Comparison of Severe Accident Phenomena according to the Concrete Composition

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1. Introduction

When the severe accident happened in the Nuclear Power Reactor, the molten corium was relocated in the lower plenum. In this status, the molten corium could not be cooled some reasons, the reactor vessel should be penetrated and the molten corium ejected or poured into the cavity according to the in-vessel pressure.

The molten corium ejected into the cavity reacted with the concrete in the cavity floor and this phenomenon was called MCCI (Molten Core Concrete Interaction). The MCCI was treated as the important factor in the severe accident progression. The large amount of gases and hydrogen generated during MCCI, threatened the integrity of containment. In addition, the containment failure due to basemat melt through (BMT) was caused by the ablation of concrete floor by MCCI.

So, in this point of view, the characteristics of concrete have been the issues in the severe accident analysis. Actually, in the MAAP5 code, revised severe accident analysis computational code, the characteristics of concrete is treated more detailed than those in the MAAP4.

In this study, for the effect of the MCCI, the results of MAAP5 and MAAP4 were briefly compared at first. Then, the analysis results according to the specific concrete composition of Korean nuclear power plants and the default values provided in the MAAP5 were compared.

2. Methods and Results

2.1 Concrete Characteristics in MAAP

In MAAP parameter file, the characteristics of concrete is classified into 2 categories; the first is the composition of concrete and the second is the liquidus and solidus temperature profiles of concrete. In the previous version of MAAP, MAAP4, the composition of concrete should be obtained by the chemical analysis of concrete specimen or paper analysis of the report by the manufacturer. In MAAP5, the 3 types of concrete characteristics such as Basaltic, Limestone/Common Sand, and Limestone concrete are given as an option, so the users can select the appropriate option for their plants without the specific chemical analysis.

In the MAAP code, the limited Plant-Specific data that is sufficient to at least loosely quantify one or two key mass fraction variables in this group is an adequate basis for identifying the c oncrete category. The key variables are CaO mass fraction MFCN(2) and CO2 mass fraction, MFCN(11). Relatively small values (below approximately 0.15 for CaO and 0.05 for CO2) typify Basaltic concrete. Relatively high values (above approx. 0.35 for CaO and 0.30 for CO2) are typical for Limestone concrete. Limestone/Common Sand values are generally within a range of 0.25 to 0.35 for CaO and 0.15 to 0.25 for CO2. [1]

In Korea, the composition of concrete was obtained by analysis of specimen (UCN) or the manufacturer report (YGN and KOR). However, the selection of concrete type for domestic concrete is some obscure. Because it may be the Basaltic concrete from the view point of CO2 mass fraction, but it may be the Limestone concrete from the view point of CaO mass fraction as shown in Table 1.

Table 1. CaO and CO2 Mass Fraction

	L/C Sand	Basaltic	Limestone	Zion	UCN	YGN	KOR
MFCN(2)	3.13E-01	8.82E-02	4.54E-01	3.13E-01	2.27E-01	1.20E-01	1.69E-01
MFCN(11)	2.12E-01	1.50E-02	3.57E-01	2.12E-01	1.31E-02	3.00E-02	3.00E-02

2.2 Accident Scenario

In order to maximize the effect of MCCI, the Large LOCA accident sequence among the major severe accident analysis scenario in PSA report was selected. In this Scenario, the Double Ended Guillotine Break in cold leg is occurred and at the same time the AC power is lost. So, the ESF(Engineered Safety Features) function is not operable. [2]

2.3 Analysis Case

For the comparison of the model improvement, firstly we compare the results of MAAP4.0.8 and MAAP5.0.2 beta using Zion plant parameter file given in the MAAP Distribution Package with the same accident scenario described above. In the next step, since the concrete type of Zion plant is Limestone common sand, we changed the parameters for the concrete type to Basaltic default values and Limestone default values.

And then, we changed the composition of concrete based on the domestic concrete composition. As described above, the selection of concrete type for domestic concrete is some obscure. So, we classified cases for each site concrete composition into the

Basaltic and the Limestone characteristics. The analysis cases are shown in Table 2.

