# Comparison of MARS-KS and SPACE for UPTF TRAM Loop Seal Clearing Experiment

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## 1. Introduction

Loop seal clearance is one of the important phenomena in a small or medium break loss-of-coolant accident (LOCA) in a pressurized water reactor(PWR). In a SB or MBLOCA situation, firstly loop seal is filled with water after blowdown. Then, steam generated from the core cannot flow through the loop seal, therefore the water level in the downcomer rises and water level in the core decreases. The loop seal clearing equalizes the core water level and the downcomer water level. Consequently the uncovered region of the core is reduced.

Therefore, the capability of a safety analysis code to simulate the behavior of the loop seal clearing is needed, and this allows to predict the distribution of the primary coolant system inventory properly and to adequately predict the behavior of the system and the core. In this study, the authors assessed SPACE code, which was developed by a consortium led by Korea Hydro & Nuclear Power Co., Ltd. (KHNP), now in licensing process and MARS-KS code for UPTF TRAM loop seal clearing experiment to evaluate the code predictability regarding loop seal clearing for supporting the regulatory review [1].

## 2. Problem Definition

Liebert and Emmerling reported the flow behavior in the loop seal with a full-scale experimental facility, UPTF [1]. In this facility, separate effect tests (SET) and integral effect tests (IET) were performed to investigate the flow phenomena in the primary loop of a PWR, but the authors selected the TRAM test as a reference SET for this study. Fig. 1 shows the schematic drawing of the test in the UPTF.

In this experiment, water and steam were injected at the same time. Then water injection was ceased for a period of time. At that period, experiment variables were measured in the horizontal pipe. Water injection was resumed and steam flow rate was increased after then. These procedures were repeated during the whole experiment. Fig. 2 shows the steam and water injection mass flow rate of the experiment. Water and steam were under the saturated condition at 0.318MPa.

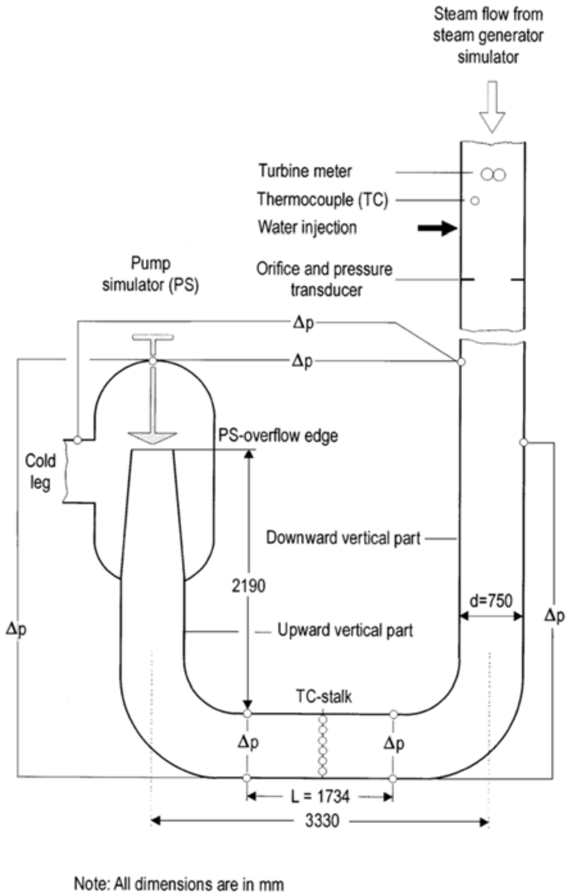


Fig. 1. Configuration of the UPTF loop seal [1].

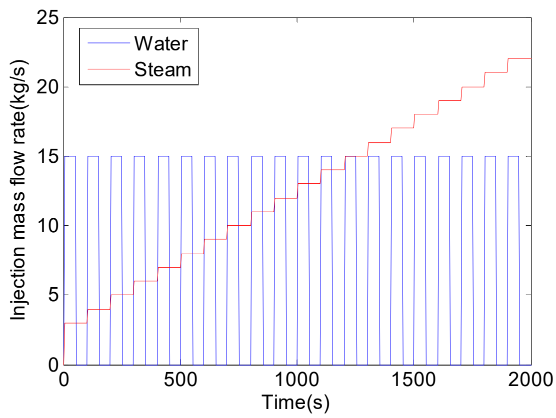


Fig. 2. Steam and water injection mass flow rate.

