Validation of OECD CCI-2 Experiment using MCCI Module of CINEMA

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1. Introduction

Corium is made by combining the structure inside the nuclear reactor core and molten nuclear fuel in the process of a nuclear severe accidents and maintains a very hot temperature due to continuous decay heat. Therefore, if proper cooling in not achieved, the integrity of the reactor systems will be affected.

The MCCI phenomenon refers to a phenomenon in which the corium outside the reactor vessel reacts directly with the concrete in the reactor cavity, and the dropped corium is cooled by transferring heat to the concrete and the upper atmosphere (or water). In the reaction between corium and concrete, the high temperature of corium causes the concrete to melt, which refers to concrete ablation.

CINEMA (Code for Integrated severe accident Evaluation and Management) code can analyze phenomena related to a nuclear severe accident history of a large pressurized light-water reactor type. It is possible to analyze the normal operation and the accident situation (the analysis of in-vessel, ex-vessel, containment).

Among a nuclear severe accident phenomenon, the MCCI analysis using CINEMA code is the subject of this study. The OECD CCI-2 [1-3] experiment was adopted as a validation experiment. The detailed results of this work is described in the following section.

2. OECD CCI-2 experiment

This section provides a rough description of the CCI-2 experiment adopted as a validation experiment and explains the experimental parameters that were mainly analyzed during the validation.

2.1 OECD CCI-2 experiment overview

CCI tests carried out by OECD/NEA [1-3]. In particular, the CCI experiment was conducted in Argonne National Laboratory (ANL) through international cooperation. The main purpose of CCI test is to evaluate the cooling mechanism of corium according to toe upper situation over the corium (dry or wet cavity conditions) when MCCI occurs.

The CCI-2 experiment is one of the series of CCI experiment in which the dry cavity situation occurs until the first 300 minutes and then the wet cavity is simulated. The CCI-2 experiment investigated the interaction of oxidized 400 kg corium with designed Limestone/Common Sand (LCS) concrete test section with an initial area of 50cm x 50 cm (Fig. 1). The input power of 120kW was applied.

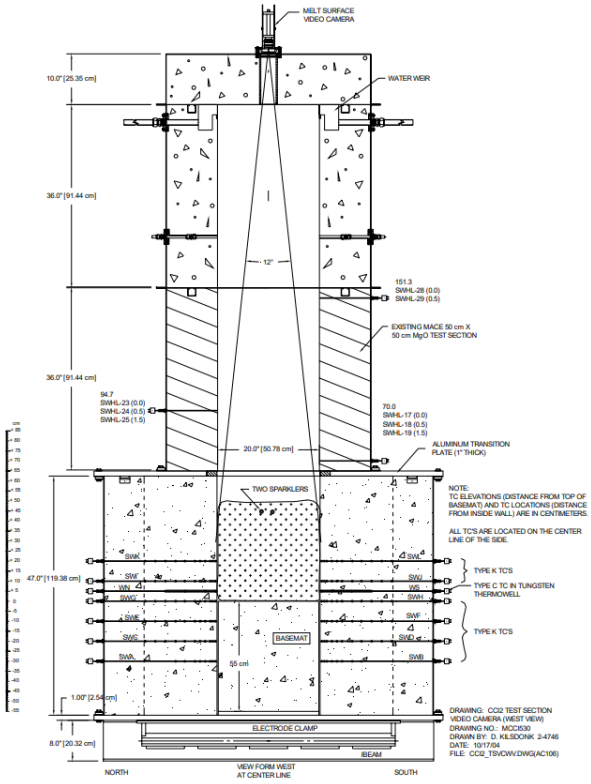

Fig. 1. The experiment test section of the CCI-2 test [1]

Table 1 is the initial composition of corium, and the composition of the product portion of the table was used as a CINEMA input.

Table 1. Initial corium compositions

Constituent	Reactant		Product	
	Wt %	Mass, kg	Wt %	Mass, kg
U_3O_8	63.01	252.04	-	-
UO_2	-	-	60.62	242.48
Zr	18.42	73.68	-	-
ZrO_2	-	-	24.90	99.60
Si	1.03	4.12	-	-
SiO_2	1.18	4.72	3.39	13.56
Mg	0.69	2.76	-	-
MgO	-	-	1.14	4.56
Al	0.22	0.88	-	-
Al_2O_3	-	-	0.41	1.64
CaO	3.13	12.52	3.13	12.52
CrO_3	12.32	49.28	-	-
Cr	-	-	6.41	25.64
Total	100.00	400.00	100.00	400.00

2.2 Results parameters of CCI-2 experiment

In order to analyze the characteristics of MCCI phenomenon in the CCI-2 experiment, several major parameters were selected: Melt temperature, Concrete ablation depth.

Several thermocouples were placed in the experimental apparatus to measure the major parameters. Among them, the five multi junction Type K thermocouple arrays were used to monitor the axial concrete ablation in the basemat (Fig. 2.), while six arrays were used to monitor the side wall concrete ablation.

The results of these major parameters of CCI-2 test were compared with the calculation results of the CINEMA code. In this comparison, the MCCI phenomenon analysis performance of CINEMA code was evaluated.

