Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Evaluation of Two-Phase Flow Parameters of a Subcooled Boiling Flow in SUBO Test Using TRACE Code

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1. Introduction

For licensing review of the Safety and Performance Analysis Code for Nuclear Power Plants (SPACE) developed by Korean nuclear industry, many separate/ integral/component effect tests (SET/IET/CETs) are being independently calculated with other safety analysis codes.

Among several SETs, the subcooled boiling (SUBO) test under low pressure conditions was chosen to validate prediction capability of SPACE for subcooled boiling which is an important phenomenon for the safety analysis of nuclear reactor [1]. In SUBO test carried out by Korea Atomic Energy Research Institute (KAERI), bubble behavior was investigated and local two-phase flow parameters were measured [2].

In this study, the prediction capability of the TRACE code [4] for subcooled boiling was identified with SUBO test results as an independent validation so as to compare to the results obtained by SPACE.

2. SUBO Test

The test section of SUBO test facility is shown in Figure 1 [2]. The outer diameter of heater rod is 9.98 mm and the inner diameter of flow channel is 35.5 mm.

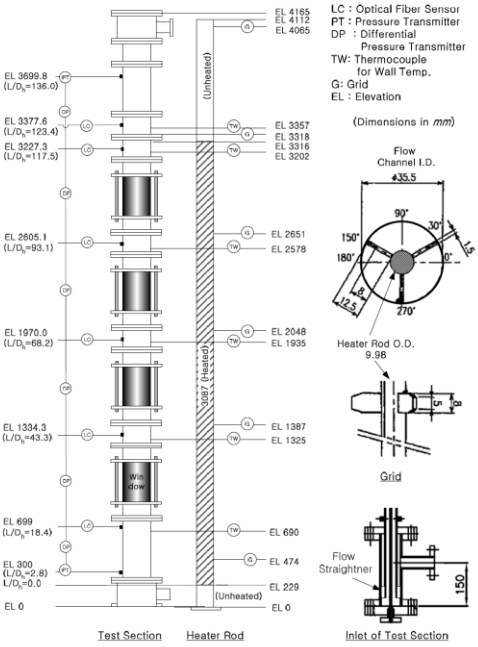

Figure 1. Test Section of SUBO Facility

The heater rod providing constant heat flux consists of three parts in axial direction; unheated lower part, heated part and unheated upper part. The lengths of these three parts are 0.229 m, 3.087 m and 0.796 m, respectively.

Two-phase flow parameters are measured at 6 elevations including local void fraction, temperature and velocity of bubble and liquid, etc. Those parameters are also measured at 11 locations in radial direction between the heater rod and outer wall at each elevation.

6 test cases were selected for the identification of parametric effects of heat flux, mass flux and temperature as shown in Table I [3]. Test was performed by two-stages for the measurement of local bubble parameters and local liquid parameters respectively. The two-stages are identified by “RL” and “RB” in the test matrix.

Table I. SUBO Test Cases

Test matrix	Heat flux (kW/m^2)	Mass flux (kg/m^2-s)	Inlet temperature (K)
Base-RL	472.1	1107.1	374.6
Q1RL	370.5	1107.6	374.5
Q2RL	570.6	1093.1	374.6
V1RL	472.6	2055.6	374.9
V2RL	567.3	2063.0	374.9
T1RL	469.9	1090.8	362.80
Base-RB	473.7	1124.7	374.65
Q1RB	373.6	1122.9	374.25
Q2RB	565.7	1115.3	374.75
V1RB	471.4	2093.2	374.55
V2RB	563.7	2086.6	374.55
T1RB	470.8	1113.8	362.45

3. TRACE Code Modelling of SUBO Test

The TRACE V5.0 patch 4 was used in the calculation. The TRACE model is created with the Symbolic Nuclear Analysis Package (SNAP) version 2.2.10.

The TRACE model of SUBO test section is shown in Figure 2. The three flow channel parts are modeled by PIPE components (30, 40 and 50). The heated PIPE (30) consists of 32 cells while the lower and upper unheated PIPEs consist of 2 and 6 cells respectively. The heater rod is modeled by a heat structure connected to the PIPE component (40). A FILL component (20) is used as the water injection boundary. A BREAK component (10) is used for modeling of outlet boundary

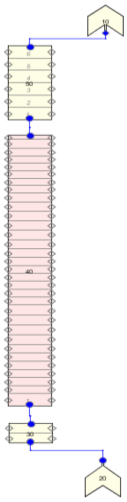

Figure 2. TRACE Model of SUBO Test Section

4. Analysis Results

Figure 3 and 4 plot liquid and bubble velocity obtained from RB and RL test cases, respectively. The calculated liquid velocity matches closely with the predicted one while the predicted bubble velocity is overestimated in all cases such that it could have an influence on the calculation of void fraction. As shown in Figure 4, bubble velocity is assumed to be equal to liquid velocity when void fraction is 0 or very small.

