ATLAS Cold Leg Top Slot Break Analysis using RELAP5

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1. Introduction

U.S. Nuclear Regulatory Commission (US-NRC) has been reviewing the design certification application for APR1400 submitted by Korea Electric Power Corporation (KEPCO). US-NRC addresses the issue of cold leg top slot break, since loop seal elevation of APR1400 is close to the midpoint of the active core height [1]. The main concern about cold leg top slot break is that cladding temperature might be increased by core uncover due to four loop seal reformation following flooding of safety injection water.

An integral effect test for cold leg top slot break was performed by KAERI (Korea Atomic Energy Research Institute) using ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation), which is a scaled down experimental facility for APR1400. The break size for test condition was determined to be 0.00712 m in diameter for the ATLAS, which is equivalent to 0.1016 m (4 in.) for APR1400. [2].

In this study, RELAP5/MOD3.3/Patch04 is assessed by experimental result of ATLAS cold leg top slot break. Also, thermal hydraulic phenomena by four loop seals reformation is observed by RELAP5 result.

2. Methods and Results

2.1 Test Assumptions

In the experimental result, loop seal clearing and reformation phenomena are observed in the case of 7.12 mm sized break in the ATLAS facility, which is a scaled down diameter for 4 inch of APR1400.

The test condition is assumed that four safety injection tanks (SITs) and four safety injection pumps (SIPs) are credited in order to easily refill four loop seals by flooding safety injection water to cold leg. Initial core power is assumed at 8 % rated power of the APR1400. The decay heat is described to heat by using 1.2 times of ANS-79 curve.

Table 1 shows used trip logic in the experiment. The trip signal for primary side is activated by low pressurizer pressure (LPP). The trip signal for secondary side is activated by steam generator (SG) pressure and SG water level.

2.2 RELAP5 model

In the experiment, the broken cold leg is installed on the cold leg which is located on the loop 1A as shown in Fig. 1. Offtake model is applied to describe top slot break at the junction between cold leg and break line.

The orifice, which is described for 0.00712 m break, is installed at the junction between the C395-06 and C395-07. The opening valve is installed between C597 and C595-20.

Ransom-Trapp model is applied as critical flow model. The break line is only modelled until the opening valve, since downstream from the opening valve rarely affects the calculation result. Break line from the cold leg to opening valve is fully filled with RCS water until transient starts.

2.3 Calculation Results

Table 2 shows the sequence of transient event for experimental result and calculation result. Both experimental and calculation results show that loop seal clearing and reformation phenomena occur. According to the experimental result, loop seal clearing on the broken intermediate leg always occurs. In the calculation result, however, loop seal clearing on the broken intermediate leg does not always occur. In terms of duration of loop seal reformation, the calculation result is more conservative than experimental result since the final loop seal reformation is continued from 3,730 sec to 3,985 sec.

Table 1: Trip Logic

Events	Remarks
Primary logic	
LPP	PT-PZR-01<12.48MPa
Reactor scram/ TCP trip/RCP trip/Turbine trip/MFIV and MSIV close	LPP+0.0sec
SIP on	PT-PZR-01<10.7MPa+28.0s delay
SIT on	PT-DC-01<4.03MPa
Secondary logic	
MSSV1,2-01 open MSSV1,2-01 close	PT-SGSD1,2-01>8.1 MPa PT-SGSD1,2-01<7.7 MPa
MSSV1,2-02 open MSSV1,2-02 close	PT-SGSD1,2-02>8.3 MPa PT-SGSD1,2-02<7.9 MPa
MSSV1,2-03 open MSSV1,2-03 close	PT-SGSD1,2-03>8.48 MPa PT-SGSD1,2-03<8.05 MPa
AFW open AFW close	LT-SGSRS2-01<2.76m LT-SGSRS2-01>3.61m
AFW Flowrate	0.2kg/sec

