Prediction Capability of SPACE Code about the Loop Seal Clearing on ATLAS SBLOCA

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1. Introduction

The DSP-04(Domestic Standard Problem-04) is a benchmark program of the cold leg top slot break accident of APR1400 reactor[1][2]. During the auditing procedure of design certification, NRC has pointed that the deep loop seal of APR1400 may cause the loop seal reforming and fuel surface temperature rising as the consequence. In order to resolve the concerns, KAERI has performed series of ATLAS experiments about the cold leg top slot break accident[3]. Also, KAERI organized a domestic standard problem for code validating bench mark. The most possible break size for loop seal reforming has been decided as 4 inch by the pre-calculation conducted by the RELAP5 and MARS[4]. Many organizations have participated with various system analysis codes: for examples, RELAP5, MARS, TRACE. KAERI also anticipated with SPACE code.

The SPACE code is a newly developed system analysis code with the capability of droplet field. SPACE code has been developed for the use of design and safety analysis of nuclear thermal hydraulics system. KHNP and other organizations have collaborated during last 10 years. And it is currently under the certification procedures. SPACE has the capability to analyze the droplet field with full governing equation set: continuity, momentum, and energy. The SPACE code has been participated in PKL-3 benchmark program for the international activity[5]. The DSP-04 benchmark problem is also the application of SPACE as the domestic activities.

2. Loop Seal Clearing

The top slot break accident is a kind of middle break LOCA. Unlike the large break LOCA, lots of coolant may remain in the core right after the break. The two-phase mixture break flow may be kept for a long time. The top slot break has the concept that the major composition of break flow is the steam. Also, the coolant liquid from the core may pass the break position and the loop seal can be filled with water. The liquid filled loop seal may cause the high pressure of the core upper plenum. If the loop seal depth is moderate, the high pressure of core upper plenum may push the loop seal water to the downcomer through the break and cold legs. But if the seal depth is deep, the upper plenum may stay in high pressure state. As the consequence, the fuel may be uncover. In spite of the scram of the core, the decay heat is sufficient to raise the temperature as long as the fuel is uncover. The ATLAS facility has been used to simulate the top slot break accident of APR1400.

3. SPACE Model and Results

3.1 ATLAS Modeling of Top Slot Break

The ATLAS facility model of SPACE code has been made for the assessment of SPACE code. The heat leakage of the facility has been surveyed and modeled as the constant wall temperature and heat transfer coefficient around the reactor vessel, steam generator, and pressurizer as well as the pipe lines. The applied power is 1.64 MW for the ATLAS facility. The facility heat leakage is postulated as 88.67 kW. Considering these power and heat leakage, the SPACE modeled power is 1.56MW and 5.6 kW for the average and hot-pin, respectively. Table I shows the results of the steady state summary of SPACE calculation. The heat loss has been modeled as 8.0 kW/m^2K at the 300.0 K ambient temperature condition.

Table I: Steady State SPACE Calculation

Parameter	ATLAS	SPACE
Core power (MW)	1.64	1.56
PZR pressure (MPa)	15.5	15.551
Core inlet temp. (^oC)	291.0	292.0
Core exit temp. (^oC)	326.8	327
Feed water flow (kg/s)	0.41	0.43
SG pressure (MPa)	7.83	7.89
Cold leg flow (kg/s)	1.98	1.88

The problem time of the transient calculation is 8,000 second. The first low pressure signal arises at 14.52 second after break. This first LPP signal makes the power scram. The second LPP signal is connected to the HPSI pump operation. The 28.0 second delay is added to the HPSI pump operation. The 4 train HPSI pimps are all operated without single failure assumption. Safety injection is actuated after 703 second from the break. The safety coolant water mainly comes from the HPSI pumps at the beginning of the transient. The transient scenario is summarized in Table II.

Table II: Transient Scenario of Top Slot Break Accident

Event	Time (sec)	Remark

break	0	
LPP	14.52	PT-PZR-01<12.48MPa
LPP	37.16	PT-PZR-01<10.7MPa
HPSI open	65.16	LPP second+ 28.0 second delay
SIT	703.68	PT-DC-01<4.03MPa

The break line of ATLAS facility is not simple as shown in below figure. For the detail description of the break line of ATLAS, SPACE model adapted vertical pipe, break nozzle and break valve from the lateral direction of the cold leg pipe model of 1A loop.

