Simulation of the condensation experiment for the SG primary of SMART with MIDAS/SMR

Jong-Hwa. Park[a], Dong-Ha Kim[a],Young-Jong Chung[a], Sunhee-Park[a],Seong-Won Cho[b],
a KAERI, 1045 Daeduck daero,Yuseong., Daejeon, 305-353, jhpark3@kaeri.re.kr
b KORTIC, 34 Gwahakro,Yuseong, Daejeon, 305-338,swcho@kortic.co.kr

1. Introduction

SMART is new concept of reactor that all the main components such as the steam generator, the coolant pumps and the pressurizer are located inside the reactor vessel. MIDAS/SMR V1.0.3 code has been used for estimating the severe accident from SMART [1]. SMART has the SG tube with helical shape that is different from that of PWR.

MIDAS code has the condensation model for the both sides of surfaces from the various kinds of geometry. But it does not have the condensation model for the helical type of tube. In this study, the condensation experiment for the outer surface of the SG tube in SMART that was performed by Po-Hang university was simulated with MIDAS/SMR under the assumption of straight pipe [2]. The simulation results showed well predictions of the amount of heat removal from the SG tube primary side and thermal hydraulic parameters.

2. Methods and Results

2.1 condensation experiment

The actual helical SG primary side was a circle with 360 degree. But with considering the possible flow rate range, the test section for the condensation in the SG primary side was designed to account only for the part of 14 degree. The pitch size between the upper and lower horizontal tube was 25mm. It is the same size as that of SMART. In the rectangular shape of test section as seen in Figure 1, the radial distance between the test section wall and tube outer surface was 5.5 mm and the peripheral tube length within the test section was 60.85 mm.

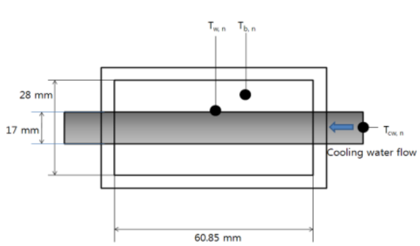

Figure 1 Cross-sectional view of the test section

Figure 2 shows the side view of experimental test section for the condensation in the primary side.

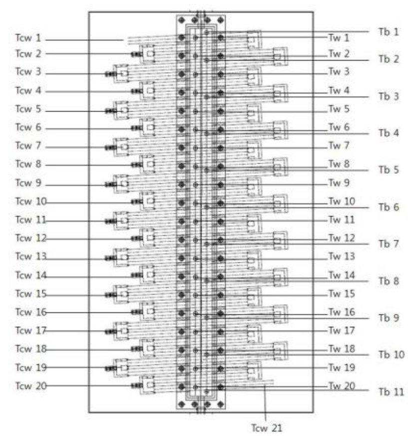

Figure 2 Side view of the test section for the experiment

The primary steam flow rate in the experiment was prepared based on the mass flow rate of about 0.02 Kg/s being anticipated from LOCA. The experiment was performed from 1.5 MPa to 6 Mpa with changing the primary pressure. The steam injection temperature was distributed from 200 ℃ to 275 ℃. The secondary experimental conditions such as pressure, injected coolant temperature and mass flow rate were kept constant. The outer and inner radius of tube was 0.017 and 0.012 m respectively. Total tube length within the test section was 15.555 m and its volume was 5.5247E-4 m^3. The total free volume in the primary side was 3.89E-3 m^3.

Table 1 shows the experimental matrix for the 4 cases on the primary steam condensation phenomena.

Table 1 Boundary & initial conditions for the experiment

	Primary side			Secondary side		
	Pressure (bar)	flow rate (kg/s)	T inject (℃)	Pressure (bar)	flow rate (Kg/s)	T inject (℃)
case-1	15	0.0202	200.148	3.681	0.2143	11.469
case-2	20	0.0187	211.252	3.686	0.2131	11.415
case-3	40	0.0203	248.206	3.694	0.2151	10.816
case-4	60	0.0202	275.438	3.702	0.214	10.637

The local condensation heat transfer coefficient could not be measured directly. They were derived indirectly using the measured parameters such as the coil outer surface temperature, the primary fluid temperature, the secondary coolant flow rate and the axial enthalpy change of the coolant in the secondary. The following equations show the derivation processes of the local condensation heat transfer coefficients using the measured parameters as mentioned above.

$$h_{cnd} = \frac{\dot{m}_c (i_{c,n-1} - i_{c,n})}{2\pi r_o L(T_o - T_b)}$$

where $\dot{m}_c$ = secondary coolant flow rate [kg/s]
$i_{c,n-1}$ = enthalpy at the axial level 'n' [J/kg]
ro = tube outer radius [m]
T_o, T_b = tube out wall and primary fluid temperature [K]

2.3 Simulation of the condensation experiment

Figure 3 shows the conceptual view of the nodalization on the condensation experimental system for MIDAS/SMR.

