MCCI Simulation for the APR-1400 TLOFW sequence

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1. Introduction

If retention of molten core debris inside a reactor vessel is not assured during a postulated severe accident, the molten core debris will attack the concrete wall and basemat of the reactor cavity. Thus, this accident might lead to inevitable concrete decompositions and possible radiological releases. In the OECD/NEA MCCI project, a series of tests such as water ingression, melt eruption, and 2-D core concrete interaction tests was performed to secure the data for cooling a molten core spread out at the reactor cavity and for the long-term MCCI (Molten Core Concrete Interaction).

This paper deals with the MCCI (Molten Core Concrete Interaction) phenomena for the APR1400 investigated by using the CORQUENCH Version 3.03 [1] and a comparison with the MELCOR 1.8.6 calculations [2]. For the ease of a direct comparison, the same major inputs and basic heat transfer models were used. The CORQUENCH Version 3.03 includes a melt eruption model based on a turbulent jet entrainment correlation and an up-to-date water ingression model[1] which was developed at the Argonne National Laboratory during the OECD/MCCI project. On the other hand, since these models are not incorporated in MELCOR 1.8.6. [2], a phenomenological difference of heat transfer to the upper coolant exists between the codes. Important parameters of the MCCI such as concrete ablations, heat fluxes, and melt temperature etc. are analyzed and compared with the MELCOR 1.8.6 calculation results. Some sensitivity studies with a change of system pressure, heat transfer model at the melt/concrete interface, and coefficient of water ingression and melt eruption models are performed.

2. Input data for MCCI simulation

The AR1400 reactor cavity is designed to promote a retention of, and heat removal from, a postulated core debris during a severe accident. The large cavity floor area allows for a spreading of the core debris thus enhancing its coolability within the reactor cavity region. The free volume of the cavity is approximately 963 m^3. The cavity floor comprises an approximate area of 80 m^2 available for corium spreading. This cavity floor area results in a floor area/reactor thermal power ratio of 0.0203 m^2/Mwt.

For the APR1400 concrete, the concrete composition is close to SIL concrete or CORCON1 concrete. The total loss of main feed water accident without any action of depressurization is selected for the base case. Total amount of the melt accumulated in the reactor vessel for the selected base case is 191,200 kg. The melt is released at a temperature of 2,843 K.

This same temperature is assumed for the melt layer at the onset of a concrete attack. The melt is released from the lower head at about 20,000 seconds following a reactor scram. For the nominal reactor operating power of 4,666 Megawatts thermal, the corium inside the cavity has an initial power of about 26.5 Megawatts at 20,000 seconds after a scram.

Table 1 shows the summary of the MCCI simulation for the APR-1400 with CORQUENCH and MELCOR1.8.6.

Table 1 Summary of the input data for APR-1400

Parameter	Value
Corium mass, kg	191,200
Cavity radius/area, m / m^2	5.0576 / 80.36
Initial corium temp., K	2843
Time after scram, sec.	20,000
Initial decay power, MW / %	26.506/ 0.57
System pressure, MPa	0.1
Coolant flooding time, sec	20,000
Coolant mass, kg	577,000
Coolant temp., K	373
Concrete type	APR1400 specific
Heat transfer model at melt/concrete	Bradley
Concrete density, kg/m^3	2340
Initial concrete temp., K	300
Concrete temp., K solidus / ablation / liquidus	1350 / 1450 / 1650

This corresponds to 0.57 percent of the nominal power. It is assumed that the cavity is flooded with saturated water at an atmospheric pressure of about 4.5E+5 Pa. The mass of the water on the top of the melt is 577,000 kg. It is also assumed that all the water is flooded at the time of 0 sec. The 'gas film model' was selected as the heat transfer model between melt and concrete for the base case.

3. Simulation Results

Figure 1 showed the comparison of the maximum concrete ablation depth for two directions between MELCOR1.8.6 and CORQUENCH3.03. Axial ablation depths from two codes were similar but the radial ablations showed difference. The CORQUENCH predicted more deep radial ablation depth than that of MELCOR.

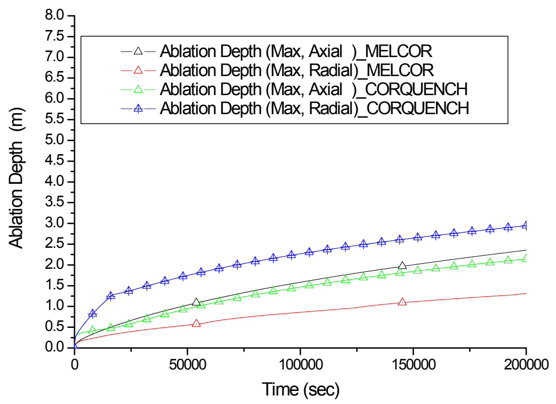

Figure 1 Maximum ablation depth for APR-1400

4. Sensitivity Calculation Results

Figure 2 showed the effect of the system pressure on the ablation depth from CORQUENCH3.03.

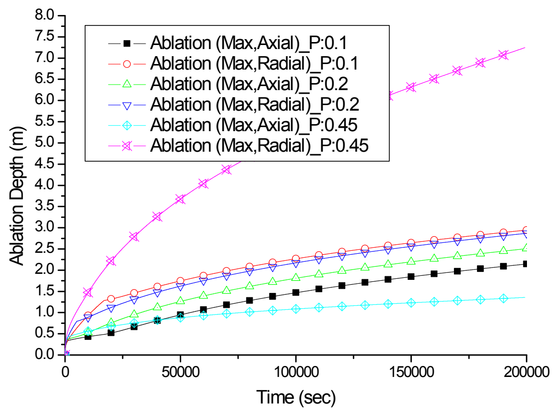

Figure 2 Ablation depth with change of pressure

CORQUENCH predict more deep radial ablation depth than that of axial direction. Also the effect of pressure on the ablation depth was negligible till 2 bar. But above 4.5 bar, the radial ablation was predicted to be increased rapidly by CORQUENCH.

5. Conclusion

MCCI (Molten Core Concrete Interaction) calculations for the APR1400 were performed by using CORQUENCH Version 3.03 which includes a melt eruption model and up-to-date water ingression model developed during the MCCI project.

The base case calculations were compared with those done by the MELCOR 1.8.6. The axial ablation depths calculated by the CORQUENCH are similar to that of the MELCOR. But the radial ablation depths calculated by CORQUENCH are larger than those by the MELCOR. The melt temperatures calculated by the CORQUENCH are higher than those by the MELCOR. The power transferred from the upper debris to the coolant for the MELCOR calculation is larger than that for the CORQUENCH calculation. But this should be reviewed by SNL.

Sensitivity studies showed that the radial ablation was largely increased in cases of an elevated system pressure and not successful in case of some given heat transfer models such as the 'slag' and the 'gas film' at the melt/concrete interfaces. Also, it seems that the melt eruption and water ingression effects are not seen in the CORQUENCH Version 3.03.

ACKNOWLEDGEMENTS

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