Preliminary Assessment of MARS-KS for ROCOM Test-1

Seung Wook Lee*, Bub Dong Chung
Korea Atomic Energy Research Institute, 150 Deokjin-dong, Yuseong-gu, Daejeon, Korea
nuclist@kaeri.re.kr

1. Introduction

ROCOM (Rossendorf Coolant Mixing) is a 1/5 scale-down test facility which was built with the purpose of investigating the coolant mixing phenomena such as temperature and/or boron concentration occurring in the reactor pressure vessel (RPV) of a pressurized water reactor (PWR). The mixing phenomenon is measured by a salt tracer (i.e. sodium chloride) and the temperature or the concentration is indirectly estimated through electrical conductivity measurements. A density or buoyancy effects can be simulated through the injection of either alcohol or glucose, together with the use of salt tracer. Currently, a series of the coolant mixing experiments which are related with the main steam line break (MSLB) accident were conducted using the ROCOM facility to investigate the coolant mixing behavior during a MSLB accident. The boundary conditions for these experiments were obtained from the results of the OECD-PKL test G3.1 [1]. This paper shows the preliminary analysis results for the ROCOM test-1 by using a multi-dimensional RPV model of the MARS-KS but the comparison with the experimental data will not be presented at this time.

2. Overview of ROCOM Test-1

The boundary condition of the ROCOM test-1 is based on the PKL test G3.1 at t=609 s when the minimum temperature occurs at the broken loop. Table I shows the condition of the PKL test G3.1 at that time.

Table I: Condition of PKL test G3.1 at t=609 s

Loop	1	2~4 (Avg.)
Temperature (^oC)	153.0	236.1
Mass flow rate (kg/s)	267.4	69.0
Normalized mass flow rate (%)	5.46	1.41
Density (kg/m^3)	915.9	819.9
Relative density (-)	1.12	1.00

To establish the boundary condition for the ROCOM test, scaling factor based on the Froude number is used to replicate phenomena on the reactor scale because the density difference between the coolants in the broken and intact loop plays an important role for the ROCOM test. The Froude number, Fr is defined as follows:

$$Fr = \sqrt{\frac{\rho v^2}{\Delta \rho g L}}$$

where, v is velocity; g is gravitational acceleration;
ρ is density; $\Delta\rho$ is density difference;
L is characteristic length.

On the above basis, the following boundary conditions for the ROCOM test-1 were selected as shown in Table II.

Table II: Boundary conditions for ROCOM test-1

Loop	1	2~4
Normalized volumetric flow rate (-)	12.21	3.15
Volumetric flow rate (l/s)	6.27	1.62
Relative density (-)	1.12	1.00

The water with higher density is injected into loop-1 from an external tank with a pipe connected to loop-1 in a distance of 2.5 m from the inlet of the vessel. The experiment was performed under quasi-stationary flow condition according to the following procedure.

Table III: Test procedure of ROCOM test-1

Time	Task
Before experiment	Preparation of the water/sugar solution with the given density
T = -30 s	Establishing stationary flow in loop 2 ~ 4
T = 0 s	Start of injection of higher density water into loop-1
T = 90 s	End of injection

3. MARS-KS Assessment

3.1 MARS-KS Model

Fig. 1 shows the overall layout of the ROCOM facility and red dot line is the boundary of the MARS-KS simulation. The RPV including all pipes near the vessel is simulated except for the pumps and dummy steam generators.

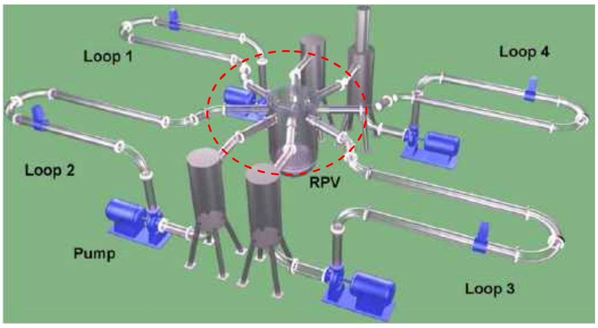

Fig. 1. Overall layout of ROCOM facility

The base input deck for the ROCOM test-1 was based on the MARS-KS multi-dimensional input deck which was provided by the UNIPI GRNSPG [2]. UNIPI provided two different MARS-KS multi-dimensional input decks; one is a fine mesh RPV model which consists of 5 multid components and the other is a coarse mesh RPV model which consists of single multid component. A coarse mesh RPV model input was used in this simulation. Detailed information on the input deck is described in the reference [2].

As shown in Fig. 1, the MARS-KS model for a ROCOM simulation is an open loop model, so that all hot legs have pressure boundary conditions whereas each cold leg has a flow boundary condition. In a stationary flow condition before the start of test, coolant densities in all loops are identical; therefore, it is reasonable assumption that each boundary pressure of the hot leg is fixed. During a test period, however, the flow rates in the loop 2 ~ 4 would be distorted due to a large flow rate with higher density in the loop-1. Therefore, the boundary pressures of all hot legs have to be adjusted to preserve the same flow rates as those during a stationary flow period. For this purpose, simple control logic for the boundary pressure control was implemented into the input.

