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Sensitivity Test of 1-D Analysis for 4 inches Cold Leg Top-Slot Break LOCA in 4th ATLAS Domestic Standard Problem (DSP-04)

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1. Introduction

In a PWR, the upper plenum of reactor vessel and/or upper head is filled with steam during a LOCA (Loss Of Coolant Accident). The steam volume in the upper part of reactor vessel may continue expanding until steam blows liquid out of the intermediate leg, and open a path for the steam to be relieved from the break [1]. This called loop seal clearing (LSC). The LSC is the major factor that affects the coolant inventory in the small break LOCA and intermediate break LOCA. However, the LSC is very complex phenomena and is not fully understood. Therefore, a prediction of the LSC is also difficult.

There was an issue about the effect of loop seal clearing and reformation on a peak cladding temperature during a cold leg top-slot break LOCA for APR1400. To resolve this issue, an experiment (LTC-CL-04R) for LOCA with a top-slot break at cold leg was performed using the ATLAS at KAERI [2]. The detail information of experiment was described KAERI technical report [3]. This simulation was focused on the loop seal clearing and reformation under long term cooling condition.

In ATLAS DSP-04 (4th Domestic Standard Problem), 13 organizations including universities, government, and nuclear industries calculated and analyzed with various safety codes for this experimental result. The organizations performed as both of "blind" and "open" calculation. They also analyzed results of parametric study. In this paper, sensitivity test results that were calculated using MARS-KS were described with major parameters that were picked out by organizations' reports.

2. Experiment

The test LTC-CL-04R simulated a scenario that has 4 inches top slot break at cold leg. For experiment, a break line was installed on upper side of the cold leg (1A). The 4 inches break for the APR1400 was simulated by using a breaking nozzle having a diameter of 7.12 mm in the break line.

During the experiment, loop seal clearing and reformation were repeatedly formed. During the loop seal, the steam collected in the upper head of RPV caused rise of core vessel pressure, decrease of core water level, and increase of core vessel saturation temperature, and rise of heater surface temperature. The surface temperature of the heater was raised, but this is not a core temperature excursion because the reason of core temperature rising was increase of saturation temperature in RPV. Therefore, there is no significant effect of the loop seal clearing and reformation on APR1400 safety.

2. Sensitivity analysis

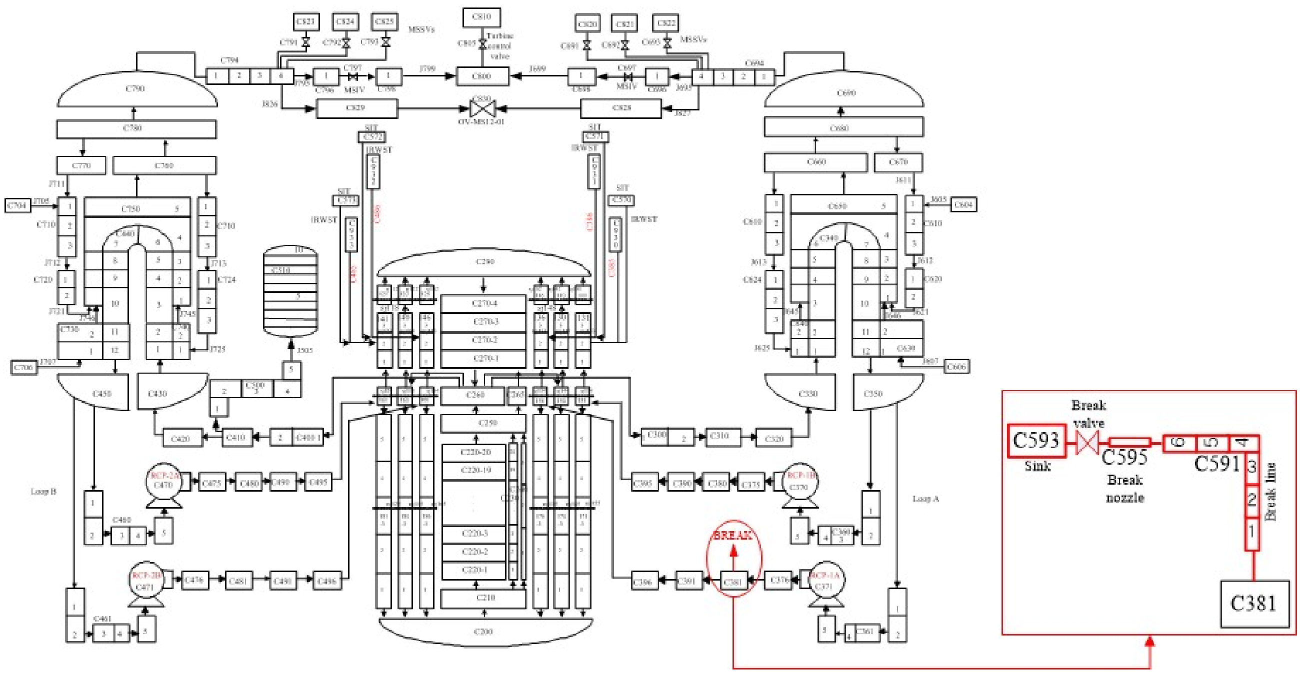
A sensitivity test of 1-D analysis for 4 inches cold leg top-slot break LOCA transient experiment was done using MARS-KS 1.4. Fig. 1 shows nodalization of ATLAS. Break line was simulated from junction to break nozzle because nozzle makes critical flow. Upward break model and offtake model at break junction were applied to simulate top-slot break. Wallis model for CCFL was applied at loop seal and break line. Heat loss model was not applied and total power excludes measured heat loss rate was applied. In the base case, Ransom-Trapp model with $C_{d\_subcooling}$=0.8, $C_{d\_two\ phase}$=1.2, $C_{d\_superheated}$=1.0 was applied for critical flow model. The sensitivity analysis matrix is summarized on Table I.

