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Code Assessment of MARS-KS for RD-14M Small Break LOCA Experiment

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1. Introduction

Nuclear safety analysis has been carried out to evaluate compliance with safety requirements for nuclear power facilities [1]. In order to fulfill this purpose, various thermal-hydraulic codes have been used as a quantitative tool for many countries. MARS-KS is a one-dimensional thermal-hydraulic code to analyze nuclear systems. MARS-KS has been developed to calculate system thermal-hydraulic variables and verified to ensure whether the results are credible or not. MARS-KS development and verification have mainly focused on Light Water Reactor (LWR) facilities which account for the majority in South Korea. Thus, it has been demonstrated that MARS-KS has the ability to model thermal-hydraulic behaviors of LWRs. While the applicability of MARS-KS has not been fully determined to simulate thermal-hydraulic conditions for Heavy Water Reactor (HWR) because the design basis of HWRs is considerably different from LWRs. For this reason, it is necessary to conduct code assessment of MARS-KS for HWR applications. The aim of the present study was to undertake code assessment of MARS-KS (v1.5) from the viewpoint of HWRs. To achieve this objective, the current study used experimental data of a test facility to compare with MARS-KS results.

2. MARS-KS Modeling

RD-14M is a test facility to examine thermal-hydraulic environments in PHWR, especially CANDU (CANada Deuterium Uranium) [2]. Diverse experiments have been performed in the RD-14M for several decades and our study utilized data of small break LOCA experiment.

2.1 Small Break LOCA Experiment without ECC Injection

Test B9802 was a 3 mm inlet header break experiment without emergency core cooling (ECC) injections [2]. The test stated from gathering data in the RD-14M, and the surge valve was closed at 8.2 seconds later. The break valve representing the hole was opened at 11.2 seconds and kept unclosed until the end of the test at 1362.7 seconds. During the test, the power of the heated channels was remained at the full capacities, and there existed no rundown of the speed in the primary pumps and the pressure of secondary heat transport system in the steam generators.

2.2 MARS-KS Modelling

The RD-14M nodalization using SNAP (Symbolic Nuclear Analysis Package) is shown in Fig. 1. The input model consisted of hydraulic components, control systems, and heat structures to stand for the primary heat transport system and two feedwater systems. The hydraulic components and control systems were implemented based on their real geometries and test procedures respectively. Heated sections of the RD-14M were modelled to the hydraulic components combined with the heat structures as boundaries conditions with power sources.

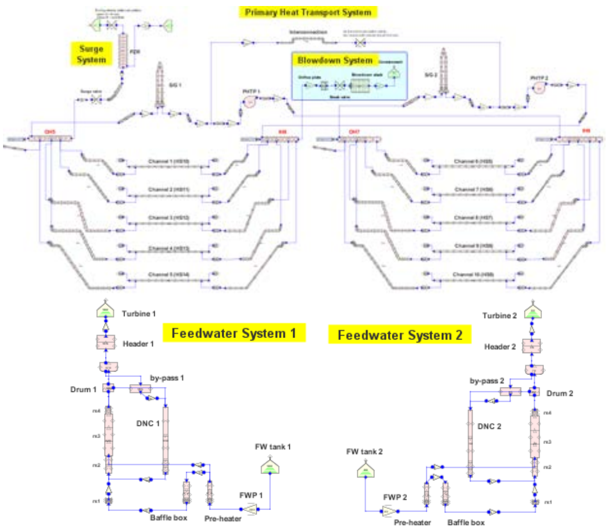

Fig. 1. Nodalization of the RD-14M test facility.

3. Results and Discussion

Generally, the thermal-hydraulic calculation is composed of two parts including the steady and transient state analysis. The steady state results are employed as the initial conditions for the transient state computation. Thus, it is important to obtain the correct results of the steady state for the transient analysis.

This study also executed the steady and transient assessment. Table 1 shows the comparison of the selected variables between the experimental and simulation results in the test and the errors of the variables did not exceed ±2%. Thus, the authors concluded that the computational results of the steady state were consistent with the experimental data and applied the steady results as the input for the transient calculation.

