MARS-KS Assessment Results on B9802 Test in RD-14M Facility

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1. Introduction

This paper presents the assessment results on the SBLOCA experiments which are performed in RD-14M test facility using MARS-KS code. The specific experiment, B9802, was modeled and simulated for the MARS-KS code validation. MARS-KS has been developed for a realistic analysis of thermal hydraulic transients in pressurized water reactors. For widening of MARS-KS applications to heavy water reactors, some important models for CANDU characteristics have been modified and applied to original MARS code and now still under development. The R&D project in order to utilize the MARS-KS as a thermal hydraulic system code for CANDU regulatory audit calculation is ongoing in KOREA.

2. B9802 Test in RD-14M Facility

RD-14M is an 11 MW, full elevation scaled thermal hydraulic test facility possessing most of the key components of a CANDU primary heat transport system. The facility is arranged in the standard CANDU two pass, figure of eight configuration. The reactor core is simulated by ten, 6 m-long horizontal channels. Each test section has simulated end fittings, seven electrical heaters and fuel element simulators, designed to have many of the characteristics of the CANDU fuel bundle. Test B9802 was a 3 mm inlet header break experiment, to provide data on the influence of condensation rates in the steam generators on primary loop response under conditions where such sensitivity is expected.

3. MARS-KS Nodalization and System Model

In modeling the primary-side nodalization, volume, length, flow area and elevation change of each MARS-KS pipe component resembles the RD-14M test facility, as closely as possible. The pipe component is adopted for heated section model because the pipe horizontal stratified criterion works for low- and moderate viscosity liquids, including water, at least in small diameter pipes up to 5 cm. In the heat structure, the seven fuel rods are combined into a single fuel rod heat structure and these fuel pins generate heat corresponding to each channel power. The power distribution in the axial direction is assumed to be uniform. The break is modeled by the trip valve attached at inlet header 8. The improved critical flow model is adopted instead of original RELAP5 critical flow model developed by Ransom and Trapp.

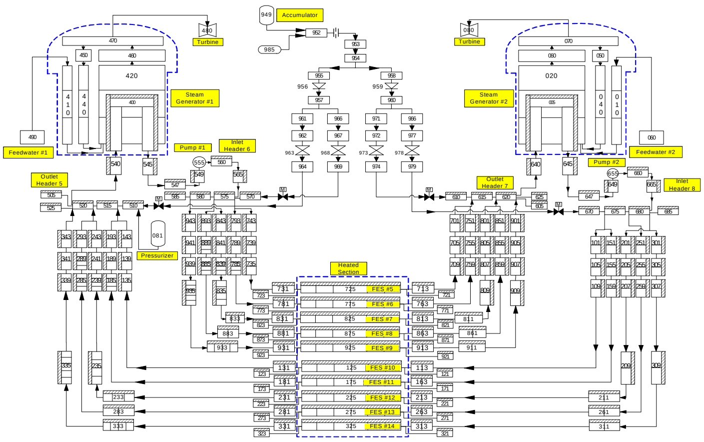

Fig. 1 MARS-KS Nodalization for RD-14M Facility

4. RESULTS

The steady state run was performed to initialize the reactor conditions to correspond to the test initial conditions. The calculated values of the major parameters are in good agreement with the experiment data.

The break was simulated by opening a trip valve to the containment at 11.2 seconds after initial steady state conditions were reached. After the break valve initiation, no power shut down, no ECC were actuated because discharge of inventory is insufficient to make the rapid transient. Primary pump 1 tripped at 1191.8 seconds due to the over voltage process protection trip, but the forced flow was not lost completely. The reduction of the primary flow resulted in rapid temperature excursion in the system. Then, a process protection trip due to high FES temperature interrupts the power supplies at 1336 seconds and it is predicted at 1418 seconds in the simulation. Table 1 shows the sequence of events in B9802 test comparing the simulation results.

