MELCOR SIMULATION OF STEAM CONDENSATION EFFCT ON HYDROGEN BEHAVIOR IN THAI HM-2 EXPERIMENT

Seongnyeon Lee[a], Jung-Jae Lee[a], Sung Joong Kim[b], Yong-Jin Cho[a]*
[a]*Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejeon 34142, Republic of Korea,*
[b]*Department of Nuclear Engineering, Hanyang University, 222 Wangshimni-ro, Seongdong-gu, Seoul, 133-791*

**Corresponding author: yjincho@kins.re.kr*

1. Introduction

Containment Filtered Ventilation System (CFVS) has been introduced as facility to prevent containment failure during severe accident. However, possibility of hydrogen risk has been issued due to inflow of hydrogen, condensation and removal of steam and complicated inner structure in CFVS. Preferentially benchmark work for THAI HM-2 experiment of OECD was decided to validate the methodology before detailed assessment of hydrogen risk in CFVS. The objectives of THAI HM-2 experiment were evaluation of hydrogen behavior, verification of numerical analysis tools and so on [1]. In this paper, therefore, MELCOR simulation was carried out in comparison with the experiment results. Additionally, steam condensation effect was considered for detailed simulation.

2. Description of THAI HM-2 and MELCOR modeling

2.1. Description of THAI HM-2

Figure 1 shows facility diagram and description of THAI HM-2 experiment. It consists of vessel, inner cylinder, 4 trays, hydrogen nozzle, steam nozzle, and so on. Test procedure of THAI HM-2 was divided into two phases for total 6,820 seconds. In phase 1, hydrogen with tracer steam was injected from a nozzle at the middle part into the upper plenum for 4,200 seconds. And then stagnation phase maintained for 120 seconds. In phase 2, steam was injected from a nozzle at the lower plenum, into the inner cylinder for 2,500 seconds [2].

2.2. MELCOR modeling

The simulation was performed using MELCOR 2.1 with SNAP [3]. Figure 2 shows MELCOR nodalization. Hydrogen was injected at CV 514 and steam was injected at CV 310. To consider steam condensation effect, three cases was selected in this study. Case 1 is base case. In case 2 and 3, mass transfer coefficient (XMTFC) of condensation model was modified in the input. Table 1 shows the description of each cases. The coefficient of case 3 was referred in Jiří Duspiva`s study [4].

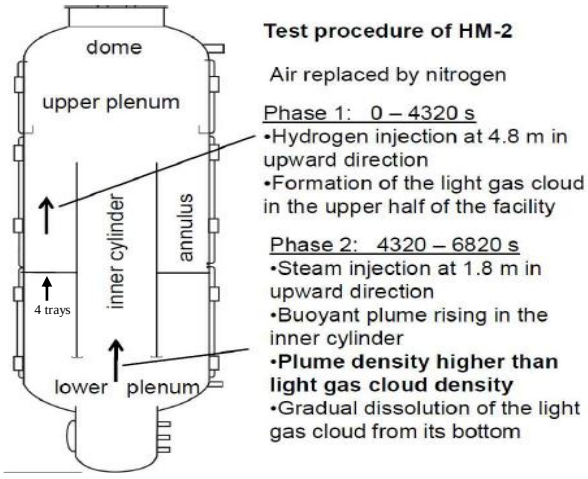

Figure 1. Facility diagram and description of THAI HM2 experiment

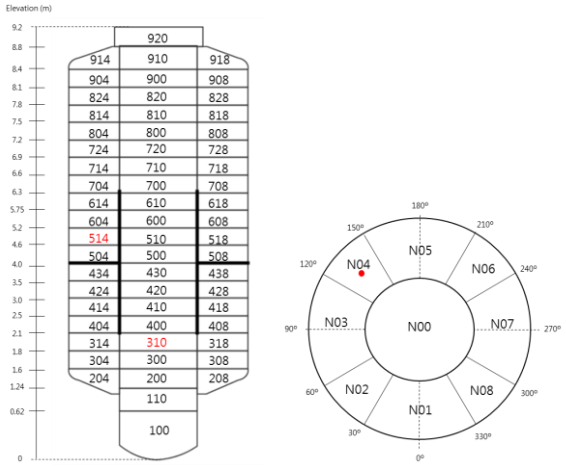

Figure 2. THAI facility and MELCOR nodalization

Table 1. Description of simulation cases

Case	Mass transfer coefficient(XMTFC)
1	1.0 (default)
2	2.0 (all of wall)
3	5.0 (Outer wall of the cylinder) 4.0 (Inner wall of the cylinder) 3.0 (Upper Dome) 2.0 (Others)

