Simulation Result of RD-14M SBLOCA Test using MARS_KS

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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, B9006, 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. Some important models for CANDU characteristics for instance critical flow model, nuclear kinetics model, critical heat flux model, valve and spray model, improvement of horizontal flow regime map, heat transfer model in horizontal channel, have been modified and applied to original MARS code[1].

2. SBLOCA Tests in RD14M-Test Facility[2]

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 B9006 is a 7 mm inlet header break experiment with pressurized accumulator emergency coolant injection. Once the break valve was opened, single phase liquid was discharged through the orifice, changing to two phase flow when the inlet header pressure reached saturation. About two seconds after break initiation, the FES power was decreased to represent decay power levels and the primary loop pump speeds were exponentially decreased to simulate the loss of class IV power. The ECC isolation valves were opened at 29 s and the high and low pressure ECC respectively injected at 80 s and 1190 s. The test was terminated at 2400 s.

3. MARS_KS Nodalization and System Model

According to the general principle of MARS-KS nodalization[3], RD-14M facility was modeled as shown in Figure 1. The system model composes of primary heat transport system including 10 heated sections, 4 headers, 2 reactor coolant pumps, high and low pressure ECC system, and secondary system. The break is modeled by the trip valve and it is connected with the downstream pipe and a time dependent volume for discharge reservoir. Heat structures were modeled for pipe walls, nuclear fuel pins simulator, heat exchanger surfaces, etc.

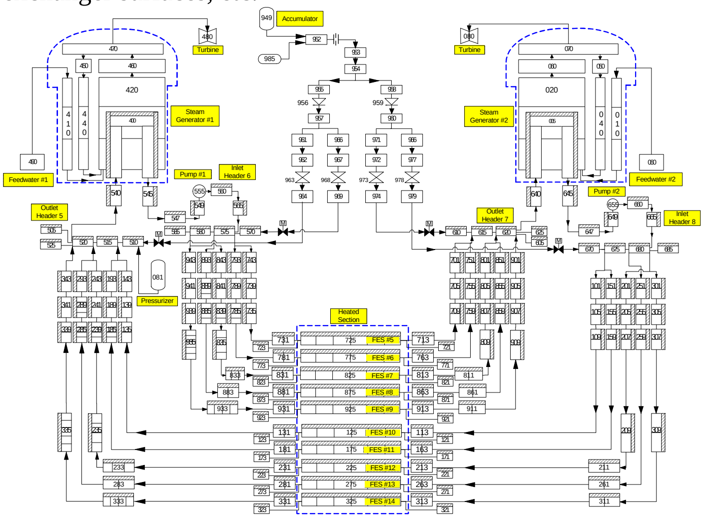

Fig. 1. MARS_KS Nodalization for RD-14M Facility

4. RESULTS

The steady state run was performed to initialize the reactor conditions to correspond to the test initial conditions. As seen in Table 1, the calculated values of the major parameters are in good agreement with the experiment data.

Table 1. Selected Variables for Comparison of Steady State

Variable Description	Exp.	Cal.	Unit
Header 8 Pressure	11.536	11.6	MPa(a)
Header 6 Pressure	11.508	11.6	
Header 7 Pressure	10.074	10.1	
Pump 1 Discharge Flowrate	21.5	21.5	kg/s
Pump 2 Discharge Flowrate	21.3	21.8	
Boiler 1 Outlet Fluid Temp.	259.4	263.4	°C
Boiler 2 Outlet Fluid Temp.	260.2	263.4	
FES Temp@top pin, middle HS13	322.4	314.7	
FES Temp@top pin, inlet HS13	311.7	302.4	
FES Temp@top pin, outlet HS13	333.6	330.7	
HS5 inlet mass flow	3.84	3.988	kg/s
HS8 inlet mass flow	4.93	4.913	
HS10 inlet mass flow	3.76	3.972	
HS13 inlet mass flow	4.78	4.947	

At 11 s, a small break LOCA was initiated by opening a valve having a feeder sized diameter to the environment from inlet header 8. When the pressure of header 6 reduced below 8.8 MPa, the reactor trip and pumps trip occurred by simulating the protection system. With the trip, the power is reduced from 4 MW to 200 kW per heated pass, and pump flow coasts down exponentially. Emergency coolant injection from a nitrogen accumulator tank is activated at 129 s when the primary pressure reached 4.2 MPa. Low pressure pumped ECC delivers distilled water to the loop at 1.5 MPa following completion of the high pressure ECC due to accumulator depletion.