Table 1: Comparison of the Selected Variables Between the Experimental and Simulation Results for Test B9082 at the Steady State

Variable Name	Unit	Exp. [2]	Calc.	Error (%)
Header 6 Pressure	MPa	11.106	11.124	0.16
Header 7 Pressure	MPa	9.962	10.135	1.74
Header 8 Pressure	MPa	11.087	11.203	1.05
Pump 1 Flowrate	kg/s	18.5	18.5	0.0
Pump 2 Flowrate	kg/s	18.5	18.5	0.0
FES* Temp.@top pin, middle HS13	℃	323.0	322.08	-0.28
FES Temp.@top pin, inlet HS13	℃	313.6	310.23	-1.07
FES Temp.@top pin, outlet HS13	℃	338.0	339.94	0.57
FES Temp.@bottom pin, outlet HS13	℃	338.0	339.94	0.57
FES Temp.@top pin, middle HS8	℃	326.7	324.14	-0.78
HS5 Inlet Mass Flow	kg/s	3.40	3.41	0.23
HS8 Inlet Mass Flow	kg/s	4.27	4.23	-0.93
HS10 Inlet Mass Flow	kg/s	3.29	3.29	-0.14
HS13 Inlet Mass Flow	kg/s	4.15	4.16	0.34

(*FES: Fuel Element Simulator)

Although maintained constantly during steady state, the variables in Table 1 underwent changes after the break initiation. To compare the numerical and experimental results during transient state, the authors selected three variables explaining the aspect of pressure drop, hydraulic flow, and thermal effect. The pressure results in Header 8 where the break existed, the cumulative break mass through the hole, and the fuel element simulator temperature were displayed in Fig. 2, 3 and 4, respectively. They were in close agreements with the experiment results.

This study was designed to investigate the code assessment of MARS-KS for the applicability of HWRs using SBLOCA test data. When it comes to the code assessment, it is a fine method to identify good accord between the test and computational data. Thus, the present study indicated that MARS-KS code has the capability to apply for HWR applications.

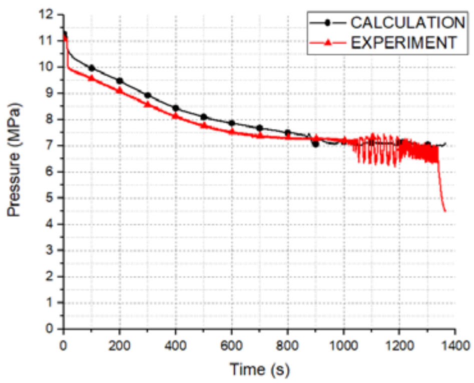

Fig. 2. Header 8 Pressure.

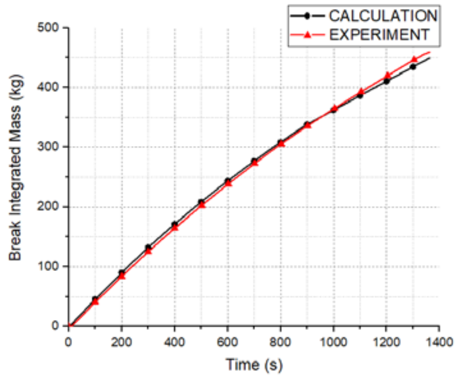

Fig. 3. Cumulative break mass.

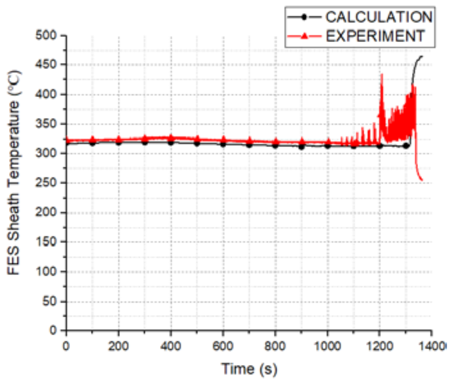

Fig. 4. Fuel element simulator (FES) sheath temperature in the heated section 13 (top pin, center)

4. Conclusion

The current study conducted the code assessment of MARS-KS to simulate HWR facilities. To accomplish this goal, the comparisons of numerical calculation and experimental data for SBLOCA in the PHWR test facility were performed and it was revealed that there was a well accordance between them and MARS-KS (v1.5) is capable of assessing thermal-hydraulic phenomena of HWRs.

ACKNOWLEDGEMENT

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