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Assessment of SPACE Code Using the LOBI LOCA Test

Yo-Han Kim*, Boram Gil, Chang Keun Yang
KHNP Central Research Institute, 1312-70-gil Yuseong-daero Yuseong-gu, Daejeon, 305-343, Korea
**johnkim@khnp.co.kr*

1. Introduction

The Korea Nuclear Hydro & Nuclear Power Co. (KHNP) has developed a multipurpose nuclear safety analysis code, called the Safety and Performance Analysis Code for Nuclear Power Plants (SPACE), through collaborative work with other Korean nuclear industries. The SPACE is a best-estimated two-phase three-field thermal-hydraulic analysis code used to analyze the safety and performance of pressurized water reactors (PWRs). As in the second phase of the project, the release version of the code has been developed through the intensive validation and verification (V&V) using integral loop test data or plant operating data and the complement of code to solve the SPACE code user problem & resolution reports.

In this study, the Loop of Blowdown Investigations (LOBI) Loss of Coolant Accident (LOCA) test, A1-66, was simulated as a V&V work. The results were compared with the experimental data and those of the RELAP5/MOD3.1 code simulation.

2. LOBI LOCA Test Description

2.1 LOBI

The LOBI was designed as a 1/712 volumetric scale integral test facility to simulate the thermal-hydraulic response of a typical Westinghouse 4-loop 1,300 MWe PWR by the joint research of Commission of the European Community and Bundesminister fur Forshung und Techmologie. The height of each component and relative elevations, however, were full scale to reflect the gravitational head. The LOBI core consists of 8X8 3.9 m heated length rod bundle. The rated thermal output of the core was 5.3 MW. For the LOCA tests, three locations of breaks, *i.e*., hotleg, coldleg, and intermediate leg, were simulated in the broken loop (BL), and one intact loop (IL) was installed to represent remained three loops. Each of the two primary loops contains a pump and a steam generator. The different mass flows in the loops were implemented through different pump speeds, since the pumps had same performance. The accumulator was designed to inject emergency core cooling water to the IL coldleg. The pressurizer was connected to the IL hotleg.

2.2 LOCA Test

The A1-66 test was the first experiment following the downcomer gap change from 50 mm to 12 mm. In the first series of LOBI, the downcomer gap of 50 mm was used, which resulted in distortion of the mass flow distribution of the scaled system. The scaled annular gap size was 7 mm and modified size was 25 mm to consider the pressure drop of reference palnt. The compromise size was determined between them to implement more realistic flow pattern in the vessel downcomer. The break event was simulated through the manual operation of a break units located on the BL coldleg. Following the steady-state condition, the break units, *i.e*., pump-side and vessel-side valves, opened and the valve for normal coldleg flow simultaneously closed. The throat diameter of the break valves were 30 mm, respectively.

3. Modeling & Simulation

3.1 SPACE Code Modeling

The LOBI facility was modeled to simulate A1-66 test using the SPACE code (Fig. 1). The core was split into the average core (C400) and hot channel (C401), and expressed as 24 stacked sub-cells, respectively. The sub-cells of average and hot cores were connected each other to simulate cross-flow. The pressurizer (C530) was connected to the IL hotleg (C510) through the surge line (C520), and expressed as 10 vertical stacked sub-cells. The accumulator (C615) was connected to the IL coldleg (C612). The valve C764 was located between C772 and C774 to simulate normal flow.

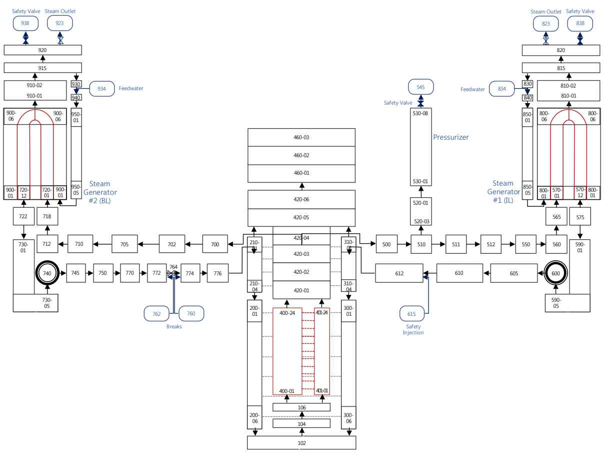


Fig. 1 LOBI model to simulate the LOCA test

The break units were connected to C772 and C774 using the temporal face boundary condition (TFBC) models, respectively. The feedwater was injected to C840 and C940 through TFBC models. The main steam was removed through TFBC C823 and C923. The safety valves on pressurizer and two steam generators were modeled as C545, C838 and C938 using TFBC models of pressure boundary conditions, respectively. The model was composed of 198 cells, 246 faces, and 120 hydraulic components. The Ransom-Trapp (RT) model was used to simulate the critical flow with various discharge coefficients (Cd) for the sensitivity study.

