Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Sensitivity studies for LOFT L9-3 analysis using the SPACE 3.2 code

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1. Introduction

The SPACE code is developed for DBA(Design Basis Accident). In the ongoing 'Development of Design Extension Condition Analysis and Management Technology for Prevention of Severe Accident' project, the SPACE code is being expanded to allow the analysis of multiple fault cases. In order to confirm the ATWS(Anticipated Transient Without Scram) accident, which is one of the multiple fault accident, evaluation ability of SPACE(Safety and Performance Analysis CodE for nuclear power plants) codes, LOFT(Loss Of Fluid Test) L9-3[1] experiment simulating loss of feedwater ATWS phenomenon was analyzed using the SPACE code and the results were compared. In this study, SPACE version 3.2 was used. This paper states the sensitivity analysis results for the critical flow model and the secondary nodes in LOFT L9-3 analysis using the SPACE codes.

2. Methods and Results

2.1 Experiment Conditions

The LOFT L9-3 experiment was conducted under following steady state conditions: 48.7MWt of core power, 557.0K of cold leg temperature, 576.4K of hot leg temperature, 14.98MPa of pressurizer pressure, and 5.61MPa of steam generator pressure. The initial steady-state conditions for the experiment are shown in Table I.

Table I: Experiment Initial Values

Parameter	Experiment	SPACE
RCS Flow Rate (kg/s)	467.6±2.7	467.63
Cold Leg Temp. (K)	557.0±1.5	555.04
Hot Leg Temp. (K)	576.4±1.6	574.56
Power Level (MWt)	48.7±1.2	48.7
PZR temperature (K)	615.2±0.3	614.78
PZR pressure (MPa)	14.98±0.06	14.98
SG Liquid Level (m)	3.15±0.09	3.19
SG Pressure (MPa)	5.61±0.06	5.55
Steam Flow Rate (kg/s)	25.7±1.1	26.6

2.2 Experiment Sequence

The LOFT L9-3 experiment begins by stopping the main feed pump to the secondary of the steam generator. When the feedwater is interrupted, the heat transfer from the primary side to secondary side of the system is reduced, and the pressure of the system is increased. When the system pressure increases, the pressurizer spray is activated to lower the pressure. Even after that, the pressure of the pressurizer is rapidly increased due to the continuous reduction of the secondary feedwater flow and the closure of the steam generator MSCV(Main Steam Control Valve), despite the operation of the spray. The pressurizer PORV(Pressurizer pilot Operated Relief Valve), SRV(Safety Relief Valve) reaches the opening set point, and it is opened and closed continuously. In addition, when the feedwater supplied to the steam generator is interrupted, thermal energy transfer from the primary system to the secondary system sharply decreases. And the temperature of the moderator in the primary side is increased. Subsequently, the core power is reduced due to the feedback effect of the moderator reactivity.

2.3 LOFT L9-3 SPACE Modeling

SPACE code input of LOFT L9-3 experiment was made with reference to NUREG/IA-0192[2](Fig. 1). The reactor pressure vessel was divided to simulate core, bypass flow, and upper and lower plenums. The core is modeled as an upper and lower non-fuel area and a fuel area represented by three vertical nodes. The steam generator was modeled as 12 PIPE components for the U-tube and 19 PIPE components for the secondary side. The pressurizer safety valves were modeled as TFBC(Temporal Face Boundary Condition) component C810(SRV) and C820(PORV).

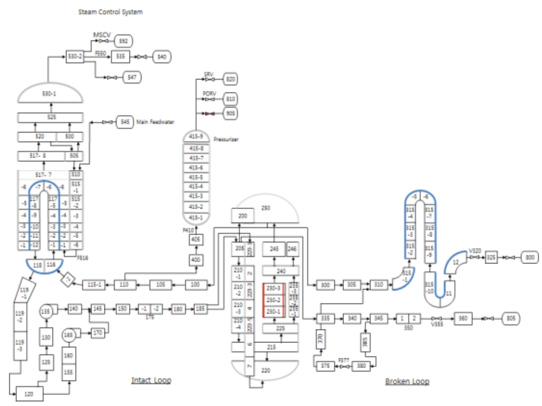

Fig. 1. LOFT L9-3 experiment nodalization.

2.4 SPACE Critical Flow Model Sensitivity Analysis

Sensitivity analysis was performed on the following three critical flow models used in the SPACE code.

1. Ransom-Trapp critical flow model
2. Henry-Fauske / Moody critical flow model
3. Henry-Fauske critical flow model

The effect of critical flow model was evaluated using the three critical flow models for PORV, SRV discharge flows. The critical flow discharge coefficient was 1.0, which is the default value, for all three models.

Fig. 2 shows the results of pressurizer pressure calculation according to the critical flow model. All three critical flow models show no significant difference until the time of PORV opening. However, after the PORV is opened, the results of the Ransom-Trapp critical flow model predict the pressurizer pressure slightly higher than those of other critical flow models.

