Analysis of TRACE Code for the Downcomer Boiling (DOBO) Test in KAERI

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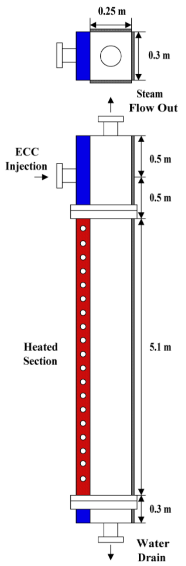
1. Introduction

In APR-1400, the downcomer boiling phenomena was issued from the safety analysis using best-estimate codes during LBLOCA reflood phase since it can significantly affect the core reflood flow rate.[1][2] Therefore, KAERI has set up the Downcomer Boiling (DOBO) test facility and performed the visual observation and measurement of the global two-phase flow parameters.[3] The facility is designed so as to meet a full scale for the height and gap of the downcomer and simulates a 1/47.08 azimuthal part of the prototype downcomer section area. The test section of the DOBO facility and the major experimental data are summarized in Figure 1. The averaged axial void fraction at each elevation is measured by using the DP transmitter. The thermocouple and the pressure transmitter are used to measure the degree of subcooling.



Heat Flux (kW/m²)	50.2	69.7	82.0	91.1
Pressure at the Bottom of the Test Section (MPa)	0.219	0.217	0.222	0.227
DP in the Test Section (kPa)	56.7	50.7	50.5	56.6
Safety Injection Flow (kg/s)	1.22	1.16	1.20	1.20
Temp. of Injected Water (°C)	109.1	110.2	109.6	109.5
Temp. of Drain Water (°C)	117.5	118.2	119.4	130.2

Figure 1. The test section of the DOBO facility and the major experimental data

In the previous study, the results of a safety analysis code, MARS were compared with the measured two-phase parameters.[3] Now, NRC has developed the TRACE code as the unified code for the reactor thermal hydraulic analyses. Because the TRACE code has not been discussed for predicting the downcomer boiling phenomena, it is interested in evaluating its capability for this phenomenon. In this study, the measured data were compared with the results of TRACE v.4.160 for evaluating the code capability for this phenomenon.

2. Calculation methods and results

The DOBO tests showed definitely a bubbly boundary layer near the wall and also the strong multi-dimensional phenomena. To reflect this multi-dimensional effects, a rectangular multi-channel model is applied, where the test section is simulated by 4x24 nodes, as well as the single-channel model as shown in Figure 2.[4] The heated section is simulated by 20 axial nodes and has the length of 5.0m. The temperature and flow rate of the water injected to the upper side of the test section and the bottom pressure are determined from the experimental data as the boundary conditions.

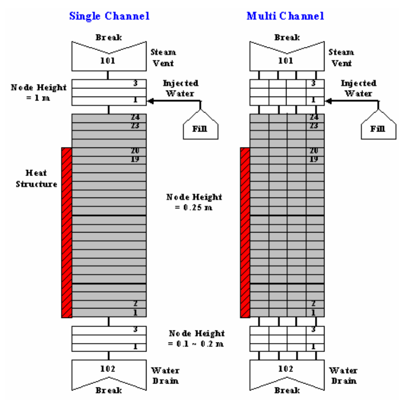


Figure 2. TRACE Model to simulate DOBO test facility

Figure 3 shows the void fraction profiles of the single and multi channels for two heat flux conditions. The single channel model does not predict the lateral void profile shown in the experiment. The multi channel model yields definitely a bubbly boundary layer due to the lateral bubble motion. As the heat flux increases, the results show well that the average voiding increases.