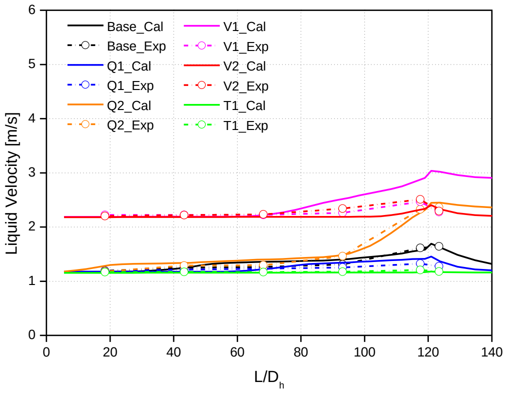

Figure 3. Liquid Velocity

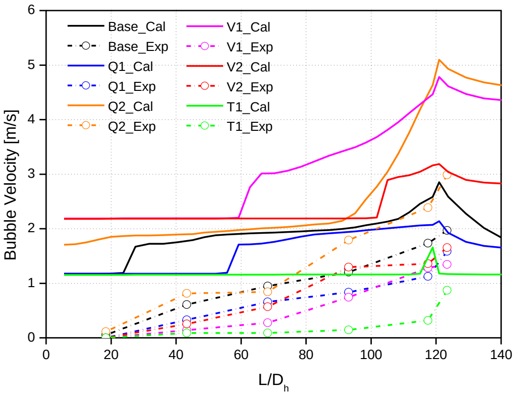

Figure 4. Bubble Velocity

Figure 5 shows the axial void fraction distribution obtained from RB test cases. Although local void fraction is not accurately predicted at inlet and central region of heated part, the predicted void fraction at the end of heated part is similar to measured one. The calculated average void fraction in V1 case differs much from the measured value. It could result from different bubble and liquid velocity.

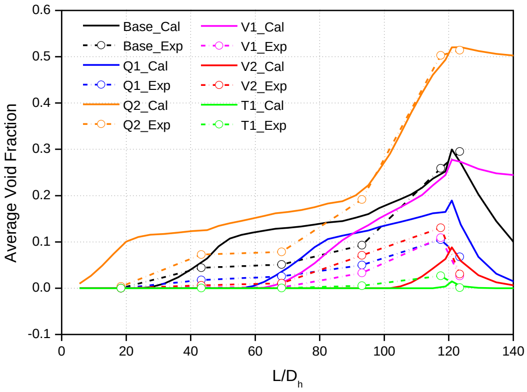

Figure 5. Axial Void Fraction Distribution

Figure 6 illustrates the axial liquid temperature distribution obtained from RL test cases. The predicted temperature agrees well with the experimental result. Though there is a little temperature differences along the flow path, the inlet and outlet temperatures showed a good agreement to the measured values.

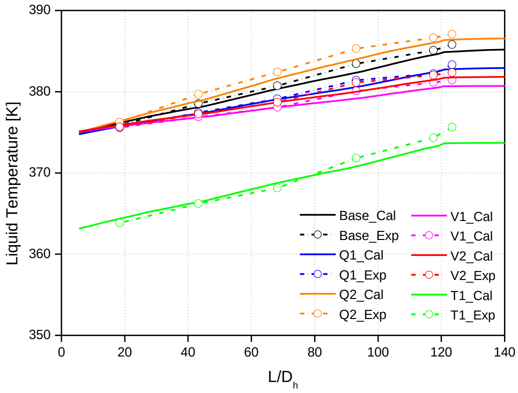

Figure 6. Axial Temperature Distribution

5. Conclusion

The SUBO test under low pressure condition was analyzed with TRACE code. The major two-phase flow parameters including liquid velocity, void fraction and liquid temperature distribution are shown to be in good agreement with experimental results. However, there was the large difference in bubble velocity. Large local void fraction in several test cases which could be led by overestimated bubble velocity shall be resolved with further studies.

Acknowledgments

This work was supported by the Nuclear Safety Research Program through the Korea Radiation Safety Foundation (KORSAFe) and the Nuclear Safety and Security Commission (NSSC), Republic of Korea (Grant No. 1305002).

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