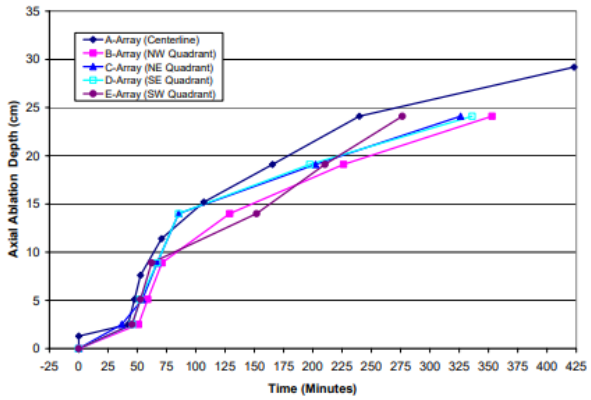

Fig. 2. Basemat axial ablation depth of the CCI-2 test [1]

3. CINEMA simulation results

3.1 Melt Temperature

The results of temperature change of the melt is important because it shows cooling of the melt, which is the goal of the MCCI phenomenon. Figure 3 shows the temperature for the four melt layers considered in the CINEMA code (Top crust layer, Upper metal layer, Mixed pool layer, Lower metal layer) and the experimental results.

The results of the top crust and mixed pool layer show similar patterns to the results of the experiment. However, since the mass of the upper metal and the lower metal layer are calculated to be zero during the calculation process, the temperature is saturated to the room temperature level.

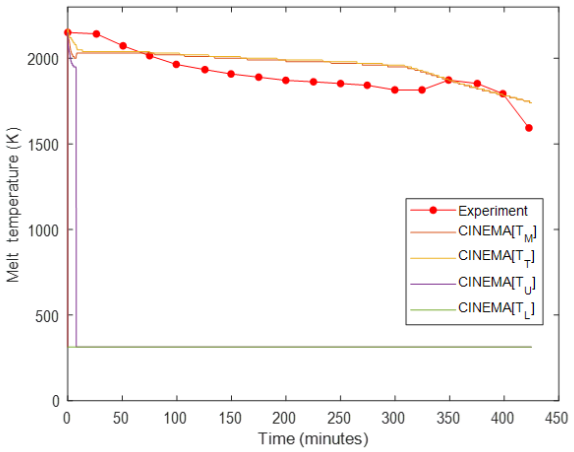

Fig. 3. Melt temperature results for CINEMA/experiment

3.2 Concrete ablation depth

In MCCI phenomenon, concrete ablation depth for axial/radial direction is important because it affect the design of the reactor cavity.

Figure 4 is a graph showing the results of concrete ablation depth of CINEMA and experimental over time. These results shows that the axial ablation depth results of CINEMA and the results of the experiment are well matched, while it can be seen that the radial ablation depth results fit well in the beginning of the simulation, but the difference is large in the second half.

Figure 5 illustrates the progress of concrete ablation over time, and it can be seen that the CINEMA code can simulates the progress of concrete ablation over time.

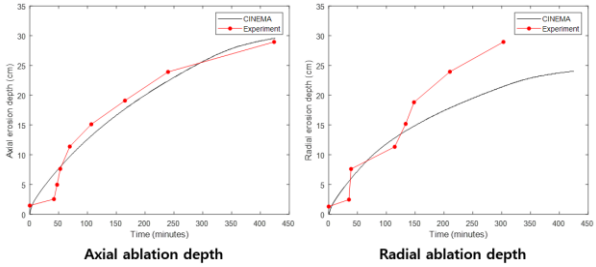

Fig. 4. Concrete ablation depth for axial/radial direction

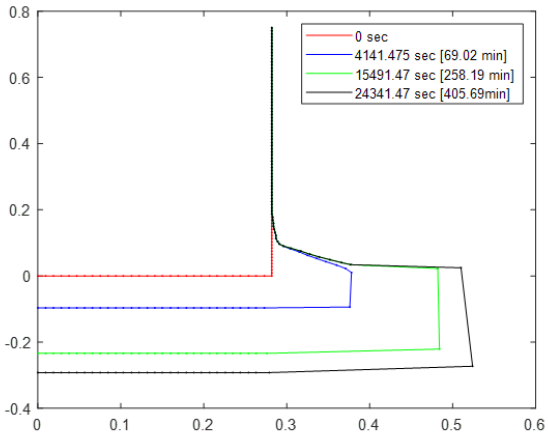

Fig. 5. Concrete ablation profile according to axial/radial direction

4. Conclusions

In this paper, we evaluated the ability of CINEMA code to analyze MCCI phenomena. As a validation experiment, the CCI-2 experiment was selected among the CCI series carried out at the Argon Laboratory.

In the CCI-2 experiment, the upper part of the corium is in dry cavity condition up to 300 minutes, and after that, it is converted to wet cavity condition. Therefore, the CCI-2 experiment is an experiment that can evaluate the performance of the MCCI module in the CINEMA code for the dry/wet cavity condition situation.

The validation of the CINEMA code using the CCI-2 experiment was performed using two parameters (Melt temperature, Concrete ablation depth). The temperature results of CINEMA showed a slight difference from the experimental results, but it was confirmed that the approximate trend was well matched. The results of the concrete ablation showed that the results for the axial direction fit well, but the results in the radial direction showed a relatively large error later in the simulation.

ACKNOWLEDGEMENT

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