Analysis of Single-Phase Circulation Test in FINCLS using the MARS-KS code

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1. Introduction

SMART is integral type reactor and all of components including reactor core, pressurizer, reactor coolant pump, steam generator are contained within single pressure vessel. To satisfy international demands for nuclear safety, the PSS (Passive Safety System) in the SMART was introduced and SMART PSS consists of PSIS (Passive Safety Injection System), PRHRS (Passive Residual Heat Removal System), CPRSS (Containment Pressure and Radioactivity Suppression System). Various PSS experiments was performed for the SMART design. FINCLS (Facility to Investigate Natural CircuLation in SMART-ITL [1]) is a simplified test loop for understanding of thermal-hydraulic phenomena and can perform single- and two-phase natural circulation in SMART design [2]. The scaling method introduced by Ishii [3] was used for conserving the thermal-hydraulic characteristics of the SMART-ITL. The volume and core power for SMART-ITL were scaled-down to 1/64 and the height of FINCLS is the same as that of SMART-ITL for conserving thermal-hydraulic characteristics.

In the present paper, we introduce the input preparation for the MARS-KS code and the calculation results for the pressure drop assessment test using FINCLS [4].

2. Description of FINCLS.

FINCLS consists of a primary system and a secondary system as shown Fig. 1. The main components in the primary system consist of SG (steam generator), RPV (reactor pressure vessel), PZR (pressurizer) and measuring instruments are arranged.

RPV design was performed by the dimensional analysis, which is Re (Reynolds number) and D_h (hydraulic diameter), for conserving flow characteristic. Maximum electric power of core heater is set to 50 kW which corresponds about 47.5% of scaled full power. PZR is utilized as regulating pressure of primary system and keeps the primary system sub-cooled. Maximum electric power of PZR heater was determined to 5 kW. On the top of PZR, vent line and FCV (Flow Control Valve) was installed, respectively, for air removal and regulating pressure. The design of SG is focused on satisfying 100% of the scaled capability in heat transfer as well as to be capable of sufficient heat removal during various experimental tests. The SG in the secondary system was designed to single helical coil tube with once-through path to ensure sufficient heat transfer area. The mass flow is driven by a coolant circulation pump during heat-up process. The pump line is isolated in the main natural circulation tests.

Before getting into natural circulation tests, a series of commissioning tests have been conducted. One of them is the pressure drop assessment test in FINCLS. In that test, the pressure drop characteristics of the facility are understood and the required size of orifices can be determined to meet the design values. In order to represent the facility with the MARS-KS code, form loss coefficients across pipe size change, valves, instruments, curvature, and other obstacles need to be identified in advance for the MARS-KS code calculation.

3. Experiment & MARS-KS code

3.1 Experiment

In this pressure drop assessment test, the mass flow rate is controlled by regulating the rotation speed of the pump motor by the inverter. The pressure drop is equal to the pressure head gained by pump.

$$\Delta P_{pump} = \sum \Delta P_{loop} \tag{1}$$

The pressure and temperature of the test are 0.13 MPa, 8 ℃, respectively. Fig. 2 shows that the pressure drop is equal to the pressure head gained by pump.

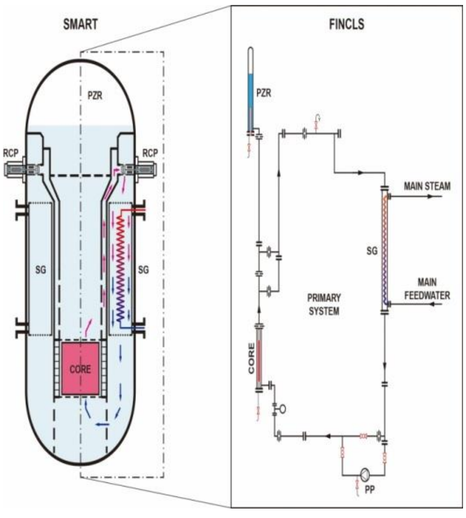

Fig. 1. Schematic diagram of FINCLS including the primary and secondary systems.

