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# Outcomes of Domestic Standard Problem-03 : Scaling Capability of Facility Data

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## 1. Introduction

A Domestic Standard Problem (DSP) exercise using the ATLAS was first proposed and discussed at the MARS user group meeting and the 3rd Nuclear Safety Analysis Symposium in 2005 [1].

The ATLAS DSP exercise was led by KAERI in collaboration with KINS. The previous two DSPs provided good research opportunities to many nuclear organizations to understand the capability of the current system-scale safety analysis codes and to find a way for further code development area. Thus, the third DSP program was launched in the 2nd half of the year 2012.

As the third DSP exercise (DSP-03), a double-ended guillotine break of the main steam line at an 8% power without loss of off-site power (LOOP) was decided a target scenario [2, 3]. Seventeen domestic organizations joined this DSP exercise. This DSP exercise was performed in an open calculation environment similar to the previous ones.

In the present DSP-03, taking into accounts the different levels of code experiences and expertise, three sub-topics were suggested by operating agency [4, 5]. Among them, the investigation on scaling capability of facility data which was the topic of Group A will be discussed in this paper.

Agreed participants should perform two calculations with the ATLAS model and the APR1400 model. By comparing major and detailed local parameters from both calculation models, scaling capability of the facility data was investigated.

## 2. Objectives

The main objective of this topic is the scaling up analysis of the ATLAS. The main objective can be divided into three specific categories.

- APR1400/ATLAS Analysis
- Analysis of the scaling distortion
- Extrapolation capability of the ATLAS

The experimental conditions and the test results which were provided by the host organization, KAERI was scaled up for the application of the APR1400 analysis. From the result of APR 1400 analysis, the scaling up effect of the ATLAS was evaluated.

## 3. Organization of Group A

Three organizations were joined in the Group A, KHNP, UNIST, and RETECH. Among them, KHNP had an obligation to lead the discussion and communication of group A.

Three organizations analyzed the steady state and the transient state of the APR1400 and ATLAS utilizing their own code. Nodalization or the modeling method of the code analysis was different between each organization. Analysis result from each organization was compared for the evaluation of the ATLAS scaling up effect.

## 4. Modeling Method

### *4.1 KHNP*

The one-dimensional model of SPACE 2.14 version was used in the analyses. The SPACE code is a best estimate code developed by KHNP. The steady state SPACE input deck of ATLAS DSP-03 MSLB was made by MARS input of KAERI. Two safety injection pumps (SIPs) were simulated as boundary conditions with TFBC through a table of flow rate according to time for correct comparison.

### *4.2 UNIST*

The one-dimensional model of MARS 3.0a version was used in the analyses. There were some modifications from the nodalization of MARS code input provided by KAERI. Delete pilot operated safety relief valve (POSRV), break system modeling, and auxiliary feed water systems were added.

In case of MARS input deck of APR-1400, the break area of main steam line on APR-1400 was set according to the ratio of break area and steam line area.

Two safety injection pumps (SIPs) were simulated as boundary conditions with time dependent junction through a table of flow rate according to pressure which was established with the interpolation of experimental data.

### *4.3 RETECH*

A break of main steam line at 8% core power, which is the test item of an ATLAS DSP-03, has been analyzed by using a MARS-KS(002 Beta Version) code.

Several items were altered in a basic model based on the input data given by KAERI such as RCP Control, feedwater logic, and MSSV open/close logic. Similar with the APR1400 nodalization, a break model, aux. feedwater model, SIP model and 8% core power decay table were added.

## 5. Analysis Results

### *5.1 Steady-State Results*

A comparison of major parameters between the calculated values and the measured values of ATLAS and APR-1400 is shown in Table 1 and Table 2. As shown in the table, overall calculated values of major parameters showed good agreement with experimental data.

However, steam flow rate and feed water flow rate of calculated values were different to those of experimental data with maximum difference of 13.46 % in the UNIST analysis result. And the differences in the mass flow rate in primary and secondary loops were obvious and those results were mainly supposed to the heat losses.

### *5.2 Transient Results*

The sequence of event of the transient calculation was shown in the Table 3. The results of time sequence from three participants were shown similar results.

Here, several major parameters which can represent the system behavior were compared between results from three participants.

