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Measurement of Air/Water Co-Current Flow in a Large Slab

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1. Introduction

A multi-dimensional two-phase flow characteristic is very important for safety of a nuclear reactor. Most conventional safety analysis codes could not predict proper dynamic features for such a flow condition since those are based on a one-dimensional flow geometry. A lot of effort to improve the capability of safety analysis codes has been made in respect to system or component-wise frames. To develop and validate an analysis code, a sufficient experiment database representing the multi-dimensional two-phase flow is required under well-defined boundary conditions. In this study, an air-water test is performed in a rectangular- shaped test section which has a large cross-section. The measured data includes global and local parameters. Local two-phase parameters such as a void fraction and liquid/air velocities are measured by local conductivity probes and BDFTs (Bi-Directional Flow Tube).

2. Test Facilities and Experiments

2.1 Test Facilities

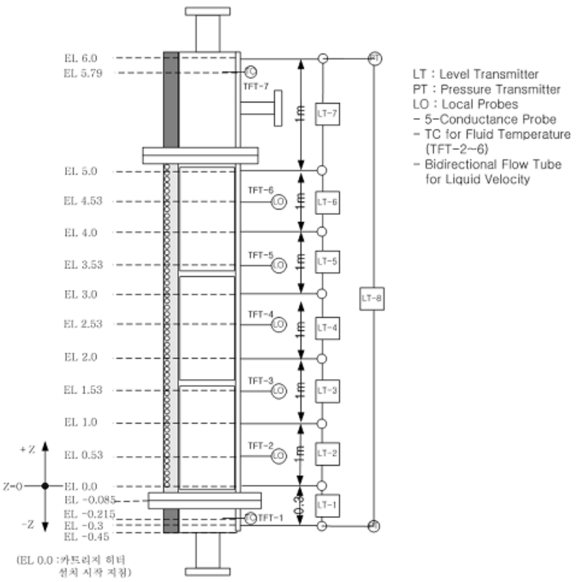

Fig. 1. Schematics and instrumentation of the test section

The DOBO facility has a test section having a rectangular cross section of 0.3m X 0.25m and a height of 6.4m with fluid systems related to air and water supply. Fig. 1 shows a schematic of the test section.

A separator is connected to the outlet pipe of the test section for the phase separation of the two-phase flow. The separated air and liquid phases are respectively split into each return line toward a storage tank. The circulating water is injected into the test section at the bottom of the test section and returned by two centrifugal pumps.

Since this study focuses on the test at the well-defined boundary conditions, the water is supplied from the bottom of the test section, which induces the co-current flow phenomena and no free surface at the upper section. The air is supplied at the lower part of the test section, which is illustrated in Fig. 2.

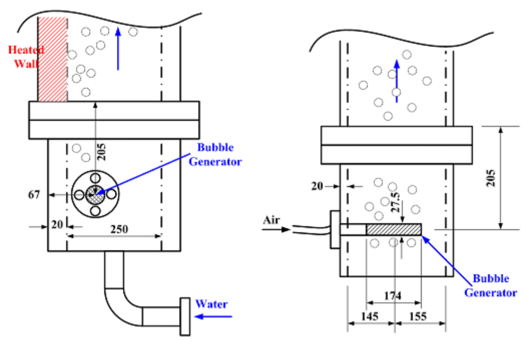

Fig. 2. Air supply into the test section

2.2 Instrumentation

Global parameters such as pressure, temperature and flow rate are measured at the test section and appropriate system position. The instrumentation at the test section is shown in Fig. 1.

The mass flow rates of the circulating water are measured by two Coriolis meters installed at the inlet and outlet pipes of the test section. The system pressure is measured at the top and bottom of the test section by two SMART-type pressure transmitters. Seven SMART -type DP (differential pressure) transmitters (LT-1 to LT-7) are axially spaced along the two pressure impulse taps of the pressure transmitters for measuring both the water level and the axial void fraction. An additional wide-range DP (LT-8) is installed to check the measured DP of the seven DP transmitters and to control the water level at the downcomer. The fluid temperatures are measured by several K-type thermo-couples. The accuracy of each instrument is described in Yun et al.[1]

Two types of local probes were specially developed to measure local two-phase parameters related to the flow dynamics. Steam parameters such as a void fraction and bubble velocity are measured by a multi-sensor conductivity probe. Liquid velocity is measured by a BDFT (Bi-Directional Flow Tube). Five local probes are inserted at each mid-level between DP pressure tabs and traversed to a pre-defined position via a remote controlled two-directional moving system. Five local probes are used for the test. The data is acquired for 30 seconds with 20 kHz at 120 points on each measuring plane.