Table I: Sensitivity analysis matrix

Case	Critical flow model	Break line modeling	Number of loop seal node
Base	Ransom-Trapp	O	5
HF	Henry-Fauske	O	5
No Break line	Ransom-Trapp	X	5
Fine node	Ransom-Trapp	O	14

2.1 Critical model effect

From Fig. 2 to Fig. 4 compare the calculation results for the effect of critical flow model. Two cases of Henry-Fauske model with C_d=0.8 / C_n=0.14 and C_d=1.0 / C_n=0.14 were applied for a sensitivity study of critical flow model. The Henry-Fauske models calculated less break flow rate for short term period and the pressure of primary side were higher than the base case. However, the calculations show similar trend for long term period.



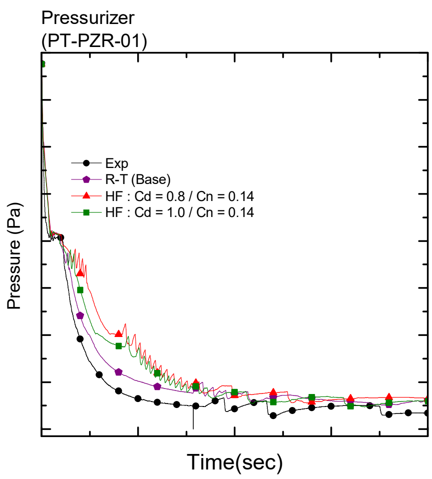


Fig. 2. Pressure of pressurizer for critical flow model effect

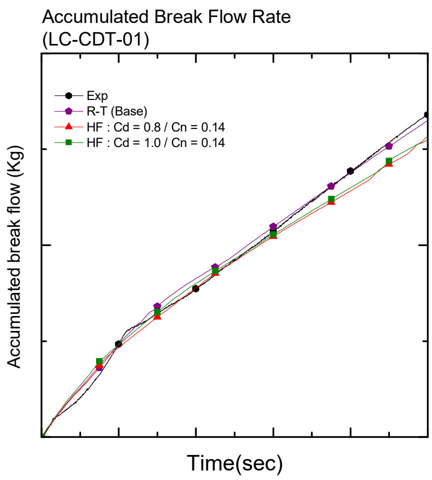


Fig. 3. Accumulated break flow rate for critical flow model effect for short term

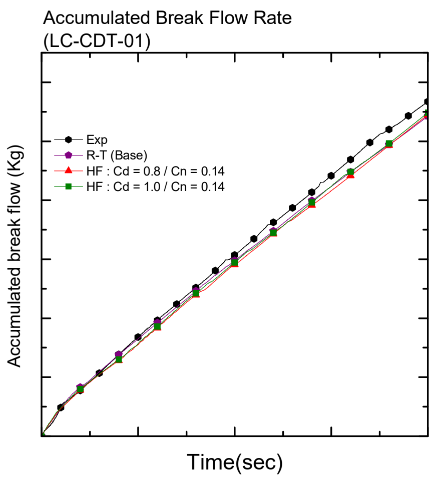


Fig. 4. Accumulated break flow rate for critical flow model effect for long term

2.2 Break line simulation effect

Fig. 5 and Fig. 6 show effect of break line simulation. In the case of No Break line, the break line was simulated with only break valve (trip valve), and sink volume. The case of No Break line shows lower primary pressure because simple break line has lower pressure resistance for break flow and it increases the break flow rate.

