Simulation of Natural Circulation Characteristics Test of ATLAS using MARS-KS Code

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1. Introduction

ATLAS is a large scale thermal-hydraulic integral effect test facility. The reactor pressure vessel (RPV) of ATLAS was modified in 2016 and 2017 [1]. The new heater rod bundle was installed, the flow skirt design was changed, and the downcomer design at lower region was modified to accommodate the partial blockage module. Following the modification of RPV, KAERI has performed the natural circulation (NC) test to investigate the scaling issue and the effect of modification on the NC performance [2-3]. In this study, we assess the MARS-KS V1.5 and our input model using the NC characteristics test of ATLAS.

2. Description of NC Characteristics Test of ATLAS

The experiment was carried out for two cases where the core power was 1.058 MW (Test ID: NC-03R) and 0.477 MW (Test ID: NC-04R), respectively. The pressurizer (PZR) was isolated from the primary system. The reactor coolant pumps operated in a free rotor manner. The pressure and temperature of secondary system were kept at nominal values of steady-state condition during entire test time.

The test started with single-phase NC under the nominal condition, and was proceeded by continuous stepwise draining of primary inventory from the bottom of RPV. As the inventory gradually decreased, the flow pattern was changed to the stable co-current NC, the unstable two-phase NC-syphon condensation, the stable reflux condensation, and the dryout occurrence.

When the steady-state was achieved at each draining, the data were recorded. The results were presented using the NC flow map (NCFM) [4]. It was found that ATLAS had pertinent NC characteristics.

3. Description of MARS-KS Input Model

Figure 1 shows the MARS-KS nodalization. The input model developed in Ref. [5] was modified by reflecting the modification of flow skirt and downcomer. The total primary volume of input model is only 0.54% larger than that of ATLAS facility. The modeling of heat loss and heat structures is not changed. All heat losses of the primary side are assumed to occur only on the outer surface of the reactor vessel. The draining unit installed at the bottom of RPV is modeled using the servo valve component. As in the experiment, the PZR and the safety injection tanks are isolated from the primary system in the calculation.

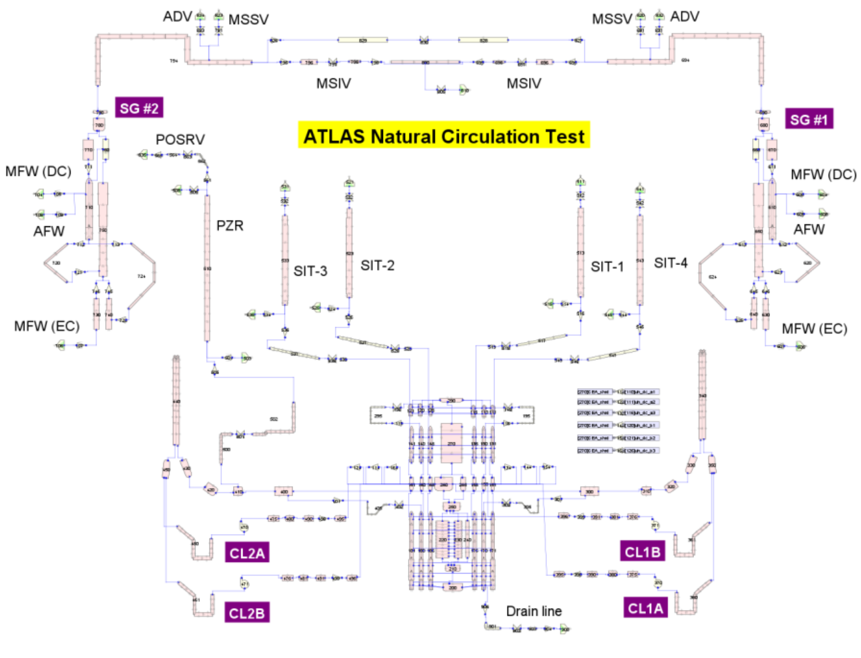

Fig. 1. MARS-KS nodalization.