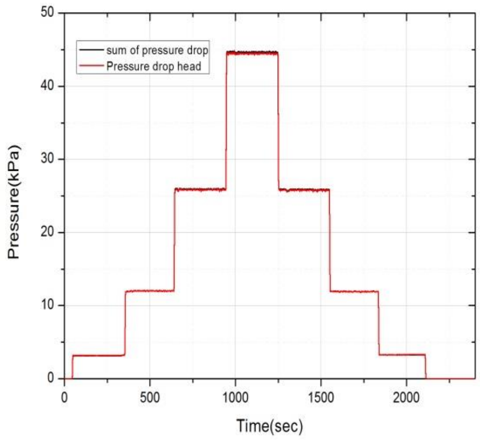

Fig. 2. Relationship between sum of pressure drop in the closed loop and pressure head from the pump.

3.2 MARS-KS code input preparation

The geometrical information of the facility was reflected in the MARS-KS input construction. The form loss for the turn and sudden expansion/contraction of pipes were calculated and imposed. The mass flow rate in the primary system was controlled by regulating the rotation speed of pump. Fig 3 shows the nodalization of FINCLS for MARS-KS code simulation.

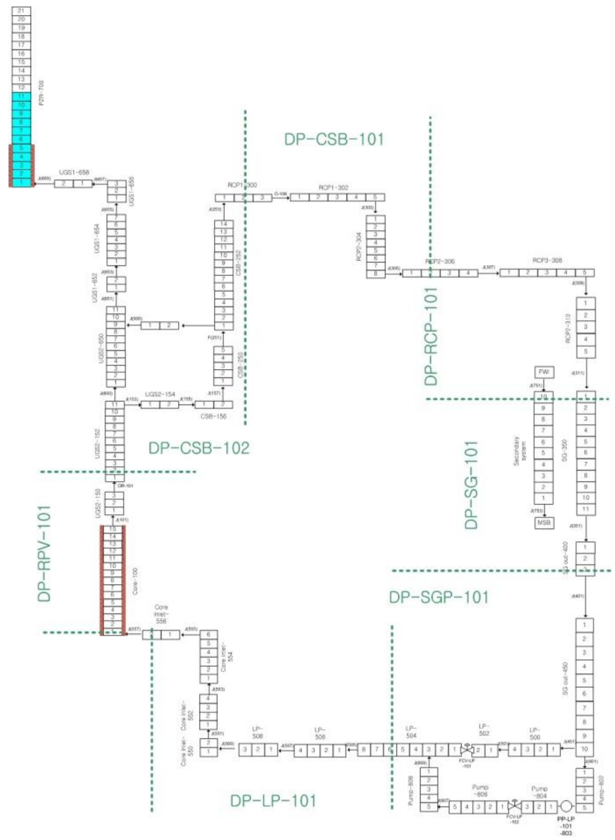

Fig. 3. MARS-KS Nodalization of FINCLS.

4. Results and discussion

Figs. 4 to 10 shows the comparison results of pressure drop of MARS-KS code simulation and experiment for each section of the loop in terms of mass flow rate. The pressure drops were measured in sections of RPV, CSB, RCP, SG, LP, and SGP, respectively.

Two experimental data under similar conditions but different dates were given. DP-LP-101 has a higher DP than other sections because of the mass flowmeter as shown in Fig. 8.

Two MARS calculation results were given under different form loss coefficients. In the first attempt, we used the input file with calculated form loss coefficients. In this case, the pressure drop was seriously underestimated by more than 80%. It was predicted that the form loss for instrument and flange was not well reflected in MARS-KS simulation. In the second attempt, we arbitrarily increased the form loss coefficients at the corresponding section, the difference was reduced significantly. In the steam generator, pressure drop showed more difference than in the other components.

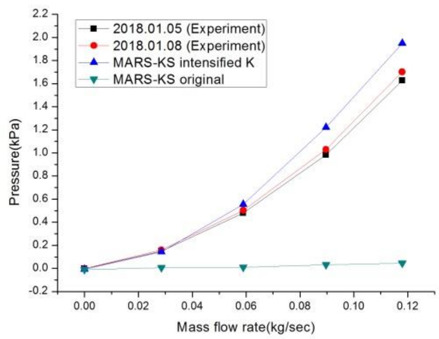

Fig. 4. Pressure drop of RPV-101.