3. Results

Figure 3 shows visually hydrogen behavior which are stratification, erosion and mixing at 0, 250, 4200, 4700, 5000, 6820 sec. During the phase 1 hydrogen injected, hydrogen cloud was stratified in upper vessel. And then, erosion of hydrogen stratification occurred during phase 2 steam injected. In the end, hydrogen and steam fully mixed in the vessel.

The results for pressure are shown in figure 4. Pressure in experiment results during phase 1 increased steadily from 1.007 bar to 1.26 bar because of the hydrogen injection. Although, steam was continuously injected during phase 2 in the experiment, pressure maintained under about 1.45 bar. Because steam condensation has an effect on pressure in vessel. In base case, pressure was overestimated in comparison with the experimental results. However, the results in case 2 and 3 considering increased steam condensation was good agreement with the experimental results. Especially, pressure of case 3 was more similar than that of case 2. Figure 5 shows mass of condensate in the whole facility from MELCOR results. The mass increased linearly after steam injected during phase 2. The total mass in case 1, 2 and 3 was 50.24, 51.18 and 52.26 kg, respectively. The mass of case 3 was the largest amount among the cases. In addition, the values of case 3 was larger than the values of other cases at every time step. Because it was considered that the coefficient was sensitively modified for the wall a large amount of condensation predicted. Therefore, sensitivity study of XMTFC with prediction of structures, where the condensation occurs significantly, should be conducted in order for more accurate assessment of pressure condition in the CFVS.

Figure 6 shows hydrogen concentration at upper plenum. Generally, MELCOR calculation reasonably captured trend of hydrogen concentration. However, the concentration from simulation was underestimated in comparison with the experimental results. The peak hydrogen concentrations of experiment and MELCOR results are about 0.37 and 0.32 respectively. In addition, the erosion occurrence of hydrogen stratification was much earlier than that of the experimental results. The erosion was completed early about 300 sec in MELCOR results. It is because MELCOR could not deal with effect of jet injection. On the other hand, hydrogen concentrations were similar among MELCOR cases. In other words, consideration of steam condensation were ineffective for overall hydrogen behavior in simulation. However, it should be necessary to assess the effect of steam condensation on hydrogen concentration.