4. Results and Discussion

The simulation starts with single-phase NC under the steady-state condition. The primary water inventory is drained for a very short time of 6 to 8 seconds every 1,000 seconds. The calculation is terminated when the maximum rod temperature reaches the set point

Figures 2 and 3 show the calculated core flow rate, residual mass (RM), void fraction at top of U-tube of SG-1, and mass flow rate at U-tube inlet of SG-1. For the initial total mass, the value provided in the experiment is used. The RM is calculated by subtracting the total draining mass from the initial mass in the primary system. The sum of four cold leg flow rates is assumed to be the core flow rate. The result of core flow rate shows similar NC characteristics with the experiment. As the RM decreases, the flow pattern is changed from the single-phase NC to the stable co-current NC and the core mass flow rate increases. After the maximum core flow rate, the unstable two-phase NC and the reflux condensation occur sequentially. The core flow rate become nearly zero during the reflux condensation [2].

Figure 4 shows the NCFM results for NC-03R and NC-04R, respectively. The parameters G, P and V denote core flow rate, core power, and net volume of primary system, respectively. The calculated values

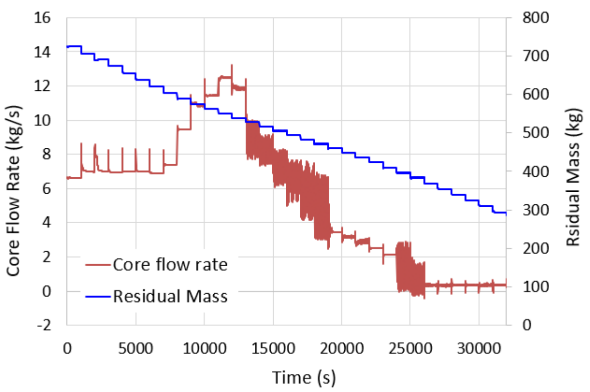

Fig. 2. Calculated core flow rate and RM for NC-03R.

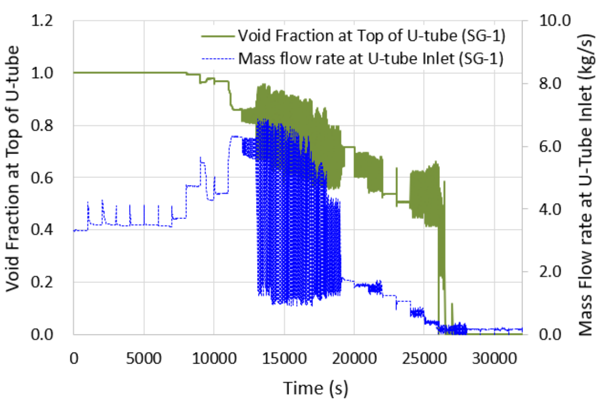

Fig. 3. Calculated void fraction at top of u-tube and mass flow rate at U-tube inlet for NC-03R.

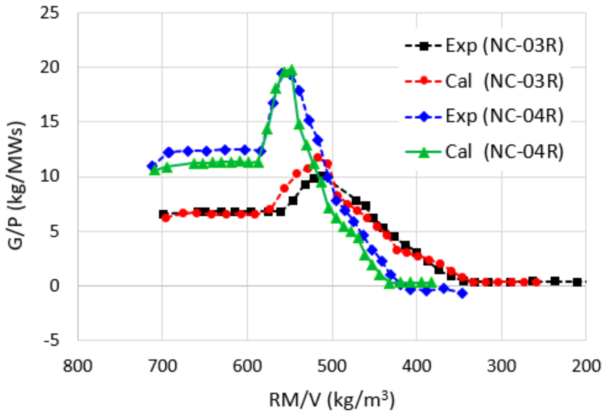

Fig. 4. Results of NCFM.

were averaged for 900 seconds during each quasi-steady-state condition. The MARS-KS predicts well overall NC performance of modified ATLAS facility. In the NC-03R, the code slightly over-estimates the maximum two-phase flow rate. The transition from single-phase to two-phase NC occurs earlier in the calculation than in the experiment. In the NC-04R, the code slightly under-estimates the core flow rate during the single-phase NC.

5. Conclusion

We have assessed the capability of MARS-KS V1.5 and ATLAS input model using the natural circulation characteristics test. It was found that the MARS-KS predicted well overall natural circulation performance of ATLAS facility.

Acknowledgements

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