After the break initiation, the primary pressure dramatically reduced as the inventory mass discharge and the reactor power trip on. Around 1100 s, the sudden header pressure increase is captured by activation of the low pressure pump in both calculated and measured results. The header pressure is maintained same as low pressure ECC pump discharge pressure. Figure 2 shows the comparison of experimental and calculated header pressure trends. The ECC flow initiate signal generated at 28 s when the header pressure reached 6.0 MPa, and all ECC isolation valves are opened at the same time. However, no ECC water enters to header until the header pressure reaches less than ECC tank pressure, 4.2 MPa. In the calculation ECC water starts to enter at 129 s but it is measured 80 s since the slower header depressurization is calculated. The low pressure ECC water into loop starts to enter at 1100 s in both experimental and calculated data.

The void fraction at outlet locations of the heated section increased because the system pressure decreased in the initial phase of the transient. Some spikes exist at outlet of the heated section after 400 s since the coolant was heated and boiled through the channel. All measured minus void fraction values considered as zero, calculated void fraction is good agreement with test data as shown in Figure 3.

Figure 5 shows the FES temperature time histories at different location. The FES temperature excursions in HS13 begin immediately down as the power is decreased to decay heat level. After the onset of the high pressure ECC injection, the FES temperature at inlet of heated section 13 begins to decrease significantly and it is well predicted by MARS_KS code. In view of long term cooling, the higher FES temperature at heated section 13 is calculated while it showed good consistency in the heated section 8. It would be considered as ECC flow mixing and distribution in the headers, which determine the channel flow and coolant temperature, have some deficiencies with experimental results.

5. CONCLUSIONS

The capability of MARS_KS code to simulate the important phenomena of CANDU reactors during the SBLOCA accident condition was assessed. In conclusion, the MARS_KS code reasonably predicted main thermal hydraulic phenomena such as primary pressure, channel void fraction, ECC flow rate, pump exponential ramp. However, further study on the ECC mixing, distribution and flow (vaporization and condensation) through the channels during the low channel flow condition is needed in detail.

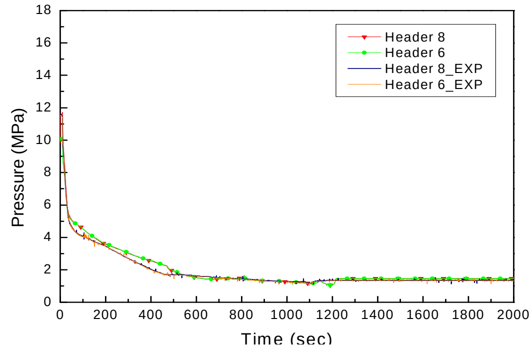

Fig. 2. Pressure at Header 8 and 6

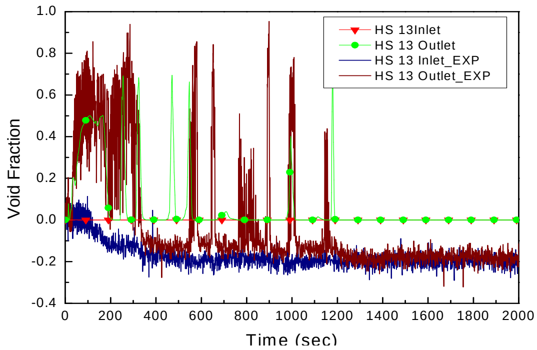

Fig. 3. Void Fraction at Inlet and Outlet of HS 13

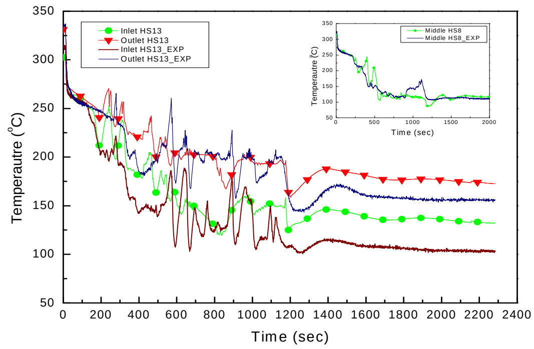

Fig. 4. FES Temperature at Inlet and Outlet of HS 13

ACKNOWLEDGMENTS

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