Break Flow

Fig. 1 compares the accumulated masses from break flow between experimental results and calculation results. The accumulated mass shows two slopes which one is break flow from secondary system and the rest one is from auxiliary feed water. The calculated accumulated mass was similar. Fig. 2 shows the accumulated mass from break flow in case of APR-1400. The trend was similar with that of ATLAS.

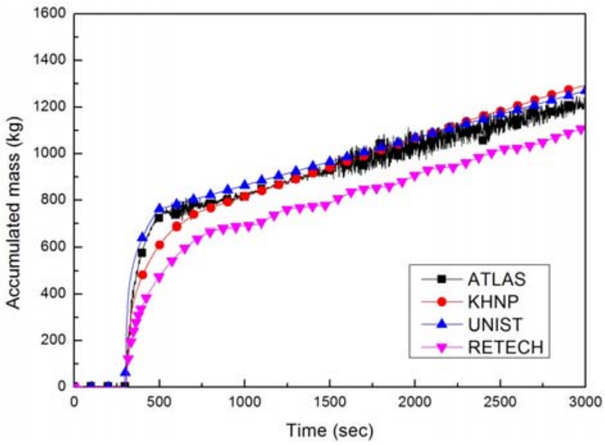


Fig. 1. Accumulated mass from the break flow for ATLAS

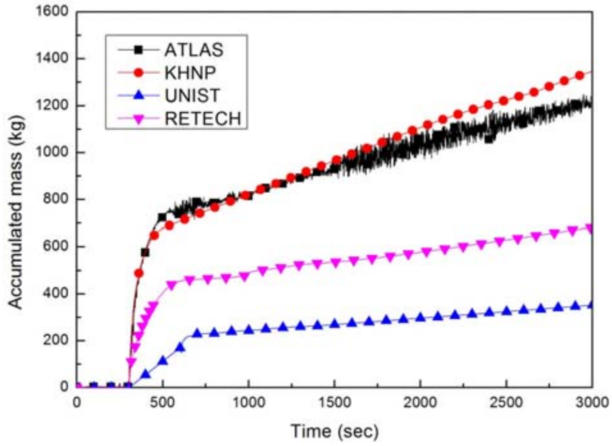


Fig. 2. Accumulated mass from the break flow for APR1400

System Pressure

Fig. 3 compares the pressures according to time of the pressurizer in the experiment and the analysis. As shown in the figure, the code values were under-predicted the pressure of pressurizer. The calculated pressure of pressurizer was increased due to the operation of SIP injection after LPP signal. Fig. 4 shows pressurizer pressure for APR1400.

