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Analysis of THAI-HM2 Test with MELCOR 1.8.5 Code

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1. Introduction

The combustible gas control in containment is one of the important items for plant safety, but there are still large uncertainties in analyzing the hydrogen behavior in the containment for the regulatory review of new plants. Moreover since the Shin Kori 1&2 and Shin Wolsong 1&2 plants – named Optimized Power Reactor 1000 (OPR1000) – are under licensing process now, so it is important for KINS (Korea Institute of Nuclear Safety) to have a reliable analysis methodology for the assessment of hydrogen risk. An integral severe accident code MELCOR which has been widely used was intensively verified against experiments, but we should always be careful about the capability of a code. As part of our efforts to establish a confident analysis environment we need to simulate experimental data using MELCOR code. This paper describes the first step of our efforts for the code verification. The HM2 test of OECD/THAI (Thermal hydraulics, Aerosol and Iodine) project was selected as a benchmark problem, which focused on the hydrogen mixing phenomenon in containment especially for the erosion process of stratified atmosphere by steam plume. THAI-HM experiment is part of the OECD/THAI Project run in Germany. Brief results of the first step approach are described.

2. THAI Facility and HM2 Test

The THAI vessel is made of stainless steel and has a height of 9.2 m and a diameter of 3.2 m to make the total free volume of 60 m^3. In the HM tests conducted in 2007, the inner multi-compartment structure was generated by installation of an inner cylinder (diameter of 1.4 m) and condensate storage trays in the annulus as shown in Fig. 1. Hydrogen is injected with light portion of steam at the elevation of 4.8 m in the annular region (R=1.15 m, φ=135°) using a vertical pipe of 28.5 mm-diameter. Steam is injected at the elevation of 1.8 m on the center of axis in the lower plenum about 0.35 m below the inlet of the inner cylinder. A vertical nozzle of 138 mm-diameter is used for steam injection.

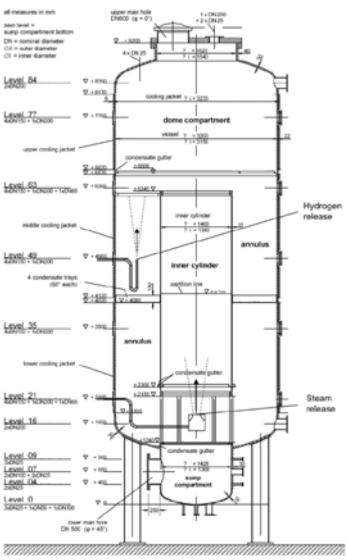

Fig. 1 Configuration of THAI test vessel for HM2 test.

The HM2 tests consist of 2 phases. The test vessel is initially filled with nitrogen. In Phase 1, hydrogen mixed with slight portion of steam is released upward up to 4,200 seconds under the ambient condition of 1 bar and 21 ℃ (average). The average temperature of injected mixture is 45 ℃. After the injection of hydrogen is finished, 2-minute interval with no injection of any source exists. During the Phase 2, saturated steam of 107.5 ℃ is then released from 4,320 seconds up to 6,820 seconds, from the vertical nozzle at the lower plenum. In the evaluation report, the Phase 2 is divided into two periods following the thermal hydraulic phenomena; Phase 2a (stagnation) and Phase 2b (natural circulation).

3. MELCOR Analysis

3.1 MELCOR Modeling of THAI Facility

A MELCOR input for THAI-HM tests was developed by Lee et al. [1]. It's a 67-CV (control volume) model with 168 flow paths and 91 heat structures. Details of the input modeling and nodalization can be found in the reference.

3.2 Calculation Matrix

A number of calculations have been conducted to evaluate the effect of modeling parameters in the code. Seven cases were selected to compare the results.

RUN20 is defined as 'default case' that was submitted to THAI project for the semi-blind calculation. RUN15 was selected to check the effect of loss coefficients of flow path. RUN14 was additionally selected to find if a difference exist when using an averaged source data.

In RUN22, RUN26, RUN29, and RUN31 film tracking modeling was added to HS package to predict more realistically the wall condensation. Comparison between RUN20 and RUN22 may give the effect of the HS film tracking modeling.

