Simulation of Cold-Leg Small Break LOCA for ATLAS using SPACE Code

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1. Introduction

SPACE code is a system analysis code for a pressurized water reactor. This code uses two-fluid and three-field system and has the capability to handle multi-dimensional flow. For a few years, a variety of validation tests have been intensively performed to secure the prediction accuracy for interfacial/wall drags, interfacial/wall heat transfers, and droplet generation. Hence, this study is dedicated to show the simulation capability of SPACE code for the integral effect tests. Toward this end, a SBLOCA scenario of the ATLAS integral loop was simulated using SPACE code. The transient was initiated by breaking a cold-leg. The break size was equivalent to 6-inch in APR1400.

2. Steady-state simulation

The nodding diagram for simulation is not shown here. Detailed configurations will be presented at the conference. The reactor downcomer was modeled using six pipes connected with cross flow. Table I shows the prediction result for the steady-state, which corresponds to 8 % power of APR1400. On the whole, the prediction agrees fairly well with the experiment. A reduced power was applied to the core, with consideration of experimental heat loss. The turbine was modeled simply using a pressure boundary. The core consists of 390 heating rods: 389 for average channel and 1 for hot channel.

Table I: Steady-state result

Parameters	APR1400	ATLAS	SPACE
Core power	3983 MW	1.64	1.553
Pressure (RCS)	155 bar	155.1	155.1
Cold-leg flow	5540 kg/s	2.2	1.92
Cold-leg temperature	564.3 K	565.4	562.6
Hot-leg temperature	597.2 K	597.6	598.0
Pressure (secondary)	69 bar	78.3	78.3
Flow rate of feed water		0.431	0.435
Circulation ratio in S/G	~ 4	>10	14.5

3. Transient simulation

3.1 Test models and conditions

Table II: Sequence of events for cold leg-break SBLOCA

Events	ATLAS experiment[4]
Break open	0 second
LPP signal	when $p < 10.7$MPa
PZR heater trip	LPP + 0.0s
Reactor scram & RCP trip	LPP + 0.35s
Turbine isolation	LPP + 0.07s
Main feedwater isolation	LPP + 7.07s
SIP start	LPP + 28.28s
SIT start	when $p < 4.03$MPa

Table II lists the sequence of accident events[1]. The transient is initiated by the opening of break valve. The break area is 8.96×10^{-5} m^2 corresponding to 6-inch break in APR1400 (4% of the cold-leg area). The decay of the core power is designed to follow the 1.2 times of the ANS-73 curve for the conservative condition. A single failure of a diesel generator is assumed, consequently, the safety water from the SIPs is injected only through the DVI-1 and -3 nozzles.

As a chocking model for break flow in the SPACE simulation, the Ransom and Trapp model was used with the discharge coefficients of 1.0 (sub-cooled), 1.2 (two-phase flow), and 1.0 (super-heated). The heat loss of steam generators was considered to make the secondary pressure decrease with time. The SIP flow rates obtained in the experiment were applied to the simulations, as a function of the primary pressure.

2.2 Results

Figure 1 show the pressure variation with time. The predicted pressures lie on the experimental lines.