## 3. Analysis

### *3.1 Input Nodalization*

To obtain the analysis result, input decks for MARS-KS and SPACE codes was prepared with respect to the UPTF loop seal. The nodalization of SPACE code is shown in Fig. 3. The same nodalization is used for MARS-KS calculation. Table I-II show the geometry of hydraulic components.

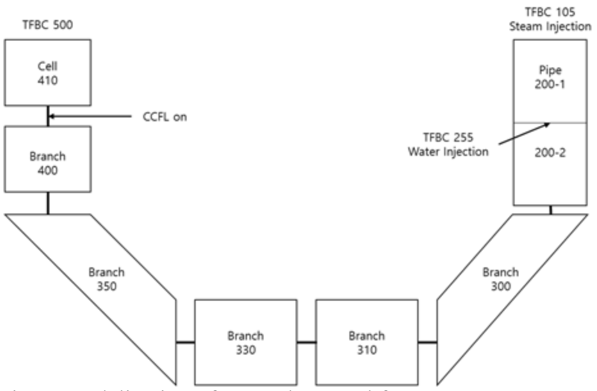


Fig. 3. Nodalization of UPTF loop seal for SPACE

Table I: Geometry of hydraulic components I

| Node # | Length(m) | Angle(˚) | Diameter(m) |
|---|---|---|---|
| 200 | 1.96 | -90.0 | 0.75 |
| 300 | 1.403 | -45.0 | 0.75 |
| 310 | 0.876 | 0.0 | 0.75 |
| 330 | 0.876 | 0.0 | 0.75 |
| 350 | 1.403 | 45.0 | 0.75 |
| 400 | 1.01 | 90.0 | 0.75 |
| 410 | 1.504 | 90.0 | 0.75 |

Table II: Geometry of hydraulic components II

| Node # | Area($m^2$) | Roughness |
|---|---|---|
| 200 | 0.441786 | 2.0e-6 |
| 300 | 0.441786 | 2.0e-6 |
| 310 | 0.441786 | 2.0e-6 |
| 330 | 0.441786 | 2.0e-6 |
| 350 | 0.441786 | 2.0e-6 |
| 400 | 0.441786 | 2.0e-6 |
| 410 | 0.19635 | 2.0e-6 |

Wallis model is adopted for the counter-current flow limitation (CCFL) model in both calculations of codes. 0.0 is applied for intercept and slope for CCFL model. Inlet and outlet boundary conditions are shown in table III.

Table II: Boundary conditions for analysis

| Node # | Type | P(Pa) | Quality | T(K) |
|---|---|---|---|---|
| 105 | Flow | 3.18e5 | 1.0 | - |
| 500 | Pressure | 3.18e5 | - | 409.0 |

### *3.2 Analysis Result*

From the input of each code, calculation results are obtained, respectively. MARS-KS 003 and SPACE 2.16 was used to obtain results. Firstly, the authors compared the code results that can be compared with the experimental data. Figs. 4 to 5 show the mean residual water level and Wallis parameter, non-dimensionalized superficial velocity of steam, during experiment in the horizontal region of the loop seal, node 310 and node 330. The authors used average value from node 310 and node 330. The Wallis parameter is calculated with eq. 1. Subscripts s and w mean steam and water, respectively.

$$J_s^* = \frac{\dot{M}_s}{A\rho_s} \frac{\rho_s^{1/2}}{[gd(\rho_w - \rho_s)]^{1/2}} \quad (1)$$

