Code Assessment of SPACE 2.19 using LSTF 10% Main Steam-Line-Break Test

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1. Introduction

The Safety and Performance Analysis Code for Nuclear Power Plants (SPACE) has been developed in recent years by the Korea Hydro & Nuclear Power Co. through collaborative works with other Korean nuclear industries and research institutes. 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. As a result of the development, the 2.19 version of the code was released through the successive various verification and validation works.

The present work is on the line of expanding the work by Kim et al. [1]. In this study, results produced by the SPACE 2.19 code were compared with the experimental data from JAERI's LSTF Test Run SB-SL-01 for a 10% main steam line break transient in a pressurized water reactor.

2. Experimental Facility Description

The Rig Of Safety Assessment (ROSA)-IV Program's Large Scale Test Facility (LSTF) is a test facility for integral simulation of thermal-hydraulic response of a pressurized water reactor (PWR) during small break loss-of-coolant accidents (SBLOCAs) and plant transients. The PWR core nuclear fuel rods are simulated by using electrical heater rods in the LSTF. The LSTF experimental facility was designed to model the thermal-hydraulic phenomena in a PWR during postulated small break LOCAs and plant transients.

Experimental run SB-SL-01 was conducted during 1990 in the LSTF, located at the Japan Atomic Energy Research Institute (JAERI). This experiment simulated a 10% main steam line break transient in a pressurized water reactor, and it was initiated by manual operation at the beginning of the break. The break was located in the main steam line of steam generator B. The break diameter was 31.9 mm, which corresponds to 10% of the main steam line. The experiment SB-SL-01 was carried out at full power [2,3]. Table 1 summarizes the sequence of events used for test run SB-SL-0l.

3. Modeling and analysis

3.1 SPACE code modeling

The LSTF facility for experimental run SB-SL-01 is modeled with 189 fluid cells and 199 connections. The system nodalization is illustrated schematically in Figure 1. A total of 180 heat structures were used in the model to represent heat transfer in the steam generator, reactor, primary system piping, and pressurizer. The 10 % main steam line break was simulated by opening a valve (component #915) at break time. The break diameter was 31.9 mm. The break line was branched from steam-line with 3 sub-CELLs and a pressure boundary of temporal face boundary condition (TFBC) model. In the modeling of break flow, Ransom-Trapp critical flow model was used and corresponding discharge coefficient 1.0 were selected.

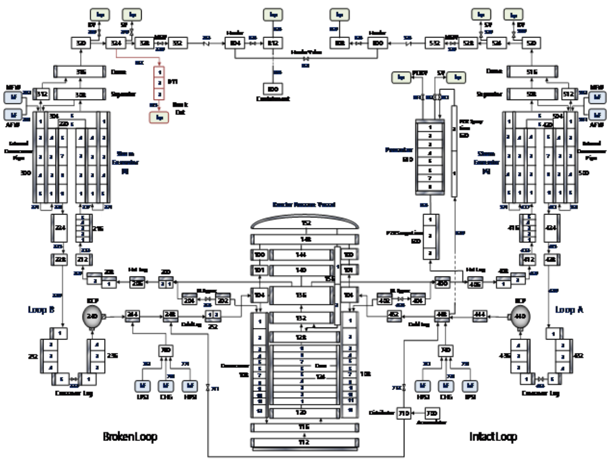

Fig. 1 Nodalization diagram of LSTF MLSB test

Table 1 Sequence of events for Experiment SB-SL-01

Event (sec)	*Experiment*	*SPACE 2.19*
Transient initiation	0	0
Reactor SCRAM	0	0
MSIV closure	2	2
Feedwater valve closure	2	2
Turbine throttle valve closure	0	2
Auxiliary feedwater injection	28	28
High pressure safety injection	1,156	1,156

3.2 Results and analysis

The steady state simulation was performed in order to obtain appropriate steady state system conditions prior to the initiation of a steam line break. A comparison between the simulated initial test conditions obtained and the corresponding measured initial test conditions are given in Table 2. The agreement between the simulated and the measured initial test conditions is satisfactory.

