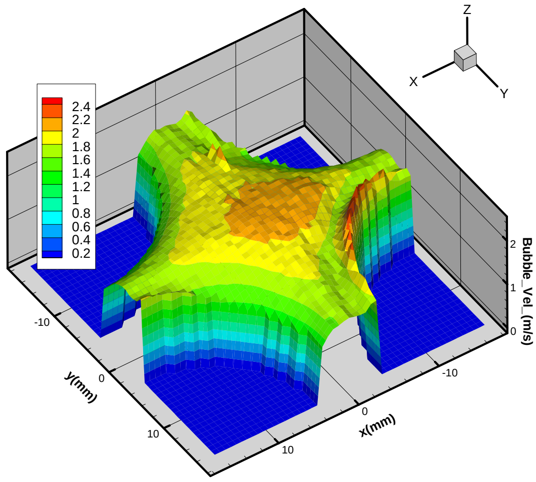


Fig. 5 Distribution of bubble velocities in a subchannel

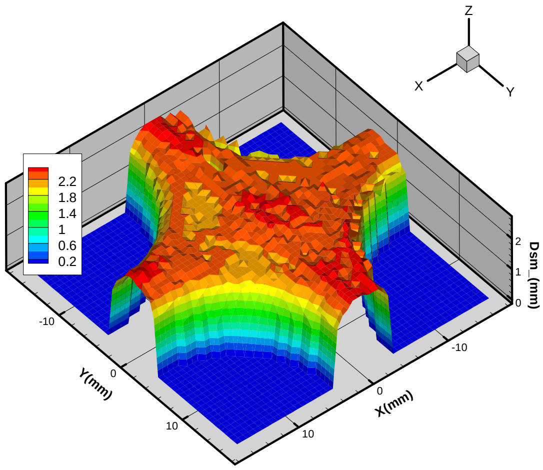


Fig. 6 Distribution of bubble diameter in a subchannel

4. Conclusions

Precise measurement of void fraction and bubble velocities in a subchannel was successfully conducted by using an optical two-sensor probe. Bubbly flow contained small bubbles (~2.3 mm dia.) showed bubble peaks at rod walls.

REFERENCES

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