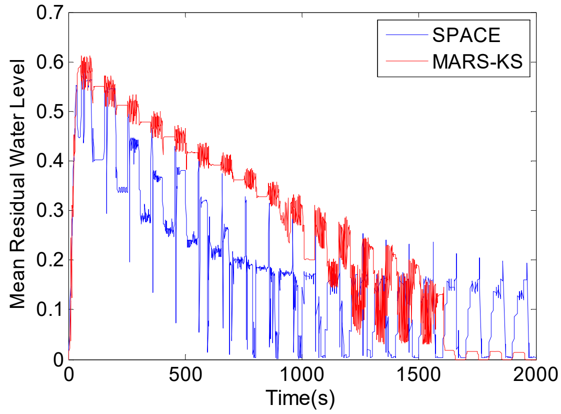


Fig. 4. Mean residual water level during experiment time

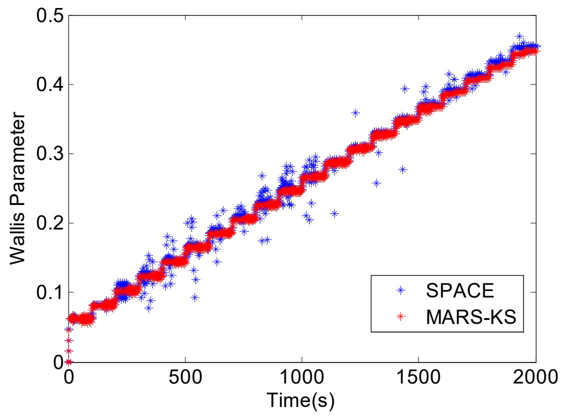


Fig. 5. Wallis parameter during experiment time

The experimental data are plotted for mean residual water level with the Wallis parameter, after water injection. The authors plotted the mean residual water level along with the Wallis parameter in Fig. 6.

To compare the calculation result with the experiment, the authors averaged the mean residual water level and the Wallis parameter when water is not injected, as shown in Fig. 2. The mean residual water level vs. the Wallis parameter with experimental result is shown in Fig. 7.

The results show that SPACE calculation has larger standard deviation than MARS-KS calculation. However, SPACE has closer prediction to the experimental data than MARS-KS in this case.

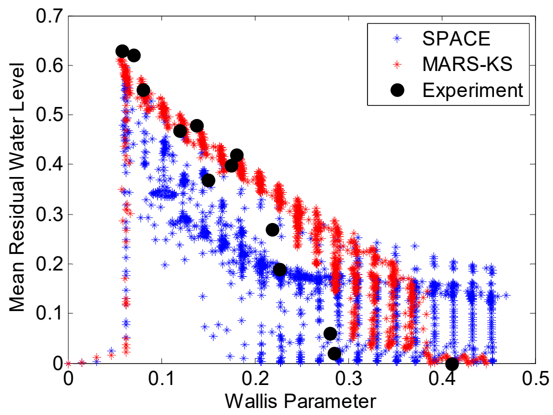


Fig. 6. Calculation result with experiment data

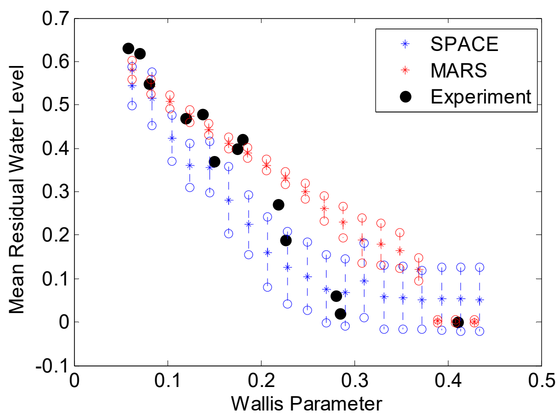


Fig. 7. Averaged result during steam-only injected period

To analyze the difference between SPACE and MARS-KS, firstly the authors compared steam mass flow rate in the horizontal region. The SPACE calculation has larger oscillation than the MARS-KS calculation. Furthermore, mass flow rate at outlet boundary of SPACE shows larger oscillation. However, the integrated mass flow at the outlet boundary doesn't show oscillation in both codes.