2.3 Test Conditions

The present geometry of flow is selected in order to simulate a multi-dimensional boiling phenomenon in the downcomer of the nuclear reactor. Therefore, the test conditions were set to have a similar behavior at the upper part of the test section as in the previous boiling test. The referred test condition is R2-1 of the downcomer boiling test. [1] The AW-1 and -2 are the tests by using the conductivity probe and BDFT, respectively. Table I summarizes major boundary conditions.

Table I: Major boundary conditions

Tag	AW-1	AW-2	Comments
PT1 (kPa)	176.7	177.3	Lower Pressure
PT2 (kPa)	118.5	119.2	Top Pressure
LT8 (kPa)	56.05	55.95	DP between Top and Bottom
FT1 (kg/s)	2.41	2.44	Water Flow Rate
FT3 (g/s)	3.62	3.76	Air Flow Rate

2.4 Results

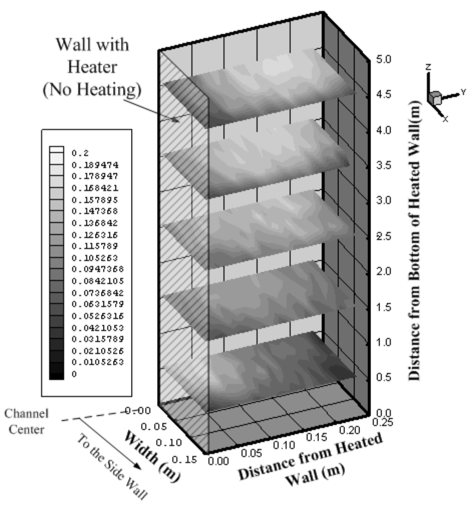

Fig. 3. Local distribution of void fraction (AW-1)

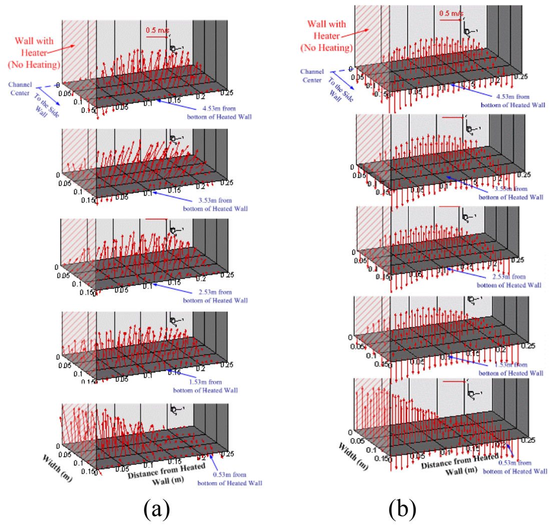

Fig. 4. Local distribution of air (a) and water velocities (b) for AW-1, 2

Fig. 3 shows a local void fraction profile measured at five elevations in the test section. At the lower part of the test section, a high void fraction is shown at the injected wall side. As the flow goes upward, the peak void fraction region is moved toward the bulk region. Fig. 4 shows liquid and steam velocity profiles at each measuring plane, which are in accord with the void fraction profile.

3. Conclusions

To generate experimental data in order to validate a multi-phase flow analysis code, an air-water test was performed with a large, slab-shaped test section. Local two phase parameters including a void fraction and bubble/liquid velocities were measured along with global variables such as an averaged void fraction from the DP. The experiments were performed under well-defined boundary conditions, which would be helpful for utilizing data in developing and/or validating two-phase analysis codes.

Acknowledgement

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REFERENCES

[1] B.J.Yun et. al."Downcomer boiling phenomena during the reflood phase of a large break LOCA for the APR1400", Nuclear Engineering & Design, 238 pp. 2064-2074, 2008.
[2] D.J.Euh, B.J.Yun, “SPACE 코드 검증을 위한 DOBO 실험”, S06NX08-A-1-TR-08 Rev. 00, KAERI, 2009