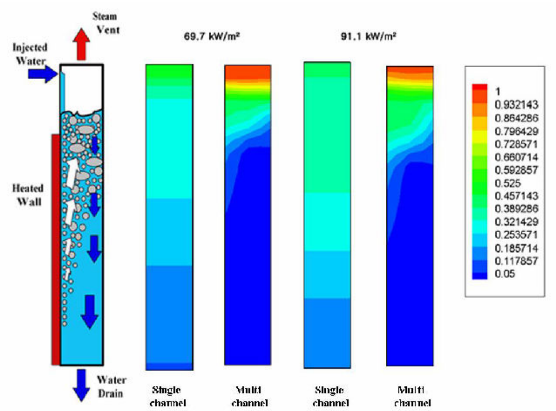
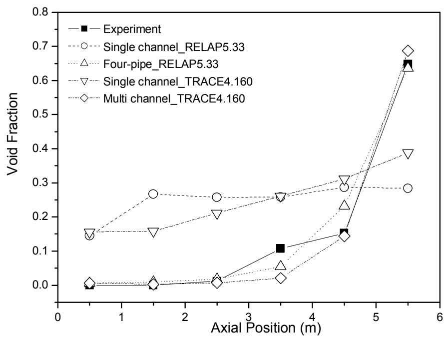
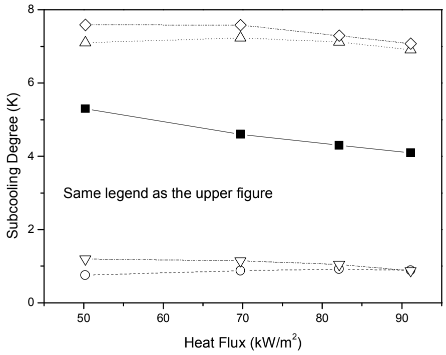


Figure 3. Diagram of a typical DOBO test and void fraction profiles



(a)



(b)

Figure 4. (a) Axial void profile in the heated section for 69.7 kW/m^2 (b) Liquid subcooling at the bottom of the test section

Figure 4 shows the void profiles and the liquid subcooling degree of the various models for the 69.7 kW/m^2 of the heat flux condition. According to the results, the single-channel model overestimates the void fraction for the most part of channel because the excessive energy of the generated steam is transferred to the liquid. This induces the underestimation of the subcooling of the drain water as shown in Figure 4(b). In the upper region, the void fraction difference between two codes for the single-channel model can come from the difference of the flow regime. TRACE treats as an interpolation regime for the range of $0.5 \leq \alpha \leq 0.75$ and closure parameters on the interfacial-drag and heat-transfer are calculated as a weighted average of the appropriate bubbly slug and annular-mist values.[5] The 4-channel model for RELAP follows the trend of the experimental data since a homogeneous cross-flow option is used to reduce the active lateral bubble motion.

Figure 5 shows the axial void profiles of the multi-channel model for the TRACE in various heat flux conditions. The multi-channel model for the TRACE has a similar axial void profile to that of the experiment. In respect of the axial void profile, the multi-channel models agree well with the experiment. However, the models yield a higher subcooling than the experiment as shown in Figure 4(b). The multi-channel models are less conservative in respect of the water temperature for the core cooling. Therefore, the separated evaluation for the subcooled boiling model is necessary to investigate the code prediction capabilities, which include the wall nucleation and condensation.

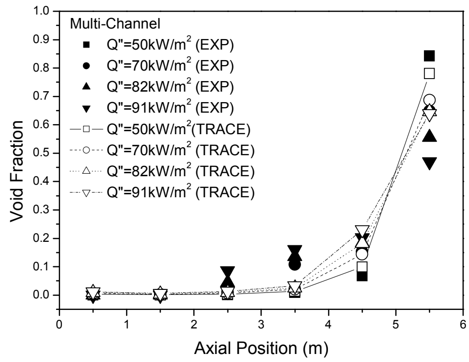


Figure 5. Axial void profile for the multi-channel using TRACE

3. Conclusions

The single- and multi-channel models are applied for the analysis of the downcomer boiling phenomena. The multi-channel models predict well the void fraction and overestimate the subcooling of the drain water. Therefore, the subcooled boiling model of TRACE should be improved for the wall nucleation, flow regime map and interfacial heat transfer.

Acknowledgement

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