Table 2 Initial and Boundary Conditions

Parameters	*Measured*	*Calculated*
Core power, MW	10.00±0.044	10.00
PZR pressure, MPa	15.52±0.080	15.59
Hot-leg temperature, K	598.10±4.396	599.38
Cold-leg temperature, K	562.40±4.134	564.10
Pressurizer level, m	2.70±0.0086	2.64
SG pressure, MPa	7.30±0.0393	7.30
SG level, m	10.30±0.0329	9.95
Feedwater temperature, K	495.20±3.8477	495.35
Main steam flow, kg/sec	2.74±0.0442	2.75

Figures 2–9 represent the thermal-hydraulic phenomena during transients. Figures 2 and 3 shows a comparison between the experimenta data and the calculated results for the steamline break flow. The data comparisons are generally good, except for about 500 sec in void fraction. The small deviation of the experimental data from this value could be attributed to uncertainties associated with experiments and the processing of test data [2].

The RCS and secondary pressure response are shown in Figures 4 and 5. The pressurizer pressure decreased according to the increased heat removal from the primary system to secondary system by the increasing steam outflow through the breaks. The pressure was recovered by the injection of HPSI. The pressure difference exists between about 550 and 1,250 seconds because of the decrease of liquid flow in the broken loop hot-leg [1]. On the other hand, the secondary side depressurization transients for the both broken loop and intact loop are predicted quite well by the SPACE 2.19 in relation to the experimental variation.

The comparisons for collapsed liquid level of the pressurizer are shown in Fig. 6. The comparisons are excellent for the initial 1500 sec. However, beyond the HPSI injection time when the refill process gets initiated, the comparisons are less satisfactory as the code underpredicts. Because the measurable range of pressurizer level measurment system is from 0.0 to 4.0m, this phenomena is due to the measurement uncertainty or processing error [3]. The maximum value of PZR level is changed from 4.8731m to 4.0m, as shown in modifed experimental data. From the comparison, the overall behavior agrees well with experimental data.

Figure 7 shows the steam generator collapsed liquid level of the intact and broken loops. The results are reasonably satisfactory, although the code prediction typically underestimates the experimental values.

Figures 8-9 represent the thermal response. The cold leg temperature variation is shown in Fig. 8. In the intact loop, the code predictions show excellent agreement with experimantal data until HPSI injection time. These comparisons have a different after HPSI injection time. The colder HPSI liquid causes a nearly instantaneous steep change in the observed temperature, leading to lowering of the cold leg temperature. On the other hands, the broken loop cold leg temperatures decrease on account of the blowdown of the secondary side by the isolated, broken loop steam generator. Figure 9 represents the hot leg temperature of the intact and broken loops. For both of these cases, the SPACE 2.19 predictions show very good agreement with the experimental data.