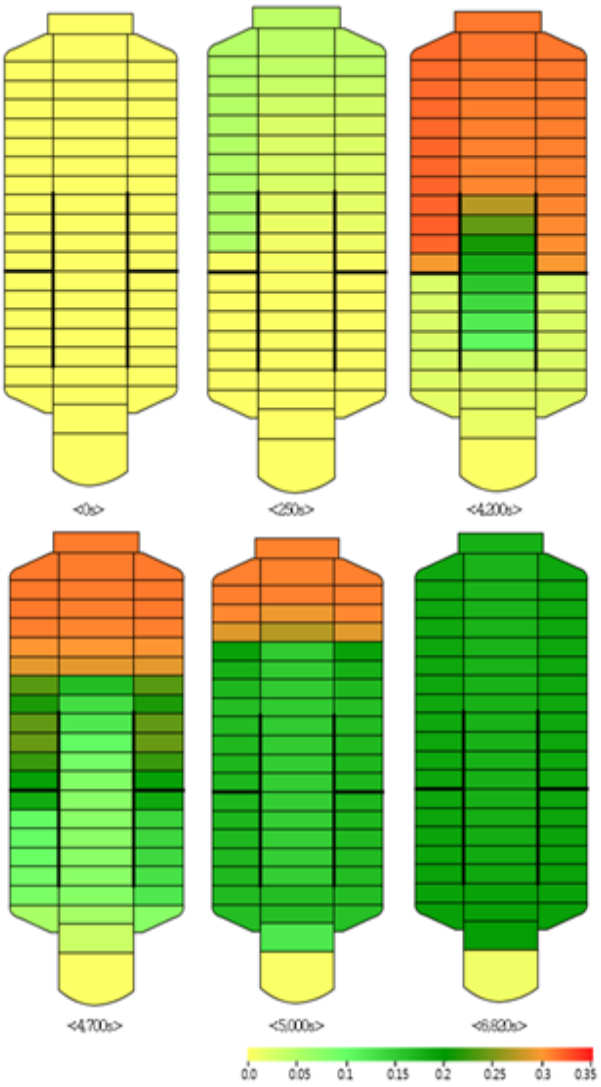

Figure 3. Hydrogen distribution at 0, 250, 4200, 4700, 5000, 6820 sec

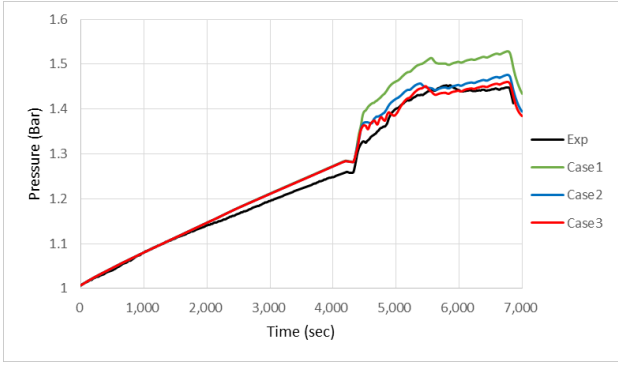

Figure 4. Pressure at upper vessel

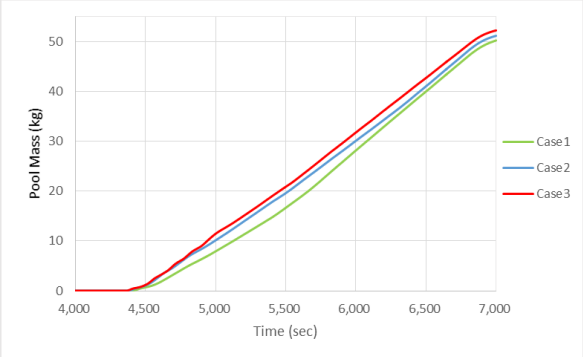

Figure 5. Total mass of the condensate in the whole vessel from MELCOR results

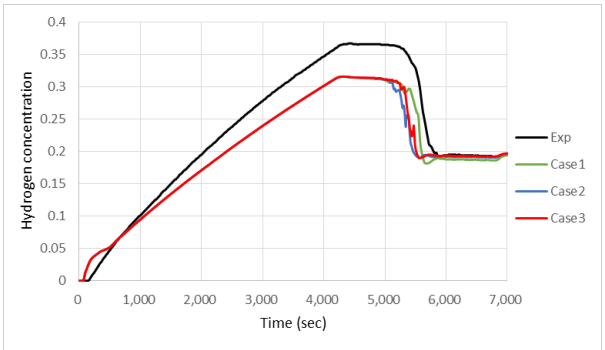

Figure 6. Hydrogen concentration at upper vessel

4. Conclusions

In this study, MELCOR simulation was carried out for THAI HM-2 experiment of OECD. As a results, stratification of hydrogen cloud was reasonably captured in MELCOR simulation. Furthermore, the pressure from simulation results in cases where mass transfer coefficient of MELCOR condensation model was modified was good agreement with the experimental results. On the other hand, hydrogen concentration from MELCOR results was underestimated in comparison to the experimental results. And it should be necessary to perform detailed assessment of the effect of steam condensation on hydrogen behavior.

REFERENCES

[1] OECD/NEA, THAI Project Hydrogen and Fission Product Issues Relevant for Containment Safety Assessment under Severe Accident Conditions, NEA/CSNI(2010)3, 2010
[2] T. Kanzleiter, K. Fischer, Quick Look Report (No. 150 1326-HM-2 QLR Rev.1): Helium/Hydrogen Material Scaling Test HM-2, Becker Technologies GmbH, 2007
[3] R. O. Gauntt et al., MELCOR Computer Code Manuals, Vol.1, Draft, SAND2015-XXXX, 2015
[4] Jiří Duspiva, MELCOR Validation against Experiments on Hydrogen Distribution, 3rd European MELCOR User Group Meeting, Bologna, Italy, April 11-12, 2011