3.2 LOCA Simulation

With the breaks at BL coldleg, the blowdown was started at the conditions listed in Table 1. The accumulator was open about 2.4 MPa.

Table 1. Initial conditions for the simulated LOCA test

Parameters	Values	
	Meas.	Cal.
Mass Flows of IL/BL, kg/s	20.5/6.9	21.1/7.0
Upper Plenum Press., MPa	15.4	15.47
IL RPV In/Out Temp., ℃	324/291	324/291
BL RPV In/Out Temp., ℃	324/290	324/291
PZR Temp., ℃	348	306
Core Power, MW	5.24	5.24
Acc.Press. & Temp, MPa/℃	2.7/3.2	2.7/3.2
Feedwater of IL/BL, kg/s	2.1/0.64	2.1/0.64
Steam Press., MPa	5.7	5.4
SG Inlet Temp. of IL/BL, ℃	179/174	179/174
SG Outlet Temp., ℃	272	268.8

For the break flows (Fig. 2), the results exhibited similar trends to those of the experiment or RELAP5. The initial flows of SPACE code showed less value than those of test, however, the difference was declined following the transient progress as mentioned in Fig. 3.

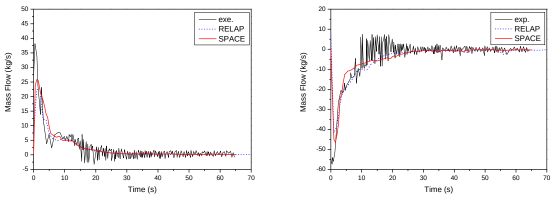


Fig. 2 Break flow (PS & VS)

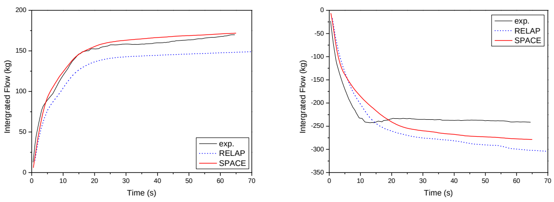


Fig. 3 Integrated Break flow (PS & VS)

The calculated pressures of hotleg and coldleg showed similar trends to those of test (Fig. 4). Before 7 seconds, the SPACE showed a little higher value than test, and followed the similar trends. The PZR pressure (Fig. 5) exhibited similar trends at initial period, and showed some difference during the period of 15~45 seconds. The core power (Fig. 6) showed the same values in most periods.

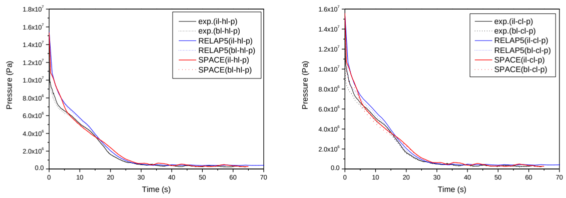
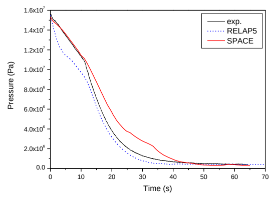


Fig. 4 RCS Pressure of HL & CL



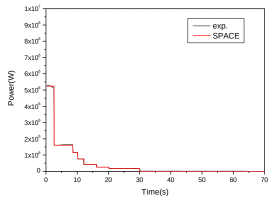


Fig. 5 PZR Pressure Fig. 6 Core Power

To confirm the effect of various Cd values, the sensitivity study was performed. As depicted in Fig. 7, the break flows were varied by the different Cd, and the break flow effect by the difference spread out to the other parameters.

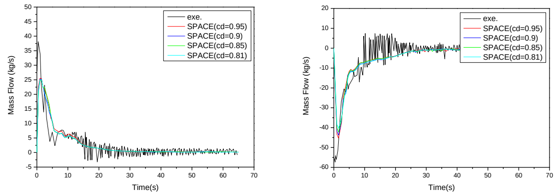


Fig. 7 Break flow (PS & VS)

3. Conclusions

The LOBI Coldleg Break LOCA test, A1-66, was simulated using the SPACE code. The results were compared with experimental data and those from the RELAP5 code simulation. Through the simulation, it was concluded that the SPACE code can effectively simulate LOCA accidents.

Acknowledgements

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