The Effect of External Vessel Cooling for a 2 inch LOCA Severe Accident Scenario at SMART with MIDAS/SMR

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1. Introduction

KAERI is developing a 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. This feature may prevent the large size of LOCA.

However it is necessary to estimate the hypothetical severe accidents progression for improving the degree of safety and identifying the unknown weakness of the system against an accident. To simulate a hypothetical severe accident for the SMART, we adopt the MIDAS/SMR code which was developed by KAERI [1].

2. Effect of external vessel cooling at 2 inch LOCA scenario

2.1 Steady state calculation with MIDAS/SMR

SMART system adopts the helical tubes with the type of once-through for the steam generator. It does not require any large volume and also any pre-heater and the dryer because it uses directly the super heated steam discharging from the exit of helical tube.

To estimate the validity of the implemented heat transfer correlations for the helical tube and the input data, the steady state calculation was done with MIDAS/SMR. For this purpose, only the helical tube region was modeled with the boundary conditions for the both sides such as the coolant inlet flow rates, inlet coolant temperatures and pressures.

The steady state was confirmed base on the exit conditions for the primary and secondary sides. The steady state conditions for the helical tube regions were obtained from the results of TASS/SMR-S code [2].

As the applications of these correlations to MIDAS/SMR result in under-prediction comparing to the target thermal-output of 330 MW, multiplication factors to the correlations were used to get the steady state conditions. Figure 1 shows the comparison of the predicted thermal power before and after the code update, respectively.

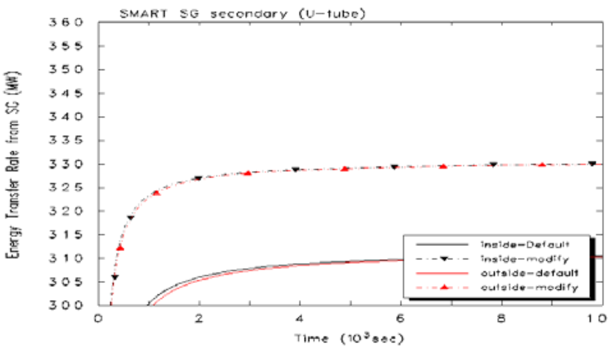

Figure 1 Predicted thermal power of SMART

2.2 Nodalization & Input data for simulating 2 inches small break LOCA on SMART

The 2 inch LOCA input was prepared by adding the LOCA scenarios to the steady state base deck. It was assumed that the 2 inches break occurred at the RCP discharge to the containment at 200 seconds.

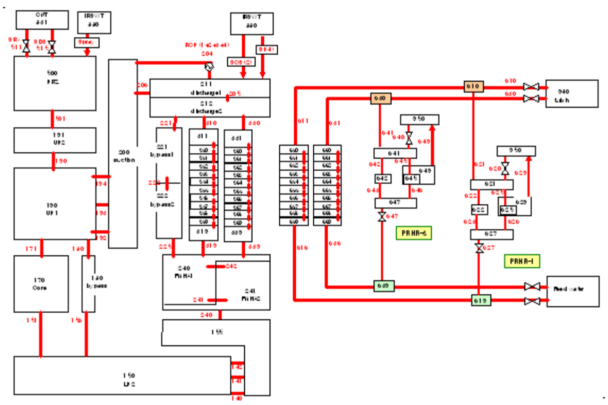

Figure 2 Nodalization of SMART system for SBLOCA with MIDAS/SMR

Also it was assumed that the function of PRHR was suppressed by closing the draining valve that was located on the line from ECT tank to the main feed water. The cavity flooding system starts when the gas temperature at the upper exit of the core reaches 1000 K. During the transient, the water level will stay constant at the top of cavity. Figure 2 shows the nodalization of the SMART system for simulating the 2 inches break LOCA sequence.

2.3 Review of the model on the lower head vessel rupture and the external vessel cooling [3]

The relocated debris mass and the pressure difference cause the lower vessel wall to suffer from a stress. The Larson Miller parameter (LMP) value is determined by the degree of stress and the type of vessel material. Using the LMP value and the mass-averaged vessel wall temperature, the vessel rupture time can be predicted. If the plastic strain exceeds 18% of the initial length, then the lower vessel head is assumed to be ruptured.

The heat transfer coefficient from the outer surface of the lower vessel head to the water in cavity is calculated based on the heat flux and the difference of temperatures between the outer surface of lower vessel head and the saturated water.

2.4 Comparison of SBLOCA sequences with and without external vessel cooling.

Table 1 compared the main events for the two scenarios during the SBLOCA in the SMART system. One is the case with the wet cavity (with EVC) and the other with the dry cavity (without EVC).

Table 1 Summary of SBLOCA sequences in SMART

Events	Cavity dry [s]	Cavity wet [s]
Break	200	200
RX trip	270	270
MFW trip	270	270
RCP trip	461	461
core uncover start	6,030	6,030
Cavity Flooding	-	12,432
Core dry-out	24,358	23430
Corium Relocation start	29,500	25,000
Lower vessel head dry-out	-	135,000
Lower vessel head Creep	80,000	Intact (~200,000 s)

For the case of 'with EVC', the relocation to the lower vessel head occurred a little earlier than that of the case of 'without EVC'. In case of the without EVC, the lower vessel head failed at 80,000 sec.

On the contrary, for the case of 'with EVC', the lower vessel head was predicted as intact until 200,000 sec. The predicted maximum heat flux from outer surface of lower vessel to the water in cavity was about 0.3 MW/m^2.

Figure 3 showed the outer surface temperatures for the case of 'with EVC' and 'without EVC'. For the case of with EVC, the outer surface temperature remains at constant temperature of around 400 K.

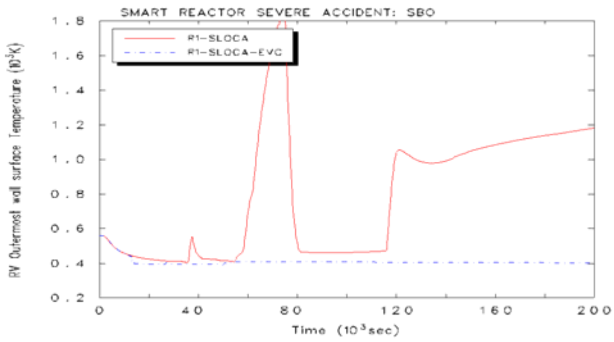

Figure 3 Outer surface of lower head temperature with and without EVC (external vessel cooling)

3. Conclusion

MIDAS/SMR code with the heat transfer correlations for the helical tube was used for the analysis of SBLOCA at the SMART plant. The calculation showed that the EVC can have an important effect on preventing or delaying the vessel failure from occurring. During EVC, the maximum heat removal rate from the outer surface of lower vessel was predicted as about 0.3 MW/m^2.

These results are preliminary because the design data are not yet determined. Also more sensitivity calculations on the important parameters that may have effects on the accident progression and the vessel failure are needed to finalize the results.

ACKNOWLEDGEMENTS

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