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Development of Parametric Correlation and Source Term Evaluation

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1. Introduction

When severe accident occurred in nuclear power plant, the severity is assessed as the amount of radiation released to outside of the plant and the amount of exposure to people around the plant. After TMI accident in 1979, a lot of experiments were carried out to improve the understanding of severe accident, and severe accident analysis code was developed actively with publishing of WASH-740, TID-14844 and WASH-1400.

In Korea, due to law enactment of severe accident in June, 2015, the amount of radioactive material released into the environment should be limited to 100 TBq or less. In this reason, precise prediction of radioactive material emissions has become important issue.

MELCOR that is one of the most widely used severe accident analysis code in the world calculates fission product behavior with based on thermo-hydraulic results and fuel state. Because of the process, it takes a long time to calculate the aerosol and gas phase fission product behavior. Moreover, the calculation time could be increased according to the number of aerosol component because sectional method is used in MELCOR [1, 2]. Therefore, it could be useful if the calculation time to derive the amount of released fission product is reduced.

In this study, it was attempted to derive the amount of released fission products into the containment by using parameters of thermal-hydraulic analysis results and the fuel state in MELCOR calculation [3]. Preliminary parametric correlation was derived and the amount of fission products released into the containment was discussed.

2. Development of parametric correlation

2.1 Target Plant and Accident Analysis Result

In order to obtain the MELCOR calculation data, existing research result was employed and the target plants are Kori nuclear reactor No. 1, 3 and 4. The study indicates that fission product (FP) distributions were calculated with different nuclides for five accident scenarios during 90000 sec. The considered accident scenarios are SBO, SBLOCA, MBLOCA, LBLOCA, TLOFW. Detailed descriptions of the accident scenarios are indicated in reference [4]. The calculation results were obtained as the form of Table 1, which indicates the major accident progress time in SBO. The results were used to construct a parametric correlation.

2.2 Selection of Parameters

The MELCOR calculation results of Kori-1, 3 and 4 were discussed and parameters which could be contained in the correlation were sorted. In addition, RN(RadioNuclide) package model in MELCOR was examined. After that, five parameters were selected, that is core uncovered time, core dryout time, gap release time, fuel relocation time to lower plenum and lower head failure time.

Three types of FP release mode from fuel to reactor vessel were considered that is explained in WASH-1400 as shown in Table 2; gap release, meltdown release, vaporization release [5]. Only lower head failure was considered as release path from reactor vessel to containment, and other release paths will be considered in the future work, such as SGTR accident.

It is reasonable to select the five parameters by discussing the fission product release model in MELCOR. In the MELCOR, gap release occurs when the cladding temperature reaches the set temperature, and all fission products in the gap are released to reactor vessel. FP release models from fuel in MELCOR are CORSOR, CORSOR-M and CORSOR-Booth, and fuel temperature is most important factor in the models. The fuel temperature increment is directly related with the amount of coolant in the core. Thus the core uncovered

Table I: Major event during SBO accident in Kori-1

Event	Time(s)
Accident Start, Reactor trip	0
MFWS trip, MSIV closed	0
RCP Trip	30.6
SG Dryout	5392
SRV(PRZ) First Open	5711
Core uncovered	10005
Core dryout	11311
Gap release	11375
Fuel cladding melt begin	14725
Fuel relocated to lowerplenum	15625
Lower head penetration failed	15675
Beginning of debris ejection	15825
MCCI start	15825
Cavity dryout	47608
End calculation	90000

Table Ⅱ: Fission product release source summary-best estimate total core release fractions [5]

Fission product	Gap release fraction	Meltdown release fraction	Vaporization release fraction
Xe, Kr	0.030	0.870	0.100
I, Br	0.017	0.883	0.100
Cs, Rb	0.050	0.760	0.190
Te	0.0001	0.150	0.850
Sr, Ba	0.000001	0.100	0.010

time and core dryout time were selected. As the fuel temperature increases faster, the fuel relocation time to lower head is quicker. Thus fuel relocation time to lower plenum was set to parameter.

2.3 Parametric Correlation

As mentioned above, parametric correlation consists of three parts; gap release, meltdown release and vaporization release. The release correlation were indicated in equations (1)~(3). Total amount of fission product released from fuel to reactor vessel is indicated in equation (4). Finally, the amount of fission product released to containment could be obtained from equation (5).

F_1=GRF(i)xRFxIV(i)xGRT (1)
F_2=MRF(i)xMFxIV(i)xFRT (2)
F_3=VRF(i)xMFxIV(i)xCT (3)
$F_{f\rightarrow r}=(F_1+F_2+F_3)$xFUT (4)
$F_{r\rightarrow c}=F_{f\rightarrow r}$xRTx(1-VRT/ECT) (5)

i: radionuclide
ECT: total calculation time (sec)
GRF: gap release fraction
RF: release factor (0 or 1)
IV: initial inventory (kg)
GRT: 1-(gap release time/ECT)
MRF: meltdown release fraction
MF: fuel cladding melt factor (0 or 1)
FRT: 1-(fuel relocation time/ECT)
VRF: vaporization release fraction
CT: 1-(core dryout time/ECT)
FUT: 1-(fuel uncovered time/ECT)