Fig. 3 compares the calculation results for the coolant discharge through the PORV and SRV with the critical flow model. When using the Henry-Fauske / Moody and Henry-Fauske critical flow model, it was confirmed that the discharge flow was predicted higher than the Ransom-Trapp critical flow model. The SPACE code recommends using the Ransom-Trapp model for best-estimate analysis of critical flow.

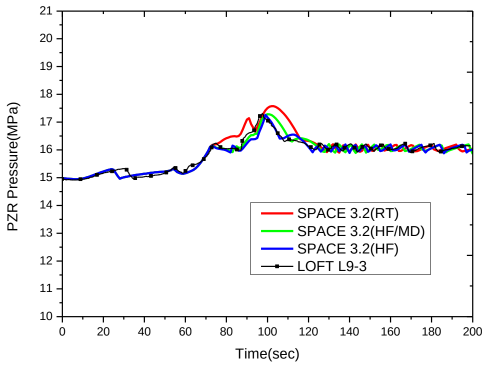

Fig. 2. Pressurizer pressure analysis results(critical model sensitivity).

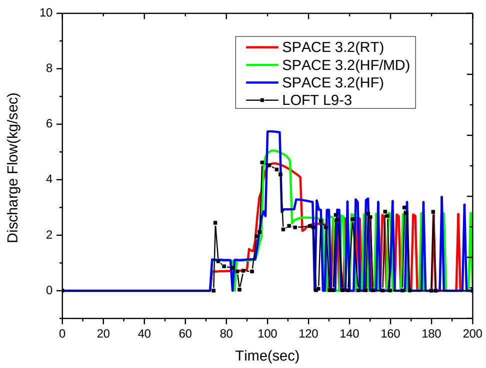

Fig. 3. Discharge flow analysis results(critical model sensitivity).

2.5 SPACE Node Sensitivity Analysis

In the ATWS analysis, the secondary side heat transfer is an important variable. So, the effect of secondary node number was evaluated. The node number was 1,2,3,6 and 9.

Fig. 4 shows the results of pressurizer pressure calculation according to the secondary node number. All five node numbers show no significant difference until the time of MSCV closing. However, after the MSCV is closed, the results of the 1 node predict the pressurizer maximum pressure much higher than other node numbers. The maximum pressures for each node are 18.99MPa, 18.0MPa, 17.71MPa, 17.58MPa, 17.82MPa. When the number of nodes is 1, the flow regime is different and the amount of heat transfer from the primary to the secondary is small. So, the temperature and pressure of the primary side is increase. When the number of nodes is 6 or less, it can be confirmed that the experimental values converge. When the number of nodes is 6 at the maximum pressure, the results is most similar to the experimental value.

Fig. 5 compares the calculation results for the coolant discharge through the PORV and SRV with the node number. Although the number of secondary nodes is changed, the same critical flow model is used for PORV and SRV, and there is no significant difference in the discharge flow rate depending on the nodes.

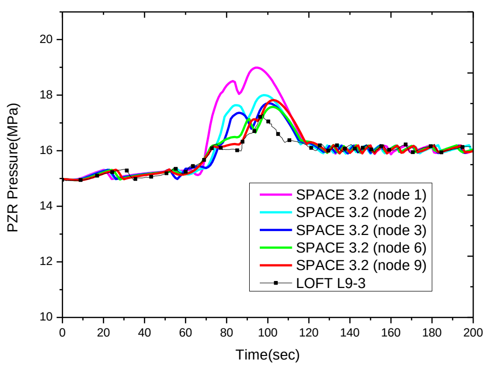

Fig. 4. Pressurizer pressure analysis results(node sensitivity).

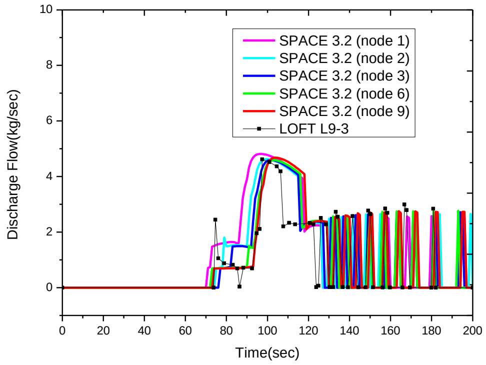

Fig. 5. Discharge flow analysis results(node sensitivity).

3. Conclusions

The SPACE code was evaluated for the LOFT L9-3 experiment to confirm its ability to analysis ATWS accidents, and the sensitivity of critical flow model and secondary side node numbers were evaluated. Although the analysis results differ according to the critical flow model, the overall behavior is similar to the experimental values. The sensitivity of the secondary node numbers was confirmed to be appropriate when the number of nodes was 6 according to the primary maximum pressure results. We confirmed that the SPACE code can properly simulate ATWS.

Acknowledgements

This work was supported by the Korea Institute of Energy Technology and Planning(KETEP) and the Ministry of Trade, Industry & Energy(MOTIE) of the Republic of Korea. (No. 20161510101840)

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