Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Analysis of Ex-Vessel Corium Coolability using MELCOR 1.8.5 Code

Namduk Suh, Yongjin Cho
Korea Institute of Nuclear Safety, Kusung-dong 19, Yusung-gu, Daejon, Korea
k220snd@kins.re.kr

1. Introduction

The coolability of corium in the reactor cavity is still an unresolved issue. In case the corium does not cool in the cavity, the long term integrity of containment might be in danger because of the corium-concrete interaction (CCI). The continuing CCI can produce fission products and steam to increase the containment pressure. As an effort to resolve this issue, OECD has performed a series of MCCI experiments including the separate effect tests of melt eruption, of water ingression and of crust failure with prototypic material. Among these tests, the water ingression test showed that this mechanism of water ingression is effective in increasing the coolability of corium. Unfortunately this water ingression effect is not modeled and implemented in the MELCOR 1.8.5 code which is used heavily in KINS. Actually one of major difficulties in assessing the long-term integrity of containment is this lack of detailed MCCI models in the code. In fact, MELCOR code simulates all the time that the corium will not be cooled even if there are sufficient water in the cavity, but we cannot be quite sure whether this is a real phenomenon . Even though the water ingression model is not implemented in MELCOR code the actual effect of water ingression is to increase the heat transfer, so our idea is by tuning the heat transfer coefficient in the code such as to best match the experimental data , we might have more realistic evaluation of the corium coolability . This paper shows our efforts and results on the evaluation of ex-vessel coolability of corium in Kori-1 nuclear power plant using MELCOR 1.8.5 code.

2. Evaluation of an OECD Experiment

The first step is to tune the parameters in the MELCOR code to best match the MCCI experiment. The experiment chosen is a Small Scale Water Ingression and Crust Strength (SSWICS) test 4 [1]. The detailed information of how we have performed the analysis can be found in the paper [2] and here we will only summarize the result. The parameters we found to assess the experiment best are shown below.

HTRINT = 1.5 : debris to surfact heat transfer
MIXING = 1 : mixing of debris
COND.OX=1.6 : conductivity multiplier of oxide phase
COND.MET=1.6:conductivity multiplier of metal phase
EMISS.OX=1.0 : emissivity of oxide phase
EMISS.MET=1.0 : emissivity of metal phase
EMISS.SUR=1.0 : emissivity of surroundings

With these parameters, the MELCOR predicts very well the experiment as in figure 1 below. The red line shows the experimental data. The black line shows the simulation result when we took the MELCOR default options and the gold line is the result we got with the tuned parameters. It is clear that our newly chosen parameters simulate very well the experiment.

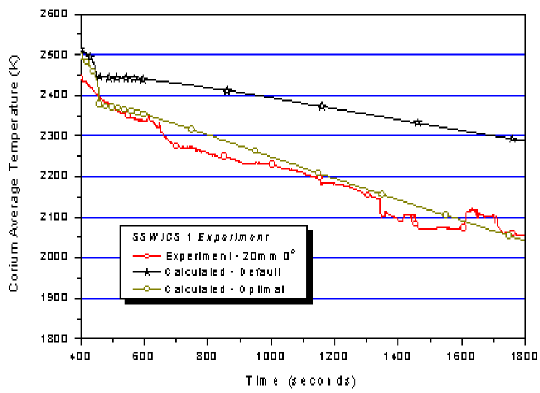

Figure 1 Evaluation of SSWICS-1 Experiment

3. Analysis of Ex-Vessel Coolability

Having parameters which simulate the experiment best, we have applied this set of options to assess the coolability of corium in Kori-1 plant. The accident scenario chosen is a station black out (SBO) accident and we have supposed that the power is recovered 30 minutes after the vessel failure and from that time on the spray has been actuated. The injected spray water eventually fills in the cavity and we are evaluating whether the corium in the cavity can be cooled by this injected water. The detailed MELCOR analysis model to simulate this accident is explained in the paper [3]

Figure 2 shows the analysis result we got. The black line shows the assessment result with the MELCOR default options. The red line shows the result we calculate with the optimal set of parameters. In the default calculation the corium temperature is higher than 1,750 K during the simulation period. This 1,750 K is a threshold value of CCI in the code meaning that if the corium temperature is higher than 1,750 K, the code assumes CCI is occurring and releases fission products and steams into the containment, thus increasing the pressure. It is clear from the figure that the corium is not cooled and the long-term integrity of containment will not be guaranteed neither.