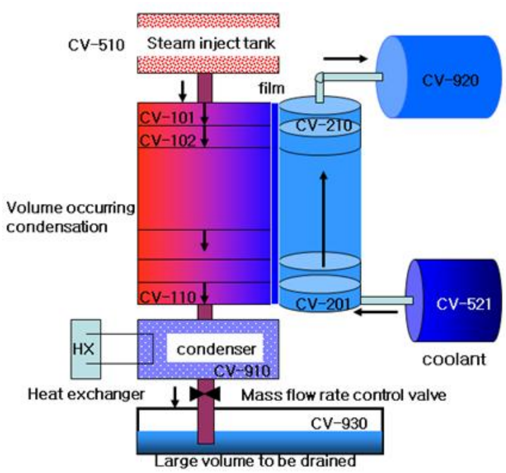

Figure 3 Nodalization for simulating the primary condensation experiment with MIDAS/SMR

For the primary side, an hot steam was injected from the upper CV-510 to the lower CV(101~110). For the secondary side, a cold coolant was injected from the lower CV-521 to the upper CV(201~210). On the discharge CV-910 in the primary, a bundle of tube for the purpose of heat sink was installed so that the un-condensed remaining steam may be condensed completely. The completely condensed water was designed to discharge to the CV-930 but the mass flow rate through the valve was controlled according to the experimental matrix. All the experiments were done under the pure steam condition and the film tracking model was not applied. The maximum film thickness was assumed as 5.0E-4 m. The maximum value of the pool fraction over the surface that calculates the heat and the mass transfer to the atmosphere was set as 0.9.

2.4 Summary of the simulation results

The calculation results with MIDAS/SMR were compared with the experimental data. The key results for each axial level were the steam temperature in the primary side, the secondary coolant temperature, the tube outer surface temperature and the primary condensing heat transfer coefficients. From this study, MIDAS/SMR can well predict the thermal hydraulic parameters (pressure, flow rate, temperature) and the primary side condensation heat transfer coefficient was estimated 30 ~ 35 kW/m^2-K. The figure 4 shows the local condensing heat transfer coefficients for the second case of experiment (20 bar).

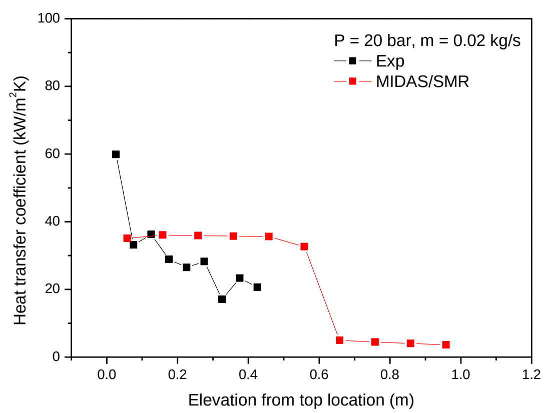

Figure 4. Condensation heat transfer coefficient (case-2)

3. Conclusion

It is estimated that MIDAS/SMR can well simulate the condensation phenomena from the helical horizontal bundle of tubes in the primary side of SG in SMART.

ACKNOWLEDGEMENTS

Authors would like to thank MEST for supporting this research with the frame of MEST long term R&D program.

REFERENCES

1. Sun-Hee Park, 'Software verification and validation report for MIDAS/SMR version 1.0.3 code', SMT-SVVR-TH-12001, Rev 0, KAERI (2011)
2. Ki-Hoon Yang, M.H Kim, Y.J Jung, 'SG shell side condensation heat transfer experiment results report', 160-TH458-022, Rev 01, KAERI (2011)