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Assessment of SPACE code for multiple failure accident: 1% Cold Leg Break LOCA with HPSI failure at ATLAS Test Facility

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1. Introduction

Design extension conditions (DECs) is a popular key issue after the Fukushima accident. In a viewpoint of the reinforcement of the defense in depth concept, a high-risk multiple failure accident should be reconsidered. So, in that sense, A5.1 test was performed at ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation) facility [1-2] in last year as a part of the OECD-ATLAS project. The target scenario of ATLAS A5.1 test was LSTF (Large Scale Test Facility) SB-CL-32 test [3], a 1% SBLOCA with total failure of high pressure safety injection (HPSI) system of emergency core cooling system (ECCS) and secondary side depressurization as the accident management (AM) action, as a counterpart test.

The SPACE code has been developed for the safety analysis for Korean nuclear power plants. As the needs to prepare the DEC accident because of a multiple failure of the present NPPs are emphasized, the capability of SPACE code, just like other system analysis code, is required to expand the DEC area.

The objectives of this study is to validate the capability of SPACE code for a DEC scenario, which represents multiple failure accident like as a SBLOCA with HPSI fail. Therefore, the ATLAS A5.1 test scenario was chosen.

2. SPACE analysis on ATLAS A5.1 test

2.1 SPACE modeling

SPACE input for the ATLAS was based on MARS-KS input. There is no consideration of heat loss at all components. Fig 1 shows a nodalization diagram of SPACE for ATLAS facility. The core region has been divided in 3 channels: one for the averaged active core, another for hot channel and the other one for core bypass. The downcomer region has been divided in 6 channels.

To simulate the ATLAS A5.1 test, the steady-state was calculated to confirm the initial conditions and the transient was started using the restart function of the SPACE code. The calculated results, which is normalized by the values of test were represented in Table 1. It seems to be a big discrepancy of the normal power between the results calculated by the SPACE code and the test ones among the parameters. That's why the heat loss in the calculation was not considered.

2.2 Sensitivity study for Discharged coefficient

To analyze any accident scenario using T-H system code, it is important to determine the inventory loss through a break like as a SBLOCA. In this calculation, Ransom-Trapp choke flow model was used.

Sensitivity study on discharged coefficient was performed from 1.0 to 1.5 for each phase. After a start of test (SoT), the subcooled liquid was discharged through the break line. After that the discharged flow condition was 2 phase, because the plenty of water at the top side of cold leg connect to a break line was initially discharged. Lastly, single phase liquid was discharged because cold water was supplied by the Low pressure injection (LPI) through the cold legs.

The best fit of integrated mass of a break flow to the A5.1 test data is that discharge coefficients for subcooled liquid, 2 phase, and superheated gas are set to 1.3, 1.3, and 1.0, respectively.

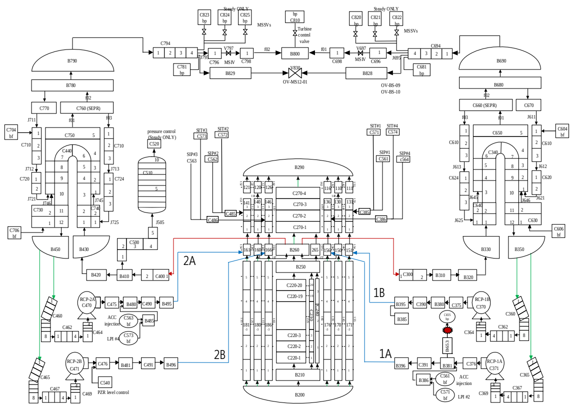

Fig1. Nodalization diagram of SPACE for ATLAS facility

Table1. Initial conditions for ATLAS A5.1 test

Parameters	**Test**	**SPACE**
Normal power (MW_{th})	1.67	1.58
Pressurizer pressure (Mpa)	15.48	15.50
Pressurizer Level (m)	2.07	2.06
Cold-leg temperature (K)	563	562
Hot-leg temperature (K)	600	599
Total core flow (kg/s)	7.76	7.58
SG pressure (Mpa)	7.86	7.83
SG level (m)	5.3	5.3
SG feedwater flow (kg/s)	0.43	0.44
SG feedwater temperature (K)	501	501

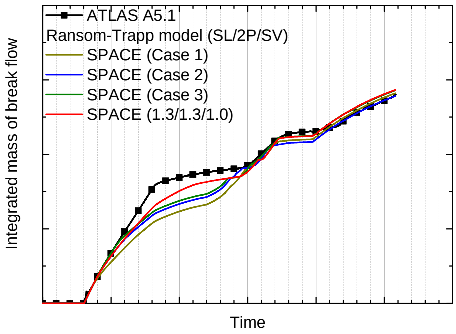

Fig 2 The results of sensitivity study on discharge coefficient comparing the A5.1 test data