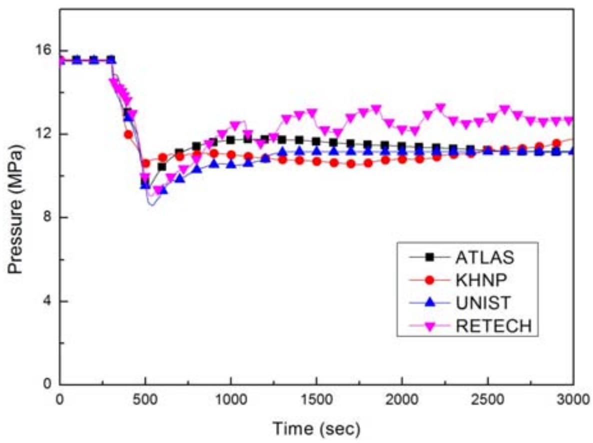


Fig. 3. Pressurizer pressure for ATLAS

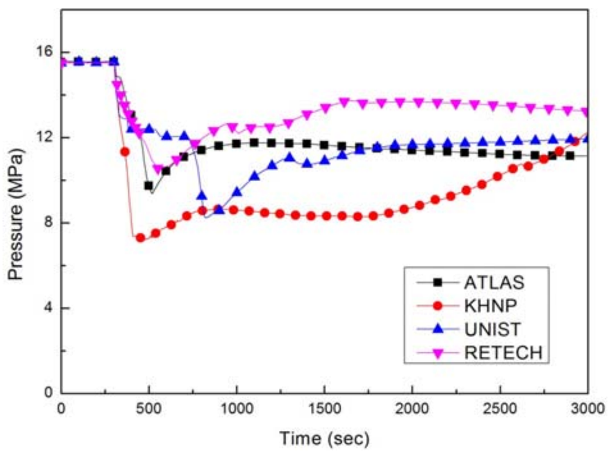


Fig. 4. Pressurizer pressure for APR1400

Table 1: Major variables in steady state condition for ATLAS

| | Design parameter | ATLAS | KHNP | UNIST | RETECH |
|---|---|---|---|---|---|
| Primary System | Normal power (MWt) | 1.634 | 1.634 | 1.56 | |
| | Pressurizer pressure (MPa) | 15.56 | 15.56 | 15.5 | 15.51 |
| | Core inlet temperature (K) | 562.75 | 563.19 | 566.3 | 567.07 |
| | Core exit temperature (K) | 567.75 | 567.96 | 570.5 | 571.34 |
| Secondar y System | Steam flow rate (kg/s) | 0.388 / 0.420 | 0.426 / 0.426 | 0.426 / 0.425 | 0.433 / 0.493 |
| | Feed water flow rate (kg/s) | 0.444 / 0.429 | 0.381 / 0.38 | 0.400 / 0.400 | 0.492 / 0.496 |
| | Feed water temperature (K) | 506.95 / 505.85 | 506.95 / 505.85 | 505.4 / 505.4 | 505.37 / 505.37 |
| | Steam pressure (MPa) | 7.33 / 7.33 | 7.32 / 7.32 | 7.85 / 7.85 | 7.74 / 7.74 |
| | Steam temperature (K) | 563.95 / 564.25 | 561.86 / 561.87 | 566.9 / 566.9 | 565.86 /565.86 |
| Primary Piping | Cold leg flow (kg/s) | 16.4 | 16.4 | 17.2 | 17.2 |
| | Hot leg temperature (K) | 567.65 | 567.27 | | 571.32 |
| | Cold leg temperature (K) | 562.65 | 563.84 | | 567.04 |

Table 2: Major variables in steady state condition for APR1400

| | Design parameter | APR1400 | KHNP | UNIST | RETECH |
|---|---|---|---|---|---|
| Primary System | Normal power (MWt) | 332.68 | 332.68 | 318.64 | 316.7 |
| | Pressurizer pressure (MPa) | 15.5 | 15.5 | 15.51 | 15.51 |
| | Core inlet temperature (K) | 563.25 | 563.26 | 563.11 | 563.3 |
| | Core exit temperature (K) | 567.05 | 566.88 | 566.63 | 566.9 |
| Secondary System | Steam flow rate (kg/s) | 92.2 | 91.2 | 105.99 | 92.0 / 91.9 |
| | Feed water flow rate (kg/s) | 92.2 | 92.2 | 81.26 | 92.2 |
| | Feed water temperature (K) | 505.35 | 505.35 | 505.62 | 505.6 |
| | Steam pressure (MPa) | 7.31 | 7.35 | 7.31 | 7.35 |
| | Steam temperature (K) | 561.95 | 562.28 | 562.54 | 562.3 |
| Primary Piping | Cold leg flow (kg/s) | 4198.3 | 4198.3 | 3339.08 | 4198.9 |
| | Hot leg temperature (K) | 566.95 | 566.77 | - | 566.8 |
| | Cold leg temperature (K) | 563.25 | 563.24 | - | 563.3 |

Table3: Sequence of events

| Event | Exp. | KHNP | | UNIST | | RETEC | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | ATLAS | APR 1400 | ATLAS | APR 1400 | ATLAS | APR 1400 | |
| Break open | 303 | 303 | 303 | 303 | 303 | 303 | 303 | |
| MFIS | 303 | 303 | 303 | 303 | 303 | 303 | 303 | Coincident With the break |
| LSGP | 310 | 309.37 | 309.91 | 310 | 310 | 316.6 | 317.4 | Steam pressure < 6.11 MPa |
| RCP trip | 311 | 310.37 | 311.33 | 311 | 312 | 317.6 | 318.4 | LSGP + 1.0 sec |
| MSIS | 315 | 320.41 | 314.92 | 314 | 316 | 320.1 | 323.7 | LSGP + 3.54 sec |
| Decay Power start | 322 | 321.44 | 326.98 | 320 | 325 | 328.7 | 338.9 | LSGP + 12.07 sec |
| AF Injection | 364 / 361 | 359.94 | 373.39 | 353 | 371 | 482.9 | 383.4 | AFAS + 43.45 sec |
| SIP Injection | 505 | 488.93 | 428.67 | 510 | 520 | 511 | 441.9 | LPP + 28.28 sec |

Collapsed Water Level

A comparison of the measured pressurizer collapsed water level with the calculated water level is shown in Fig. 5. Early stage of MSLB was well-predicted and overall results of predicted water level were similar to the experimental result. The rate of restored water was slowly predicted and it was assumed the effect of LPP start-up time.