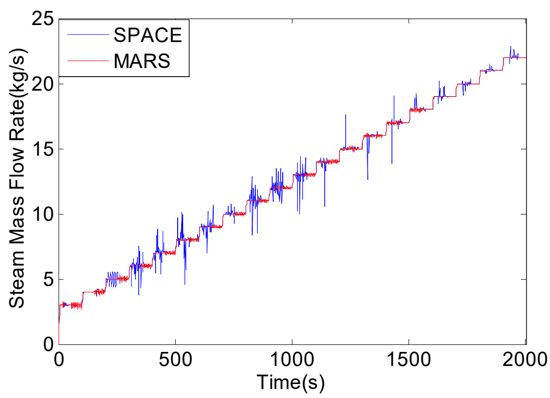


Fig. 8. Steam mass flow rate between 310 and 330

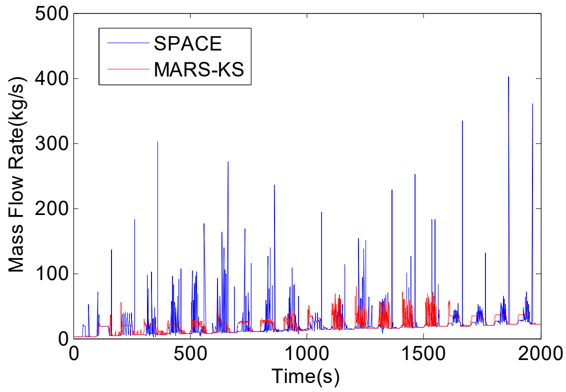


Fig. 9. Mass flow rate at outlet boundary

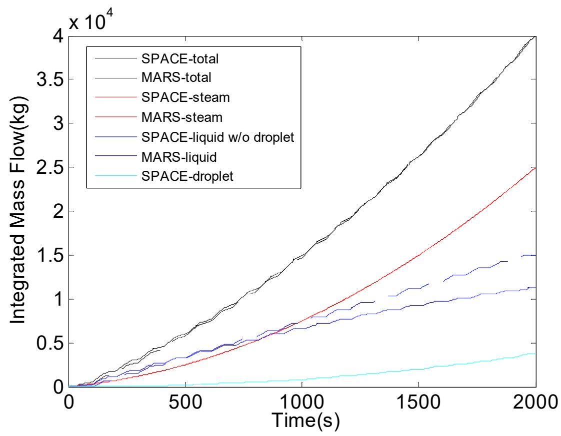


Fig. 10. Integrated mass flow at outlet boundary

Sum of the continuous liquid and the droplet integrated mass flow of SPACE is equal to the liquid integrated mass flow of MARS-KS.

## 4. Summary and Further Works

The authors compared the SPACE and MARS-KS performances for predicting the UPTF TRAM loop seal clearance experiment. An input deck was prepared for each code. The results from the two codes were compared to the experimental data, but due to the lack of information on the uncertainties it is too early to conclude the both codes' performance. However, from the obtained analysis results, some differences between MARS-KS and SPACE are initially observed. Especially, SPACE has larger oscillation in the calculated mass flow rate value than MARS-KS. This phenomenon was observed in comparison of SPACE and MARS-KS CCFL model as well [2]. And, SPACE shows lower mean residual water level than MARS-KS. It means that steam drags more water in loop seal in SPACE calculation. Then, loop seal clearing can be occurred earlier in SPACE. It means that SPACE is less conservative than MARS-KS in SB or MBLOCA analysis. More detailed analysis of the CCFL and interfacial model in MARS-KS and SPACE analysis results will be followed in the near future.

### References

[1] J. Liebert and R. Emmerling, UPTF experiment Flow phenomena during full-scale loop seal clearing of a PWR, Vol.179, p.51-64, 1998.
[2] W. W. Lee, M. G. Kim, Y. S. Bang and J. I. Lee, Study of counter current flow limitation model of MARS-KS and SPACE codes under Dukler's air/water flooding test conditions , Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 29-30, 2015.