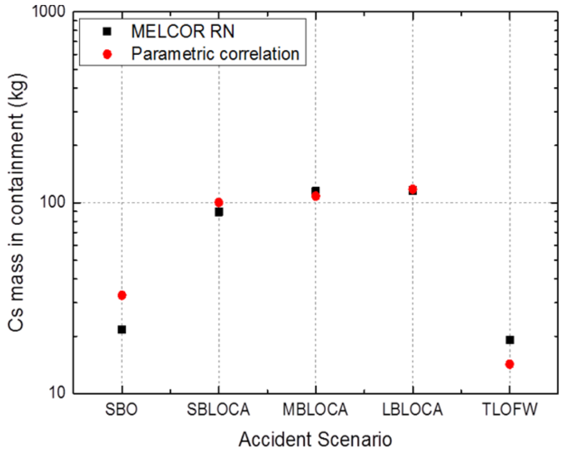

Fig. 1. Comparison result of the amount of released Cs to containment

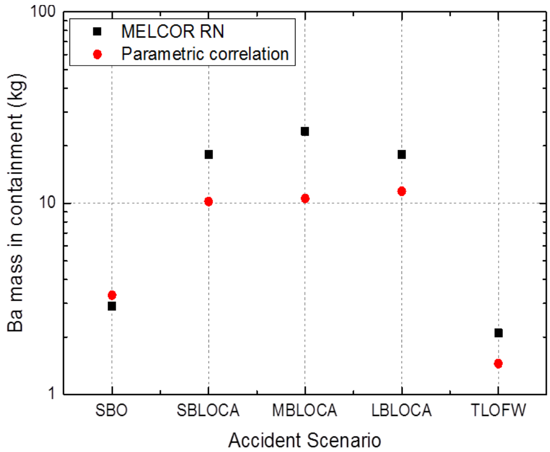

Fig. 2. Comparison result of the amount of released Ba to containment

2.4 Analysis Result

Parametric correlation validation results were presented for the major fission products; Cs, I, Ba and Te. Target nuclear power plant is Shinwolsung unit 1 [6]. The parameter values were summarized in Table 3 with accident scenarios. The amount of released fission product to the containment which was obtained from parametric correlation was compared with the MELCOR calculation result.

The comparison results were shown in Figs. 1~4 according to nuclide. As a result of the comparison

Table Ⅲ: Parameter occurrence time with accident scenario of Shinwolsung-1

Event(s)	SBO	SBLOCA	MBLOCA	LBLOCA	TLOFW
Uncoverd	7502	1811	89.8	22.8	43901
Gap release	8628	2682	17093	11225	45569
Dryout	9165	3540	19398	13730	46140
Vessel failure	12414	17793	27106	18118	50739
Relocation	10958	3184	18232	12264	48940

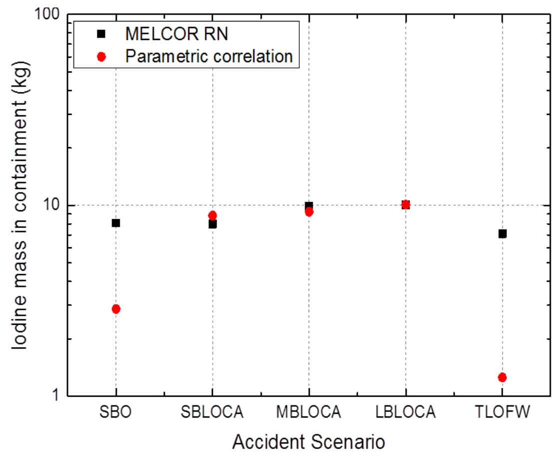

Fig. 3. Comparison result of the amount of released I to containment

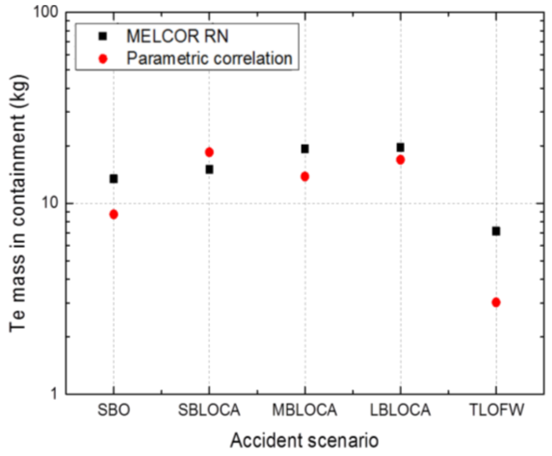

Fig. 4. Comparison result of the amount of released Te to containment

between MELCOR calculation and parametric correlation, it was found that overall tendency of correlation result shows good agreement with MELCOR result, however some data have about 50% difference. In the case of LOCA accident, safety device such as SIT can be operated, however most of the safety devices could not operate in the SBO case because power was lost. However, the operation of SIT was not considered in the correlation. Thus it is required to develop a parametric correlation including the operation of safety devices, such as SIT, HPSI, RHR. To increase the accuracy of the correlation, it is necessary to include more major parameters in the correlation. Furthermore, it is essential to collect MELCOR calculation results in various accident conditions.

3. Conclusions

Preliminary study on development of parametric correlation was performed, and the research was initiated from an attempt to determine the amount of released fission product with thermo-hydraulics calculation results to save the calculation time. Parametric correlation was developed to evaluate the amount of source term. Major parameters were selected from the thermo-hydraulic event and fuel state in the MELCOR calculation result. Correlation was established by considering the CVH, COR and RN models in MELCOR. The amounts of released Cs, Ba, I and Te obtained from the correlation were compared to the MELCOR calculation results. Although some data showed about 50% difference, it was found that overall tendency was good. In order to increase the accuracy of the correlation, it is necessary to increase the number of parameters and analyze the MELCOR calculation data in various accident sequences in the future.

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