2.3 SPACE analysis

The ATLAS A5.1 test procedure can be briefly introduced as below: The break valve in a cold leg was opened. The reactor scram signal was actuated and core power decay started with a certain of delay time. A turbine and main feedwater pumps are stopped and main feedwater isolation valves and main steam isolation valves are all closed. As the primary pressure meets with a set-up values of main steam safety valves (MSSVs), MSSVs was operated within the set-up pressures. After that accident management (AM) was initiated. The auxiliary feed was supplied to both steam generators (SGs) and actuated with some delay after the initiation of AM action with a time interval between SG1 and SG2. When the primary pressure was decreased, accumulators (ACCs) was injected into 2 cold legs. The ACC injection was set to terminate when the full inventory was injected without injection of nitrogen. The low pressure injection (LPI) was actuated at the lower pressure and the test was terminated within 20 minutes after LPI injection.

Based on the SPACE input obtained by the sensitivity study, the SPACE analysis was carried out for ATLAS A5.1 test. Fig 3~5 show the comparison of the key parameters in A5.1 test. All simulated results have a good agreement with the test data, comprehensively.

After opening the break valve, primary pressure was sharply decreased as shown as fig 3. As MSSVs at the secondary side were acted, secondary side pressure stayed within a set-up pressure (Fig 4). AM action was initiated by depressurizing the secondary side pressure of both SGs with a constant depressurization rate based on the upper plenum temperature.

As mentioned before, this test is a counterpart test of LSTF SB-CL-32. In a LSTF test, a peak cladding temperature (PCT) was occurred however, it was not in ATLAS test. Fig 5 shows the comparisons of the maximum wall temperature in the core region between the A5.1 test and the SPACE code. Just like the results of ATLAS test, the PCT was not occurred in the SPACE result. Because the most part of the active core was submerged in the water during the test.

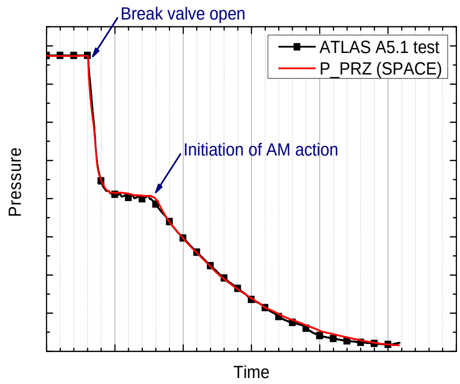

Fig 3 Comparison of Primary pressure behavior between ATLAS A5.1 test and SPACE analysis

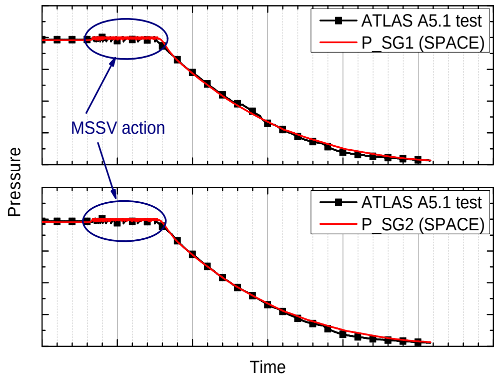

Fig 4 Comparison of secondary side pressure behavior between ATLAS A5.1 test and SPACE analysis

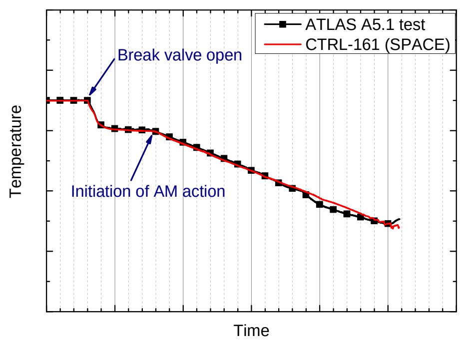

Fig 5 Comparison of the maximum wall temperature in the core region between ATLAS A5.1 test and SPACE analysi

3. Conclusions

As the needs to prepare the DEC accident because of a multiple failure of operating NPPs are emphasized, the capability of SPACE code is needed to expand the DEC area. So the capability of SPACE code was validated for one of a DEC scenario. The target scenario was selected as the ATLAS A5.1 test, which is a 1% SBLOCA with total failure of HPSI system of ECCS and secondary side depressurization.

Through the sensitivity study on discharge coefficient of break flow, the best fit of integrated mass was found. Using the coefficient, the ATLAS A5.1 test was analyzed using the SPACE code. The major thermal hydraulic parameters such as the system pressure, temperatures were compared with the test and have a good agreement. Through the simulation, it was concluded that the SPACE code can effectively simulate one of multiple failure accidents like as SBLOCA with HPSI failure accident.

REFERENCES

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