To simulate the wall region better, the CVs in the inner cylinder were subdivided into central region and ring-type volumes in RUN26, RUN29, and RUN31.

RUN29 and RUN31 are different from RUN26 in that additional division for CV300 and CV700 (just lower and higher volumes from inner cylinder, respectively). RUN31 is an additional examination in which the horizontal flow paths located far from HSs were adjusted intentionally to investigate its effects.

3.3 Comparison of Simulation Results

Fig. 2 shows the atmospheric pressure for test period. The similar discrepancies are shown among the calculations, but there are large differences (near 10 %) between calculations and experiment especially in Phase 2. The over estimation of the pressure means we are having difficulties in simulating the heat transfer.

During Phase 1, a stable stratification is achieved in test vessel. Fig. 3 compares the concentrations of two elevations of 1.6 m and 8.7 m both for experiment and calculations. It is clear that division of source injection CV plays an important role to simulate the stratification in test vessel atmosphere. At the end of Phase 1, the deviation of hydrogen concentration in the cases with non-divided injection CV is about 5 %, while in other cases the deviations are larger than 25 %. This means that a sufficient number of nodes are required in MELCOR code to demonstrate a realistic stratification. It also indicates that the second step approach of this study (sensitivity of nodalization) is important. The highest concentration predicted in Phase 1 is about 7 % lower than the experiment. According to experiment, lower hydrogen concentrations at the top and higher ones near the bottom tend to increase the erosion velocity of the stratification.

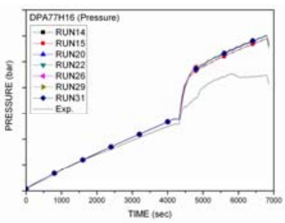

Fig. 2 Gas temperature.

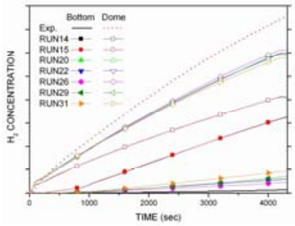

Fig. 3 H2 concentration.

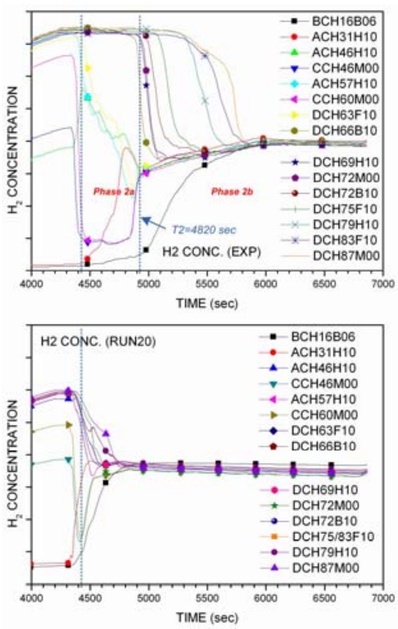

Fig. 4 Hydrogen concentration in Phase 2

Erosion of stratified atmosphere of upper region by the steam plume injected at bottom region is the major concerning phenomenon of THAI-HM2 test. Therefore the flow velocity profile at the upper end of inner cylinder has a close connection with an onset of natural circulation as well as the consequent erosion of the stratification.

As given in Fig. 4, continuous increase of rising velocity results in the erosion of stratified layers in dome region in experiment. Hydrogen concentrations collapse and atmospheric temperatures rise in order. However, those phenomena occur within very short period in calculations. No significant differences were made by variation of input parameters, CV division of inner cylinder, and modeling of film tracking on walls.

4. Conclusions

In applying MELCOR code to a condition where the stratification or the erosion process is important, we had some difficulties in following the phenomena. In this case nodalization seems a dominant factor in simulating the phenomena found in THAI-HM2 test. Therefore additional sensitivity study on the effect of nodalization which is planned in the second step of this study will be helpful to improve the code capability with reduction of uncertainties in calculation. This could also implicate that we need much larger number of control volumes in the analysis of hydrogen risk in the containment of real plant.

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REFERENCES

[1] Lee, J.J. et al., Development of a MELCOR Input for THAI HM Tests, Transactions of the Korea Nuclear Society Spring Meeting, Gyeongju, Korea, May 29-30, 2008.