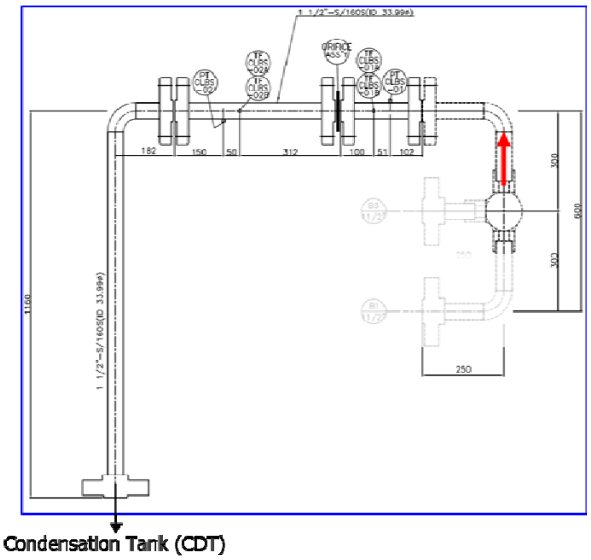

Fig. 1. ATLAS Top Slot Break Line

The leak flow paths between downcomer and upper head are open. It affects the initial upper head temperature level. If the temperature is low, not much liquid are vaporized at the instance of break, thus the more liquid is remained in the vessel. It may increase the possibility of the loop seal reforming.

Fig. 2 describes the ATLAS loop configuration and break position. All HPSI and SITs are activated.

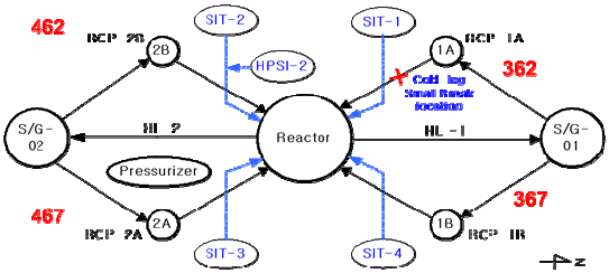

Fig. 2. Loop and Safety Injection configuration of ATLAS Top Slot Break

3.2 Results

The main result of the scenario is the loop seal collapsed level. The collapsed liquid level of the pump suction region is monitored for every 4 loop seals.

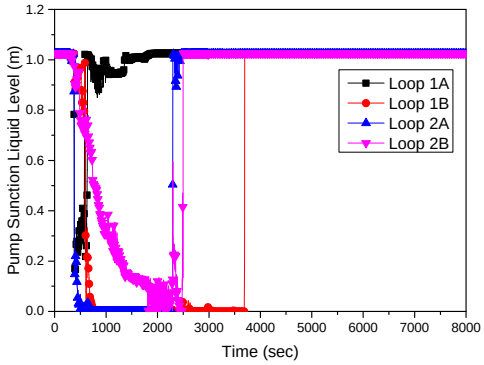

Fig. 3. The pump suction region liquid collapsed level

In the fig. 3, all loop seals are reformed after about 4,000 second. 1A loop seal reformed first and 1B loop real reformed last.

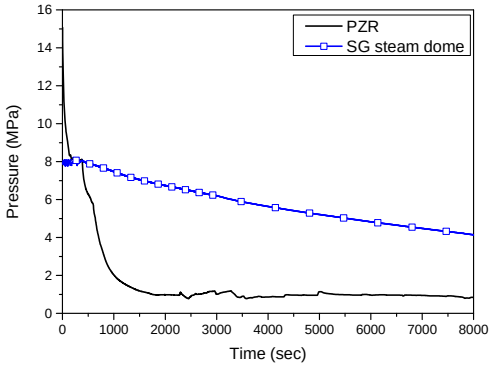

Fig. 4. PZR and SG Pressure

The primary and secondary pressures are represented in Fig. 4. There is no noticeable pressure behavior near the instance of all loop seal reform. The primary system pressure maintain at the 1 MPa level.

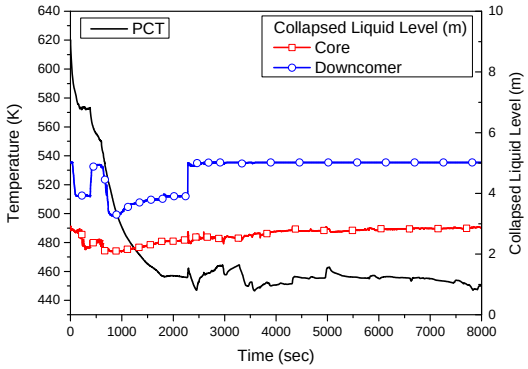

Fig. 5. Peak heater temperature and collapsed liquid level of core and downcomer

The peak heater temperature is represented in fig. 5. The core and downcomer collapsed liquid levels are plotted in the same figure. The collapsed level difference is come from the base elevation difference. After the all loop seal reform, the collapsed levels show no noticeable trends. The maximum heater temperature shows no significant peaks, neither.

The total calculation time is about 64,000 second for the 8,000 second problem time with 0.001 second time step. The last 3,000 second duration is calculated with 0.005 second time step.

4. Conclusions

The cold leg top slot break accident of APR1400 reactor has been modeled and surveyed by SPACE code. Benchmark experiment as a program of DSP-04 has been performed with ATLAS facility. The break size has been selected as 4 inch in APR1400 and the corresponding scale down break size has been modeled in SPACE code. The loop seal reforming has been occurred at all 4 loops. But the PCT shows no significant behaviors.

ACKNOWLEDGEMENTS

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