On the other hand the calculation with the optimal parameters show that the corium temperature falls below the threshold temperature of 1,750K and thus the corium is supposed to be cooled in this calculation. Because the parameters are chosen based on the water ingression experimental data, we'd like to give more weight to this assessment result with optimal parameters.

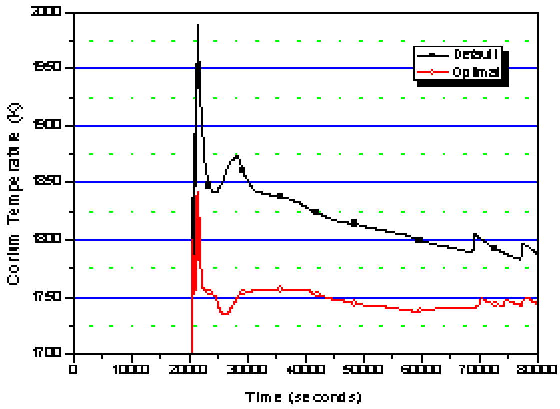

Figure 2 Corium Temperature in Cavity

Figure 3 shows the water temperature in cavity. More heat is transferred from corium to water in the optimal calculation because we have increased the heat transfer coefficient, thus the water temperature should be higher for the optimal calculation than the default case. This is clearly shown in the figure 3 and it is in good match with the figure 2.

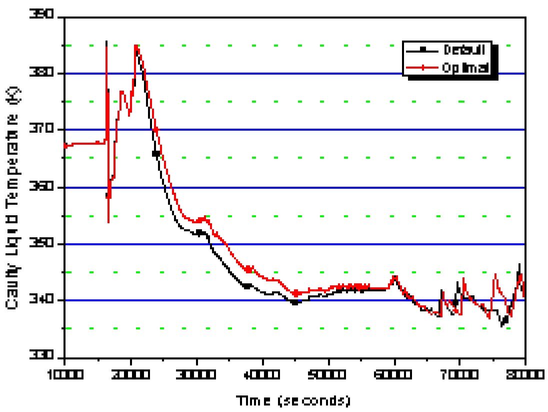

Figure 3 Water Temperature in Cavity

The best way to simulate coolability and thus the long-term integrity of containment is to use a specific code which has all the models of CCI phenomena. But even with the integral code like MELCOR, we could assess one of the CCI experiment very well by choosing optimal parameters. The MELCOR code with the optimal parameters predict quite different results about the coolability of corium in the cavity. Of course we could not easily conclude that the corium would be cooled based on this calculation and we need more efforts to come to a confident conclusion. But anyway we think we now have a more realistic way of analyzing the coolability with MELCOR code.

4. Conclusion

We have analysed the water ingression test SSWICS of OECD/MCCI experiment using MELCOR 1.8.5 code. The MELCOR code does not have the water ingression model in it, but by choosing an optimal set of parameters about the heat transfer between the corium and the environment we could very well simulate the experiment. Then the selected optimal parameters were applied in assessing the coolability of corium in the cavity for Kori-1 NPP. The calculation was performed for a SBO accident. Our previous MELCOR calculation predicted that the corium would not be cooled even if there are sufficient water in the cavity. But the calculation with our optimal parameters showed that the corium temperatures fall below the CCI threshold temperature, meaning that the corium might be cooled in the cavity. Much more analyses are in need to come to a confident conclusion, but at least we think we found a more realistic way of assessing corium coolability with an integral code like MELCOR.

REFERENCES

[1] S.Lomperski, M.T.Farmer, D.Kilsdonk, B.Aeschlimann, OECD/MCCI Project; Small-Scale Water Ingression and Crust Strength Tests (SSWICS), Final Report; Thermal Hydraulic Results, OECD/MCCI-2005-TR03, 2005

[2] Yongjin Cho, Namduk Suh, MELCOR 1.8.5 Assessment of Molten Core Concrete Interaction Experiment SSWICS-4, Transactions of the KNS Spring Meeting, 2006.

[3] Namduk Suh, Yongjin Cho, Comparative Analysis of MELCOR 1.8.5 and RELAP5 Codes for a SBO accident, Transactions of the KNS Spring Meeting, 2007.