2.3 Number of node effect

Fig. 7 and Fig. 8 show the difference between the base case and fine node case. For the base case, the node number at loop seal was 5 while the node number at loop seal was 14 for the fine node case. The fine node case calculated less break flow rate while the break flow condition was two phase. So, the primary pressure was higher than base case. After the two phase break flow condition, the break flow rate was almost same and pressure trend was also similar for two cases.

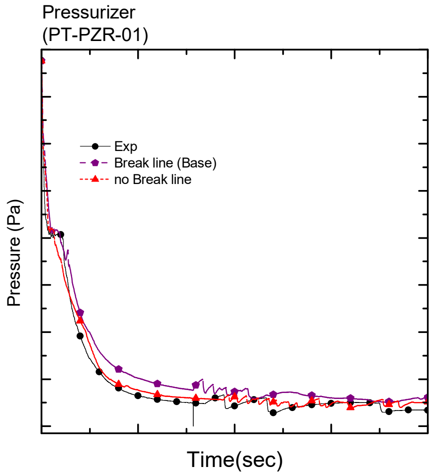


Fig. 5. Pressure of pressurizer for break line simulation effect

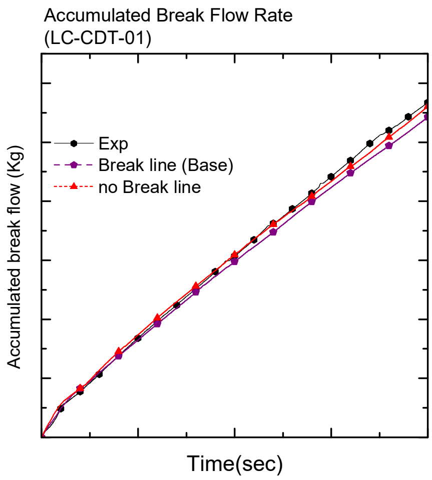


Fig. 6. Accumulated break flow rate for break line simulation effect

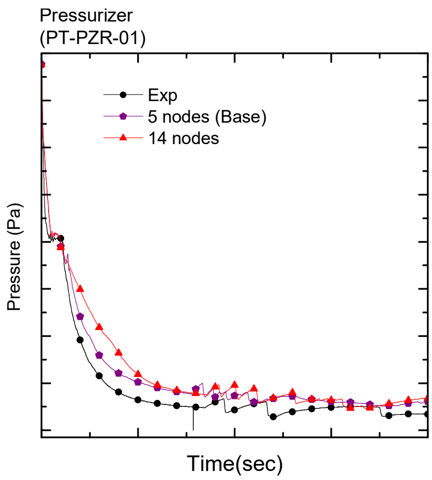


Fig. 7. Pressure of pressurizer for number of node effect

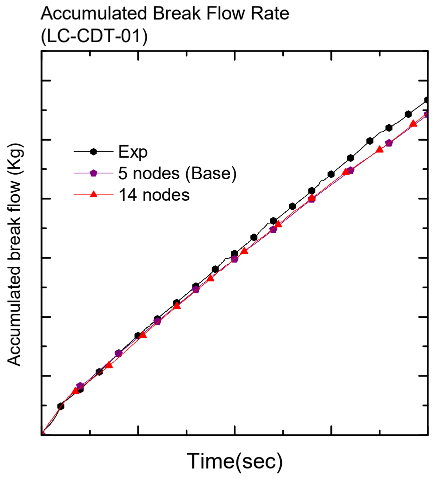


Fig. 8. Accumulated break flow rate for number of node effect

3. Conclusions

An experiment (LTC-CL-04R) for LOCA with a top-slot break at cold leg was performed using the ATLAS at KAERI to resolve an issue that the loop seal clearing and deformation of APR1400. And 13 organizations including universities, government, and nuclear industries calculated and analyzed with various safety codes for this experimental result in ATLAS DSP-04 (4th Domestic Standard Problem).

In this paper, sensitivity test results that were calculated using MARS-KS 1.4 were described with major parameters that were picked out by these organizations' reports. The effects of critical flow model, break line simulation, number of node were discussed and these modeling affected to break flow rate and led different system behavior.

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