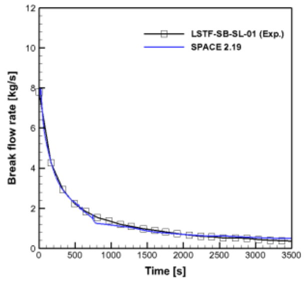

Figure 2 Break flow

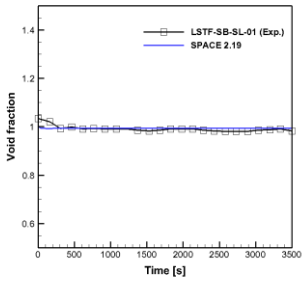

Figure 3 Void fraction of break flow

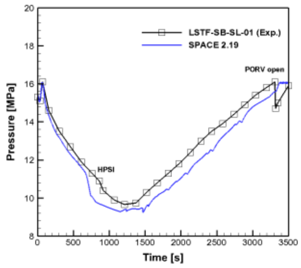

Figure 4 PZR pressure

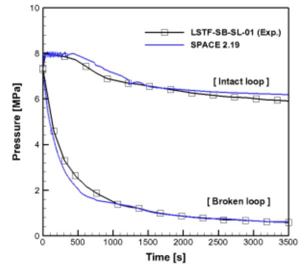

Figure 5 SG pressure

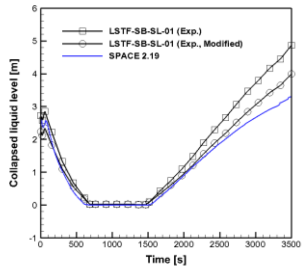

Figure 6 PZR level

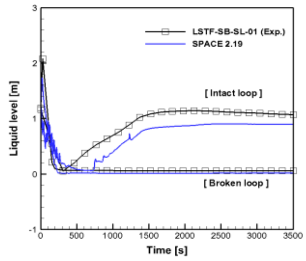

Figure 7 SG level

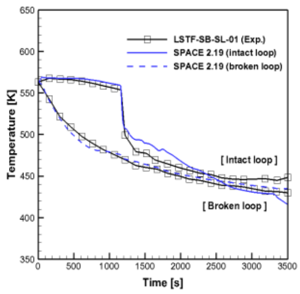

Figure 8 CL temperature

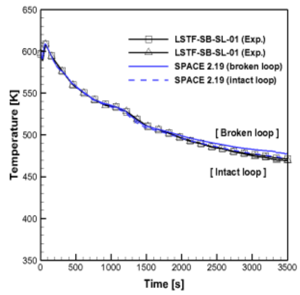

Figure 9 HL temperature

Based on the calculated results, the input model is modified for simulation accuracy of PZR pressure. For case 1, the PORV setpoint is modified by correcting the switching logic to open and close at 16.1 MPa and 14.7 MPa respectively based on the experimental data [2]. The code results show excellent agreement with the experimental data after PORV open time.

In addition, the surgeline heat structure is added for the increase heat transfer after HPSI injection time. As a result, the prediction of PZR pressure of code data is improved in the pressure recovery period, as shown in Case 2. The PORV setpoint and surgeline heat structure is applied in Case 3. The computed results show a reasonable agreement with experimental data in overall transient time.

Table 3 Input modification for PZR pressure

	PORV setpoint	*Surgeline heat strucrue*
Baseline	X	X
Case 1	O	-
Case 2	-	O
Case 3	O	O

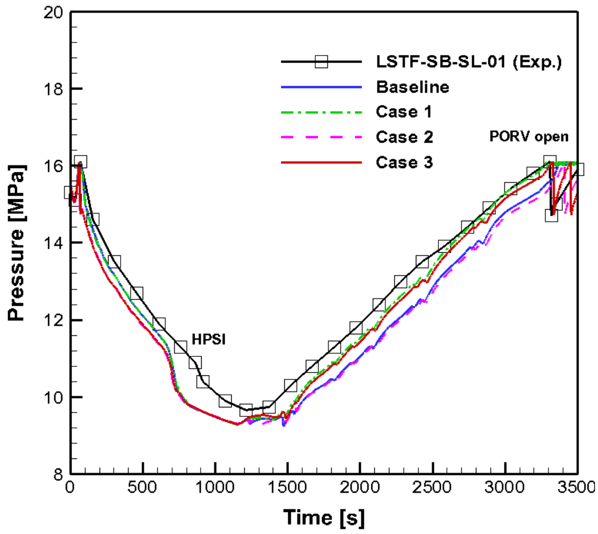

Figure 10 Modification of PZR pressure

4. Conclusions

The LSTF 10% main steam line break test were simulated using the SPACE 2.19 for code V&V work. The overall comparisons between the SPACE 2.19 code prediction and the LSTF Test Run SB-SL-01 experimental data are reasonably satisfactory. The comparisons were conducted in terms of the variations of mass flow rate, void fraction, pressure, collapsed liquid level, temperature, and system flow rate for the transient. In addition, the input model was modified for simulation accuracy of PZR pressure based on the calculated results. The correction of PORV setpoint affects to simulate the PORV open and close phenomena similarly with experiments. Also, the surgeline heat structure was added for the increase heat transfer after HPSI injection time. From the modification, the computed results show a reasonable agreement with experimental data in overall transient time.

ACKNOWLEDGMENTS

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