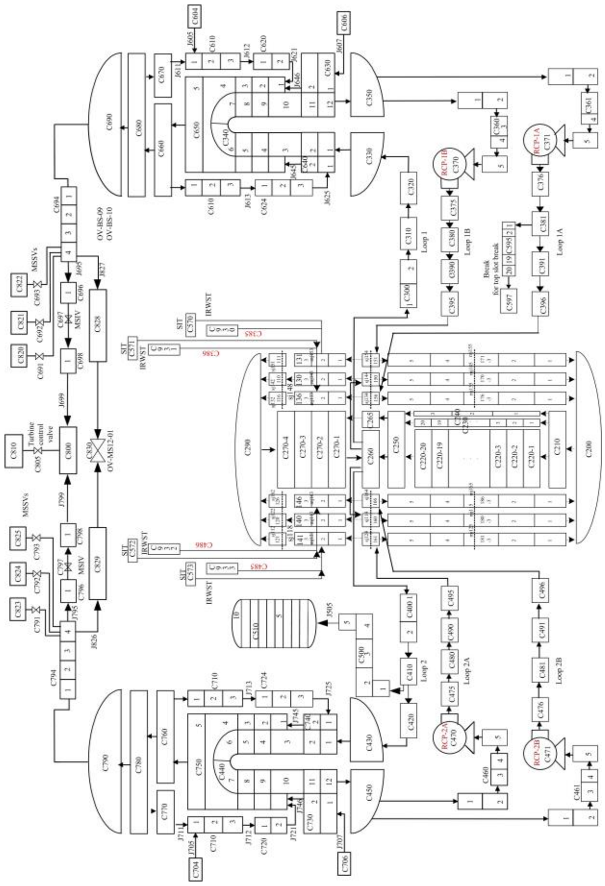

Fig. 1. Nodalization of Cold Leg Top Slot Break for ATLAS Facility

Fig. 2 shows pressurizer (PZR) pressure and SGs pressure. PZR pressure is steeply decreased to SGs pressure as soon as opening valve opens. When PZR pressure reaches to SGs pressure, a plateau appears due to thermal equilibrium between primary side and secondary side at natural circulation phase. Both of experimental and calculation results show that SG pressure on the loop 1 decreases further than that on the loop 2. In the experimental result, loop seal clearing on the loop 1A affects to decrease the SG pressure on the loop 1. However, in the case of calculation result, loop seal clearing easily occurs on the loop 2A. It seems that SG pressure on the loop 1 is affected by low temperature of flooding water by SIP on the loop 1A.

Fig. 3 shows mass flow rate from the break. Break mass flow rate temporarily increases while PZR pressure reaches the plateau. The mass flow rate from the break tends to decrease with loop seal clearing as accumulated core steam pressure is released to break line through steam path.

Fig. 4 shows water level at reactor pressure vessel (RPV). RPV water level steeply decreases to the level of the active top core at the beginning of transient event. During loop seal reformation, the RPV water level decreases intermittently under the active top core. However, the RPV water level increase is temporary during SIT low flow injection or after loop seal clearing. After 3,985 sec in the calculation result, the RPV water level is fairly high for about 3,000 sec since downcomer water level decrease is not as big as previous downcomer water level decrease as shown in Fig. 5.

Table 2: Sequence of Transient Events

Events		LTC-CL-04R (sec)	RELAP5 (sec)
Break		0.0	0.0
LPP		32.0	25.0
1st MSSV open/close		36.0/40.0	29.0/28.0
SIP on		81.0	78.0
SIT on		766.0	534.0
Loop seal clearing	1st	433 ~3,387 (1A) 454~3,419 (2A)	296~402 (1A)
	2nd	3,797 ~3,851 (1A, 1B) 3,794~3,860(2B)	426~2,086(1B) 410~2,078(2A) 410~498(2B)
	3rd	4,682~4,838(1A) 4,678~4,850(2A)	2,150~2,253(2A)
	4th	7,022~7,156(1A)	2,256~2,360(2B)
	5th	-	2,756~3,112(2A)
	6th	-	3,730~3,985(2A)