Table 2. Analysis Case

Case	Composition	MAAP Ver.	Concrete
1	Zion	4.0.8	L/C Sand
2	Zion	5.0.2B	L/C Sand
3	Zion	5.0.2B	Basaltic
4	Zion	5.0.2B	Limestone
5	UCN	5.0.2B	Basaltic
6	UCN	5.0.2B	Limestone
7	YGN	5.0.2B	Basaltic
8	YGN	5.0.2B	Limestone
9	KOR	5.0.2B	Basaltic
10	KOR	5.0.2B	Limestone

2.4 Analysis Results

The representative major event occurrence time for each case are summarized in Table 3.

Table 3. Analysis Results Using MAAP Code

Case	Core Uncover (S)	RPV Failure (S)	CV Fail (S)	Eroded Depth (M)
1	12.096	6800	151797	3.6
2	1.261	13880	112620	2.6
3	1.261	13534	127168	3.9
4	1.261	13357	114910	2.49
5	1.261	13534	133834	3.57
6	1.261	12738	146820	2.55
7	1.261	13534	133478	3.79
8	1.261	12738	147233	2.58
9	1.261	13534	137477	3.74
10	1.261	12738	150527	2.57

Though there are so many parameters which can show the effect of MCCI, we select the 3 parameters as the comparison factors as blows;

1) MH2CBT : integrated mass of H2 generated from CCI in containment
2) PEX0(3) : Pressure in Upper Compartment
3) XCNDB(1) : concrete floor erosion depth in cavity

The results of comparison for the key parameter is shown in Fig1, 2 and 3

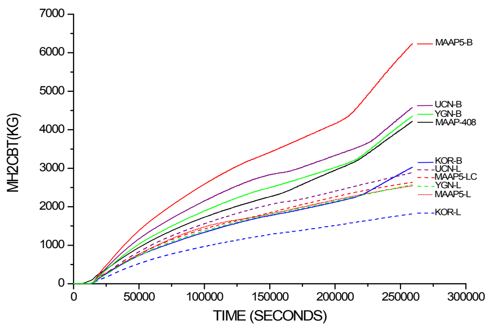

Fig 1. Comparison of MH2CBT

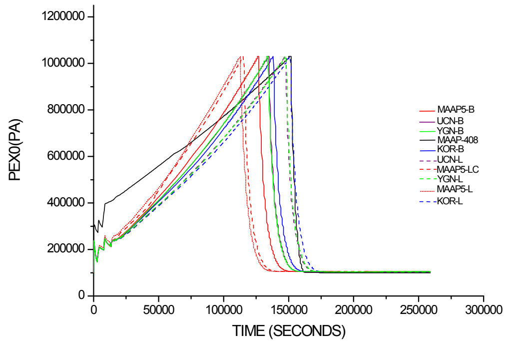

Fig 2. Comparison of PEX0(3)

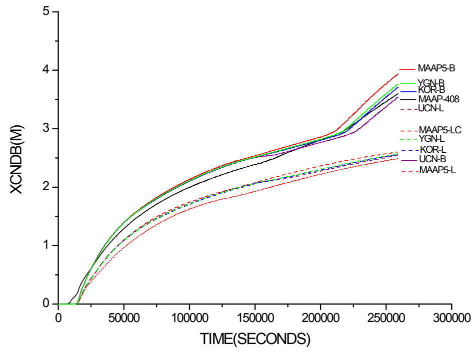

Fig 3. Comparison of XCNDB(1)

3. Conclusions

In this study, we can find some insight for the effect of MCCI according to the characteristics of concrete. The newly developed MAAP5 code requires some more detailed specific concrete information, especially such as the liquidus-solidus temperature curves (L-S Curve). In some aspect, the characteristic of L-S curve may affect the MCCI more severely than the composition of concrete. Also, the Basaltic concrete may produce the more conservative value to the containment integrity. In the case of eroded depth, the composition of concrete is not so much affected.

However, since the present MAAP5 code is the beta version, the more fundamental research should be needed after the MAAP5 commercial version is released.

REFERENCES

[1] Zion MAAP5 Parameter File , FAI, 2012
[2] Probabilistic Safety Assessment for Ulchin Units 5&6 (Phase II) ; Containment Performance Analysis (Final Report), KHNP, 2002.