3.2 Assessment Results

All loop temperatures and flow rates are the same as values as shown in Table I and II before the start of test (t=300 s). After the higher density water injection, the flow rate in each outlet of the loop is distorted as shown in Fig. 2 but the distortions are slowly reduced by the pressure control logic. The inlet temperature of loop-1 decreases as cold (high density) water is injected. Also outlet temperatures of all loops decrease.

Fig. 3 shows the temperature distribution of the downcomer during the test. It is clearly shown that a thermal stratification occurs at the below of the injection point.

Fig. 4 shows the temperature distributions in the core inlet and upper plenum and you can find out the coolant is well mixed in the core inlet within 100 s.

4. Conclusions

For the purpose of the assessment for the multi-dimensional capabilities of the MARS-KS code, a preliminary analysis for the ROCOM test-1 experiment has been performed. From the results, it is found out that the cold and hot coolant is well mixed within 100 s in the core inlet. Moreover, the thermal stratification in the downcomer occurs at the below of the injection point. These results seem to be qualitatively acceptable but in order to assess the multi-dimensional capabilities of the MARS-KS code quantitatively, a comparison with the experimental data is required and this further work will be done as soon as the experimental data is obtained.

ACKNOWLEDGEMENTS

This work was supported by Nuclear Research & Development Program of the KOSEF (Korea Science and Engineering Foundation) grant funded by the MEST (Ministry of Education, Science and Technology) of the Korean government. This paper also contains findings that were produced within the OECD/ NEA-PKL2 Project. The authors are grateful to the participants and the Management Board of the OECD-PKL2 Project for their consent to this publication.

REFERENCES

[1] Test PKL III G3.1: Main Steam Line Break (Quick Look Report), NTCTP-G/2009/en/0009, AREVA-NP, Nov, 2009.
[2] M. Cherubini, F. Moretti and F. D'Auria, Independent Assessment of Multidimensional Features of the MARS Code, DIMNP/GRNSPG NT637(08) rev. 0, UNIPI, Feb 2009.

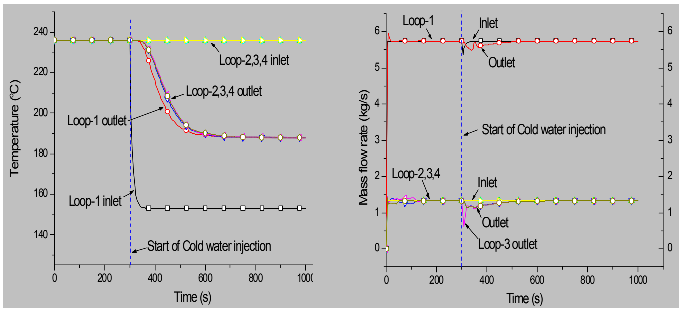

Fig. 2. Loop temperatures (left) and flow rates (right)

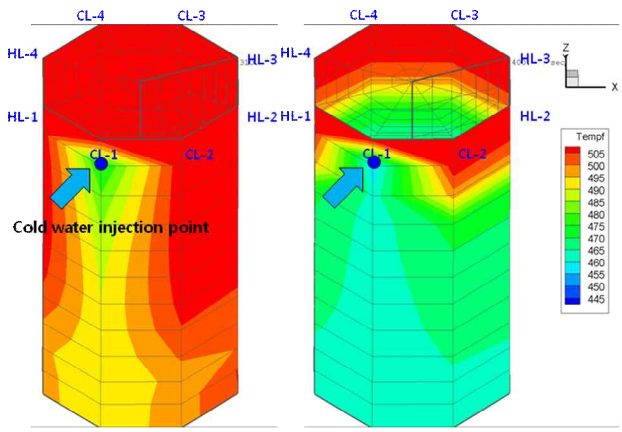

Fig. 3. Downcomer temperature at t=310 s and t=400 s

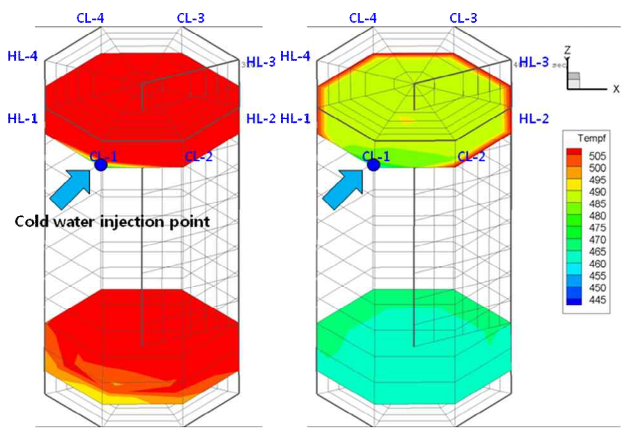

Fig. 4. Temperature of core inlet and upper plenum at t=310 s and 400 s