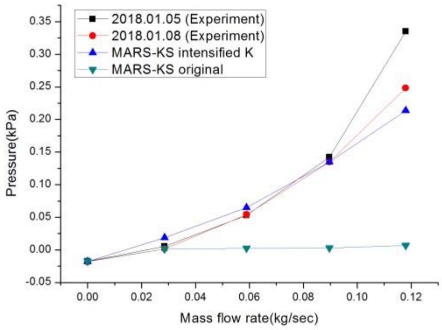

Fig. 5. Pressure drop of CSB-101.

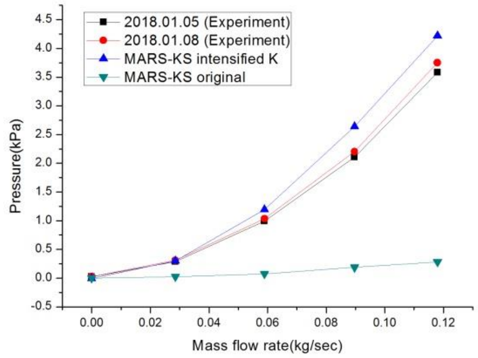

Fig. 6. Pressure drop of CSB-102.

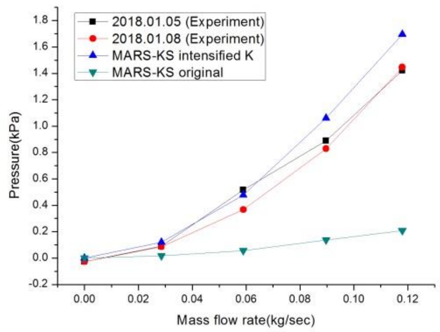

Fig. 7. Pressure drop of RCP-101.

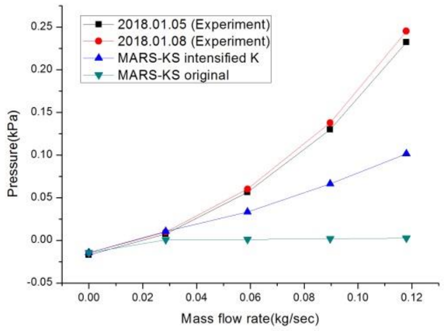

Fig. 8. Pressure drop of SG-101.

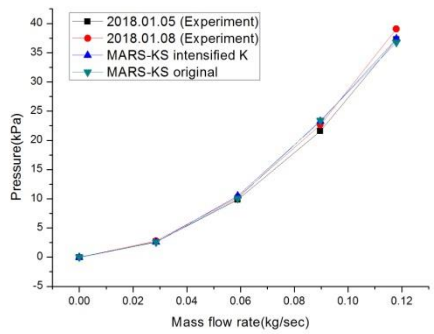

Fig. 9. Pressure drop of LP-101.

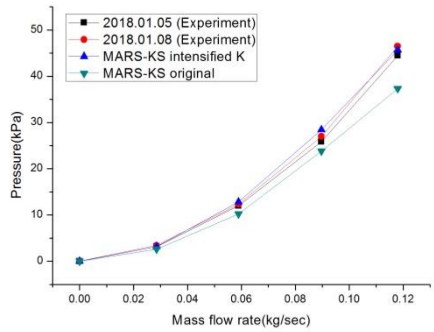

Fig. 10. Pressure drop of SGP-101.

5. Conclusion

FINCLS is a facility to investigate thermal-hydraulic phenomena for single- and two-phase natural circulation against SMART-ITL. The pressure drop assessment test was conducted before main natural circulation tests.

Forced convection using the circulation pump was made to obtain the pressure drop trend in terms of mass flow rate. The input for MARS-KS was constructed reflecting the geometry of the facility. However, regardless of the consideration of calculated form loss coefficients, the pressure drop was calculated significantly low. After intensifying form loss coefficients arbitrarily, we could match the experimental values with the code prediction.

In the future, the input should be updated reflecting the real situation and afterwards we will predict the single phase natural circulation in FINCLS more accurately.

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