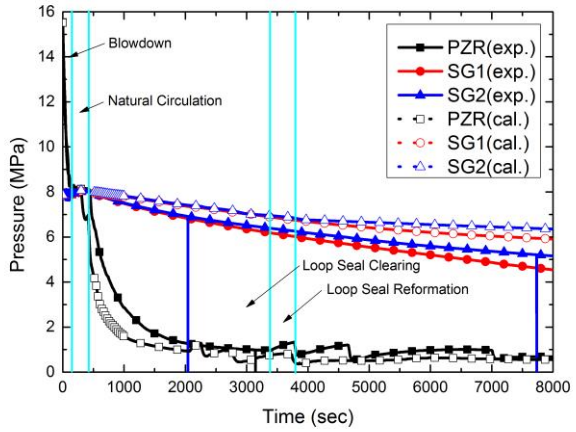

Fig. 2. Pressure of PZR and SGs

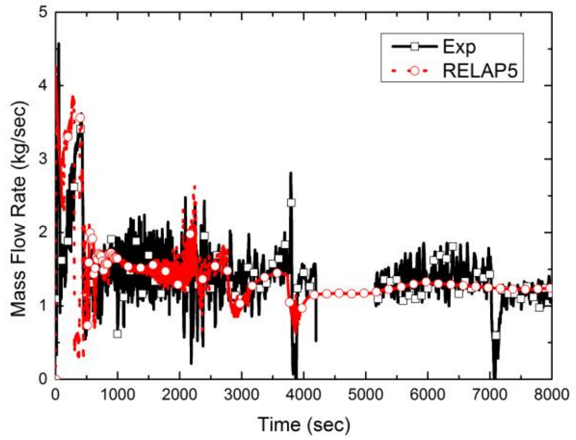

Fig. 3. Mass Flow Rate from Break

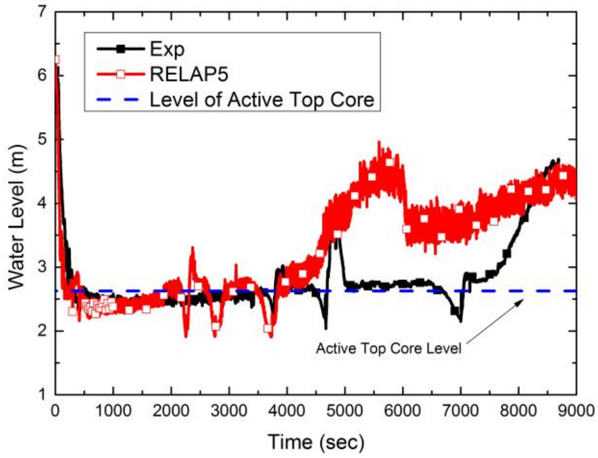

Fig. 4. RPV Water Level

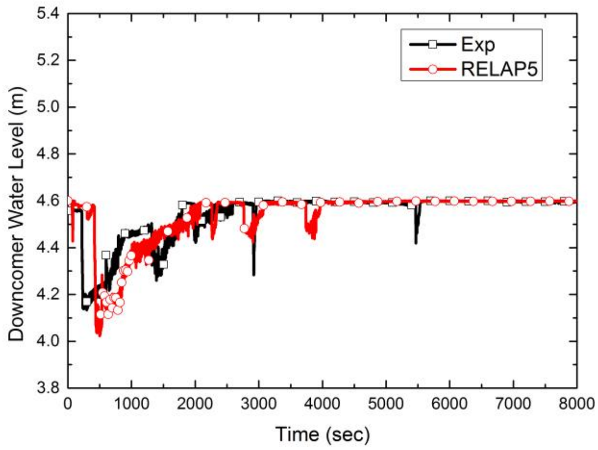

Fig. 5. Downcomer Water Level

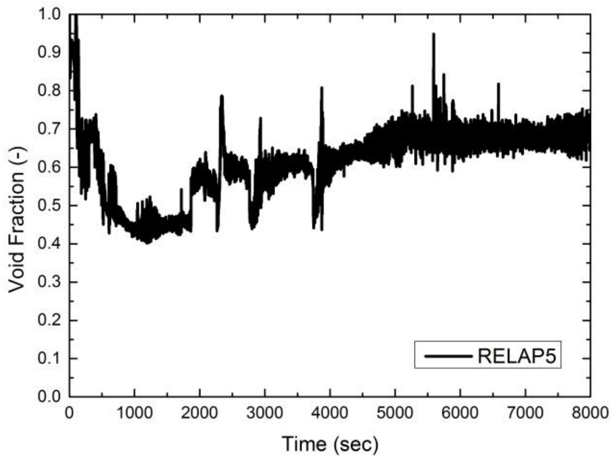

Fig. 6. Void Fraction at Active Top Core

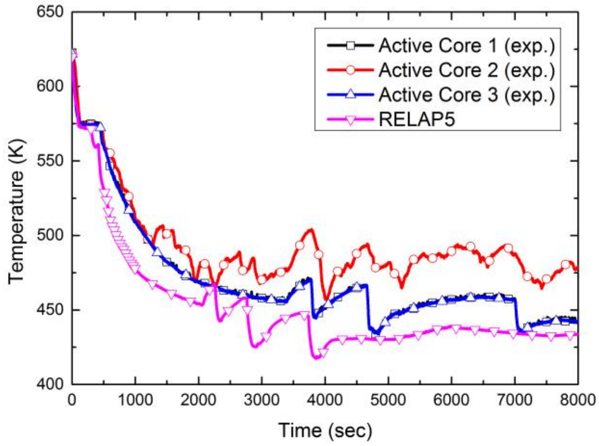

Fig. 7. Cladding Temperature at Peak Temperature Node

The RELAP5 result indicates void fraction at the active top core node is maintained over 0.4 as shown in Fig. 6. After 3,985 sec, void fraction at the active top core is increased even though loop seal reforms. This is because injected safety injection water is larger than the discharged mass flow rate from the break.

Fig. 7 shows the cladding temperature at peak temperature node. It seems that cladding temperature intermittently increases during four loop seal reformation. However, four loop seal reformation does not significantly affect to increase cladding temperature because of void fraction at the active top core.

3. Conclusions

The RELAP5/MOD3.3/Patch04 is assessed by the experimental result of ATLAS cold leg top slot break. The top slot break is described by offtake model, and the mass flow rate is fairly well estimated.

The RELAP5 well predicts the correlation between general trend and four loop seal reformation. The pressure of the core region and the cladding temperature tends to increase during four loop seal reformation due to steam path blockage on four loop seals.

However, RELAP5 has its limits in estimating the location of loop seal clearing. It is presumed that the code cannot estimate two phase phenomena by loop seal clearing as same as experiments.

In terms of cladding temperature, loop seal reformation due to loop seal elevation of APR1400 does not need to be the issue, since the void fraction at the active top core is maintained over 0.4.

REFERENCES

[1] S. Lu, APR-1400 Loop Seal and Its Impact on Long Term Cooling During a Postulated Loss-of-Coolant Accident, ML14134A347.

[2] J.R. Kim et al., Analysis Report on the Long Term Colling Test for Cold Leg Top Slot Break, KAERI Technical Report, 2016.

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