Fig. 6 shows the change of pressurizer water level in APR-1400. Similar water level was recovered with SIP operation. However, the slope of increasing water level in case of APR-1400 was more different than that of ATLAS.

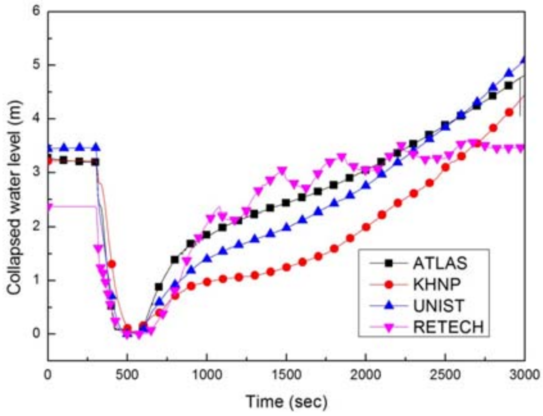

Fig. 5. Pressurizer pressure for ATLAS

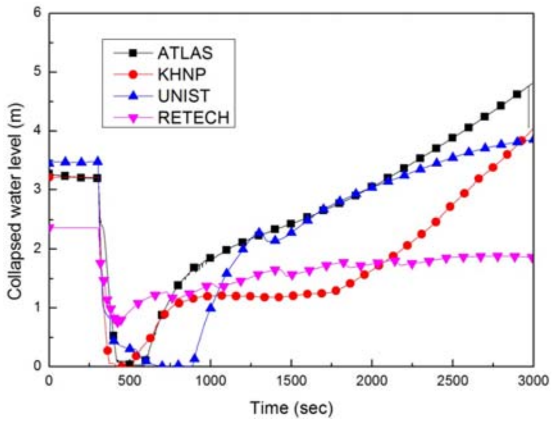

Fig. 6. Pressurizer water level for APR1400

## 5. Conclusions

The 38.6 mm MSLB in ATLAS test facility was calculated using SPACE and MARS-KS code. To analyze the effect of scaling on the system behavior, MSLB in APR-1400 was also simulated in this study and following results were obtained.

- The code predicted appropriately the overall MSLB experimental data obtained from ATLAS test facility.
- The break flow calculated by code was lower than that of experimental data.
- And the difference between calculated value and measured value was attributed to the measurement of mass from break flow.
- The temperatures of core inlet and outlet of ATLAS test facility were predicted lower than those of experimental data.

APR-1400 shows similar pressure change of pressurizer. However, the temperature changes along the system were different with those of ATLAS SLB condition. APR 1400 don't consider the heat loss and different to pump inertia. So, from decay power start (about 320 sec) to SIP injection (about 500 sec), APR 1400 and ATLAS values are different. However, almost trends are similar to ATLAS.

## REFERENCES

[1] W. P. Baek, "APR1400 현안 종결과 고유안전 해석체계 개발을 위한 ATLAS의 역할," The 3rd Nuclear Safety Analysis Symposium, June 23-24, KINS/PR-046 Vol. 3 (2005).

[2] Experimental Result for Proposed Test [ATLAS MSLB Test], KAERI

[3] K. H. Kang et al., "Test Report on the Guillotine Break of the Main Steam Line Accident Simulation with the ATLAS", KAERI/TR-4790/2012 (2012)

[4] ATLAS Domestic Standard Problem (DSP-03) Specifications, ATLAS-TS-001-R.00, KAERI, 2011

[5] K. Y. Choi and K. H. Kang., "ATLAS Domestic Standard Problem (DSP-03) Specifications", ATLAS-TS-001-12-R.00 (2012)