Application of the GEMINI2 code to Develop the Sacrificial Concrete for the Core-catcher Experiment by KAERI

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1. Introduction

In the late phase of a severe accident, the reactor lower vessel may fail, the hot molten corium discharging into the reactor cavity can threaten the integrity of the containment due to the combustible gas generation, the fission product release and the large amount of steam generation from the MCCI (molten core concrete interaction).

Therefore, it is important to make the relocated hot molten corium cool-down in a safe and fast manner. For this purpose, KAERI has proposed a new cooling concept for the corium in a cavity by simultaneously injecting water and non-condensable gas into the nozzles embedded in the concrete basement from the bottom.

From the COMET experimental results, the most important condition to achieve a cooling for a melt by a 'bottom injection' will be whether the melt can be changed into a porous structure or not [1,2]. It means that the phenomena for forming a porous structure by a fuel coolant interaction during a bottom injection are the crucial mechanisms that need to be identified.

The possible scenario to form a porous layer may be a 'local pressure build-up' by a strong steam generation. This pressure build-up may propagate and expand in a lateral direction. Also, this steam filled void region may iterate an expansion and shrinkage. In addition, this strong vibration and steaming may produce a porous layer.

KAERI is planning to perform a core-catcher experiment for identifying the debris coolability by a bottom injection. To fulfill this experiment successfully, it is necessary to develop sacrificial concrete.

The sacrificial concrete can decrease not only the corium temperature but also the viscosity. An enhanced mobility can provide a higher possibility to form a porous layer. The purpose of this study is to elucidate the CaO content in the sacrificial concrete using the GEMINI2 code.

Figure 1 is the conceptual picture for the core-catcher experiment. The melt from the termite reactions will be relocated over the sacrificial concrete. The water will be injected from the bottom after the melt has eroded the sacrificial concrete. The purpose of the experiment is to estimate whether a porous layer can be formed or not.

The main ingredient of the sacrificial concrete is CaO. The application of the sacrificial concrete can decrease not only the solidus temperature but also the viscosity.

If the molten corium has a high solidification temperature, then even a small cooling at the begin of the bottom injection may make the most of the molten material freeze immediately.

A lower viscosity can provide more mobility to a molten material. An enhanced mobility and a lowered solidification temperature can provide an enhanced possibility of forming a porous layer.

Consequently, the purpose of this study is to elucidate the CaO content for the sacrificial concrete, which can make the solidus and liquidus temperature low using the GEMINI-2 code [3]. This sacrificial concrete will be applied to a test for estimating the corium coolability under a bottom injection based on the new cooling concept developed by KAERI.

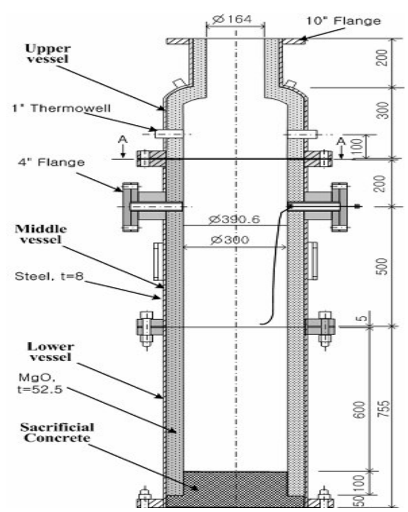

Fig. 1. Core Catcher experimental system

2. Methods and Results

In this section, the features of the GEMINI2 code are introduced. The change of the solidus and the liquidus temperature by GEMINI2 code according to the CaO content in the termite are shown with a table.

2.1 Features of the GEMINI-2 code

GEMINI2 code can calculate complex multi-phase multi-component chemical equilibrium by minimizing the total Gibbs energy of a system under either a constant pressure or a constant volume conditions. .

In order to determine the thermo-chemical equilibrium state for a multi-phase, multi-component system containing an ideal gas, the condensed solution and the stoichiometric substances, after the constraints of the problem such as the mass balance conservation conditions are take into account, the whole Gibbs energy of a system can be minimized with regard to the independent variables. The adopted minimization method is the "direct search method".

2.2 Prediction of the solidus/liquidus temperature of the termite melt according to the content of CaO

From the COMET-T test, it was reported that the termite composition that is similar to the viscosity of the real corium consists of 37 w/o iron melt and 63 w/o oxide melt. The oxide melt consists of 56 w/o Al_2O_3 and 44 w/o CaO respectively.

The "NUCLEA-07_1.GEM" for the material data base was applied for this calculation. The mass ratio of Al and Fe_2O_3 were fixed as 1 to 3. The mass ratio for the CaO was varied from 0 to 1.0 with an interval of 1/2.

Table 1 shows a summary of the calculation results for the solidus and liquidus temperature changes for the melt (Al+Fe+O+Ca) according to the CaO content from the GEMINI-2 code.

Table 1. Solidus/liquidus temperature of melt according to the Cao content (based on the mass ratio)

	Case1	Case2	Case3	Case4	Case5
Al	0.25	0.22	0.2	0.18	0.16
Fe	0.525	0.46	0.42	0.38	0.35
Ca	0	0.08	0.14	0.19	0.23
O	0.225	0.23	0.237	0.24	0.245
$^{a}T_s$	1794	1768	1508	1261	1260
$^{b}T_l$	2283	2027	1857	1808	1812

[a]: solidus temperature [k] [b]: liquidus temperature [k]

Case 1 is the case of not adding the CaO. Case 5 was the case of adding the largest amount of CaO, which is a mass ratio of 2.0. The liquidus and solidus temperature of the melt have a decreasing tendency according to the increase of the CaO content.

The predicted liquidus and solidus temperature are planning to consider in designing the sacrificial concrete of the KAERI test. Therefore, it is expected that the GEMINI-2 code can be used to develop the composition of the sacrificial concrete for the core catcher at KAERI.

3. Conclusions

From the GEMINI-2 code, the liquidus and solidus temperature of the melt have a decreasing tendency according to the increase of the CaO content. The predicted liquidus and solidus temperature are planning to consider in designing the sacrificial concrete of the KAERI core-catcher test.

Therefore, it is expected that the GEMINI-2 code can be used to develop the composition of the sacrificial concrete for the core catcher experiment at KAERI.

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