Experiment (sec)	Simulation	Procedure / Significant Events
0.0	0.0	Start
11.2	11.2	Break valve opens
1191.8	1191.8	Pump 1 trip due to over voltage process protection trip
1336.13	1418.0	Power supplies tripped on high FES sheath temperature process protection trip

After the break opened, the primary system pressure rapidly decreased due to the sudden discharge of the inventory mass. After then, the pressure relatively and slowly decreased since the power supply and reactor coolant pumps are still operated. The header pressure transient is shown in Fig. 2.

Fig. 3 implies the inlet, middle and outlet FES temperature comparison in channel 13. The void fraction at outlet locations increased as transient time passed because the system pressure reached to saturation while the power is still operated. On the other hand inlet void fraction is maintained almost zero whole the transient by steam condensation in the boilers and steam separation in the headers. As a result, the outlet FES temperature shows the highest transient. The sudden increase of FES temperature appeared around 880 seconds in the simulation, at the same time the heat transfer model is changed from nucleate boiling mode to film boiling mode. After the pump 1 trip on, the outlet FES temperature transient is also well predicted by MARS-KS. However, the calculated inlet and middle FES temperature shows inconsistency with measured data. The bundle effects such as parallel flow, cross flow, and mixing in the horizontal channel could be caused of different heat transfer model prediction. Further study on the heat transfer model prediction considering bundle effect of a large diameter long horizontal pipe is required.

For a sensitivity study on the channel node number, the simulation results with 12 nodes and 6 nodes are compared. The FES temperature of channel 13 resulted from 12 nodes is more closed to measured data as shown Fig. 4. The sensitivity study on two phase discharge coefficient effect carried out for MARS-KS calculation sensitivity. The larger two phase discharge coefficient predicts rapid increase of outlet FES temperature and the faster power trip initiation due to more void generation. The FES temperature transient in the post dry out heat transfer regime is seriously influenced by node size and two phase discharge coefficient. Sensitivity cases on node size and two phase discharge coefficient are needed to have a good match with measured data.

5. CONCLUSIONS

Through the simulation results of B9802 SBLOCA test, MARS-KS code reasonably predicts main thermal hydraulic behaviors such as the primary pressure, temperature, mass flow rates, void fraction, outlet FES temperature, etc. during the steady state condition and overall transient. This paper suggests that a further study on the heat transfer model prediction considering bundle effect in the large diameter long horizontal pipe and a sensitivity study in respect of the discharge coefficient and node number of horizontal fuel bundle effects should be conducted to have more accurate and conservative code prediction.

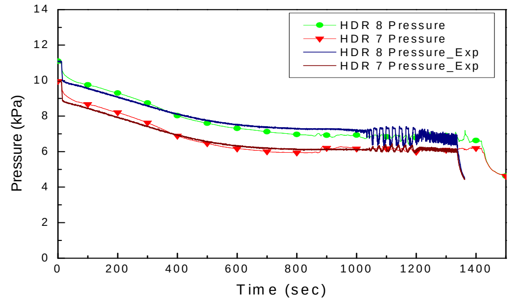

Fig. 2 Header Pressure

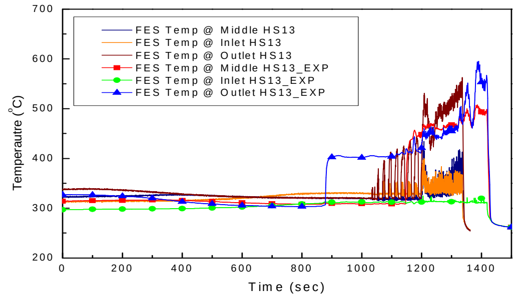

Fig. 3 Channel 13 FES Temperature

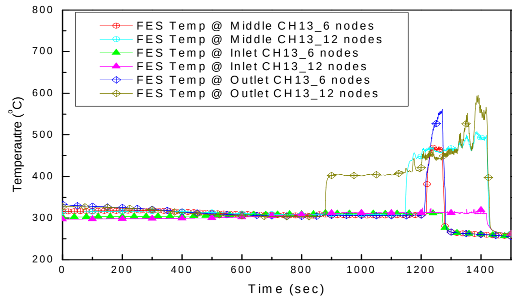

Fig. 4 Channel 13 FES Temperature Comparison vs. Node Number

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