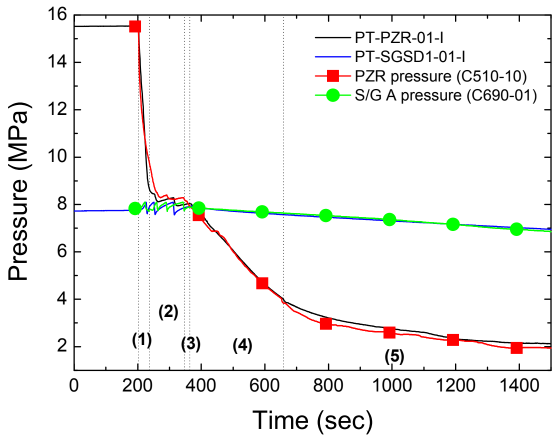

Fig. 1. Variation of primary and secondary pressures

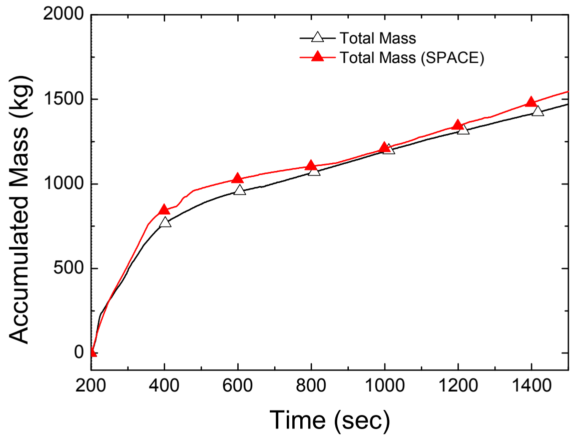

Fig. 2. Accumulated mass of break flow

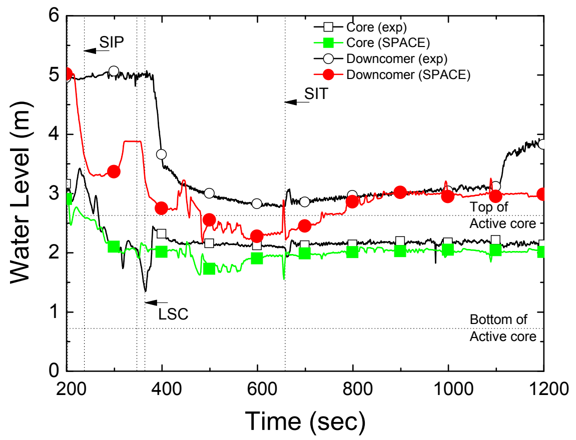

Fig. 3 Collapsed water levels in the core and the downcomer

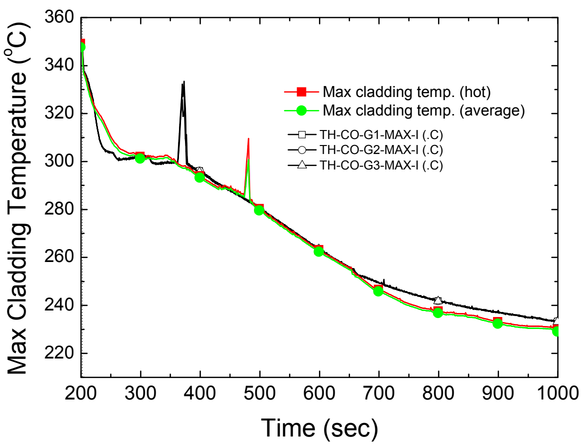

Fig. 4 Maximum cladding temperature

The major parameters are compared with experiment through Figs. 2~5. It is observed in Fig. 2 that the break flow is well predicted. As for the water level, general trends are similar to the experiment. However, clear loop seal clearing is not seen. In the early stage, the downcomer level is lower than the experiment, which may be due to the wrong initial temperature in the upper head. The bypass flow between the upper head and the downcomer is upward in the simulation, thus, the water temperature in the upper head is close to the hot-leg temperature. The bypass flow direction was not reported in the experiment. The downcomer level is not recovered and it remains at a cold-leg level even after a long time. We presume that these results might originate from insufficient ability for horizontal gravity effect and ECC bypass prediction. It is clearly observed that the water levels fluctuate at the moment when SITs start to work at about t=650s. Figure 5 shows the water levels in the cross-over legs. In the experiment, loop seal clearing occurs in three cross-over legs (1A, 2A, 2B) and the clearing times are around 370 seconds. In the simulation, the first loop seal clearing occurs at the same location as the experiment. The clearing time is around 360 seconds. But loop seal clearing is not as evident as the experiment.

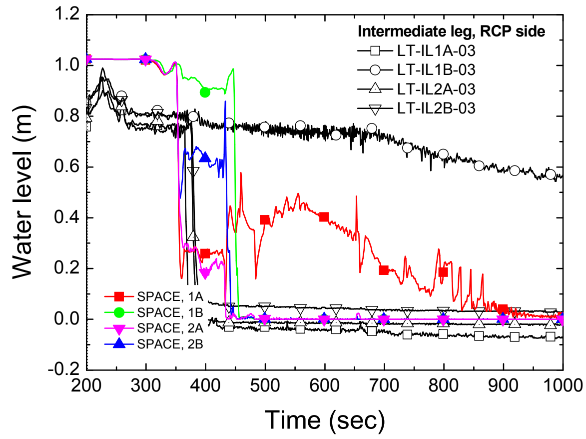

Fig. 5 Collapsed water level in the cross-over leg

4. Conclusions

A cold leg break SBLOCA has been simulated using SPACE code. The reference experiment is the ATLAS integral test. The break size is equivalent to the 6-inch in APR1400. The predictions are reasonable on the whole. But there are some discrepancies between the simulation and the experiment. In particular, the downcomer level and loop seal clearing show some needs for code improvement. At this moment, many efforts are being made to improve the prediction capability to cope with the aforementioned phenomena.

ACKNOWLEDGMENTS

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REFERENCES

[1] Cho et al., 6 inch Cold Leg SBLOCA Simulation Test(SB-CL-09) Report Using the ATLAS, KAERI/TR-4077, 2010.