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A Preliminary Analysis of Fission Product Deposition Using MAAP5 Simple and Detailed Nodalization

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1. Introduction

After the Fukushima accident, KHNP have been performed more than 50 safety enhancement measures. Also, the establishment of Accident Management Program (AMP) for all domestic nuclear power plants due to revision of Nuclear Safety Law becomes the urgent issue and is being developed. In AMP, the scope of management is divided as Prevention and Mitigation. In the Mitigation region including the severe accident, the newly introduced safety goal related with accident consequence should be satisfied [1]. However, since the current consequence analysis for severe accident has so much uncertainty in the analysis method and phenomena itself, the importance of realistic and detailed analysis methodology has been increased, especially for the fission product behavior in the containment during the severe accident [2]. The fission product behavior in the containment is known to be varied considerably due to many factors such as the code embedded model, accident progression, and operator action. Therefore, it is necessary to find the uncertainty caused by the above factors and try to reduce them in order to satisfy the safety goal

For the analysis of severe accident progression and FP (fission products) release to the environment, MAAP5 code [3] has been widely used by industry side. Generally, the simple (lumped) containment nodalization model (7~14 Node) has been used in the PSA or SAMG development. However, in order to analysis the consequence effect to meet the safety goal, the more detailed models and analyses are required. So, the detailed containment nodalization models (27~38 Node) are under developed.

In this paper, we try to compare the change of FP aerosol deposition inside the containment using MAAP5 simple nodalization and detailed nodalization model, since the amount of release to the environment is decreased as the amount of deposition is increased.

2. Analysis Method and Conditions

The code used for the analysis is MAAP 5.03 and the target plant is typical OPR1000 type nuclear power plant. The simple containment nodalization is consisted of 7 compartments and the detailed model is consisted of 27 compartments [2] as shown in Fig. 1. The detailed model divides the annulus region (Node 4) and the lower compartment region (Node 3) into more detailed regions, which are expected to affect the deposition amount of FP.

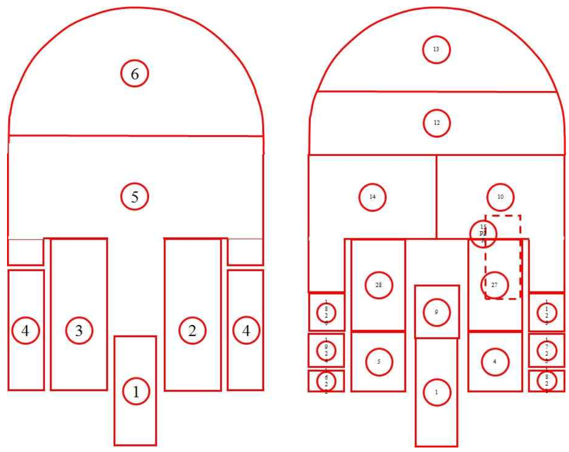

Fig. 1. Containment Nodalization for Simple/Detailed Model

The initiating event is selected as SBO (Station Black Out) sequence. So, all active safety systems except the passive one such as Safety Injection Tank injection are not available.

In this analysis, we evaluate the amount of aerosols deposited in the heat sink and the amount of fission products released to the environment. The evaluation time is limited to 1 hour after containment failure for deposition analysis. In the case of FP release analysis to the environment, the evaluation time is expanded to 72 hours after containment failure

3. Analysis Results

3.1 Comparison of Aerosol Deposition

Figure 2 shows the total aerosol mass deposited in the containment for each containment nodalization model.

As shown in this figure, total aerosol mass deposited in the containment for the case using the detailed model is 3 times larger than that for the case using simple model. Also, the characteristic of deposition in case of detailed model is more gradual. In other words, in the case of simple model, the deposition rate is faster and the amount of deposition is smaller than that for the case of detailed model.

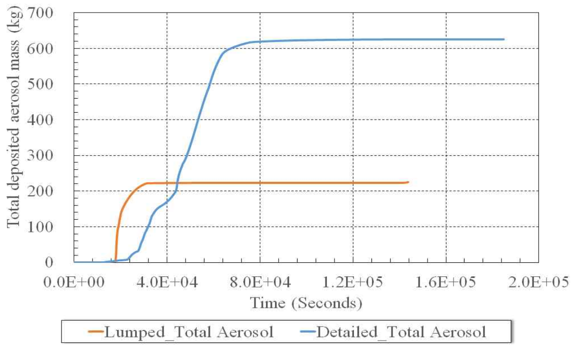

Fig. 2. Comparison of Total Aerosol Mass Deposited in the Containment

There are quite difference in the deposition rate by the containment region (compartment) as shown in Table 1 and Figure 3. In the case of the simple model, 95% of the total aerosol is shown to be deposited in the reactor cavity compartment. And, only the small amounts of aerosols are shown to be deposited in other compartments, 1% in the lower compartment containing the steam generator and the pressurizer, and 2% in the annular compartment. However, in the case of detailed model, aerosols are shown to be distributed over a wide range, with 71% in the reactor cavity compartment, 8% in the lower compartment regions and 13% in the annular compartment regions.

Table 1. Comparison of Aerosol Deposition Rate by Region (%)

	Rx-Cavity	Lower	Upper	Annular	Dome
Lumped	94.5	1.47	1.5	2.38	0.15
Detailed	71.18	7.53	7.43	12.47	1.39

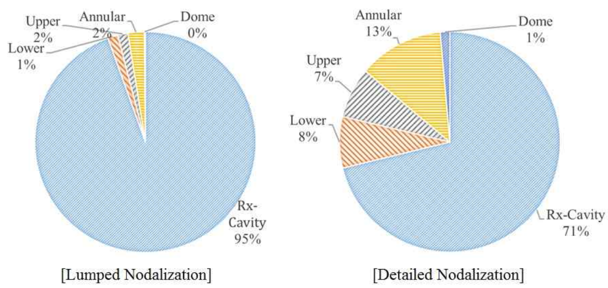

Fig. 3. Comparison of Aerosol Deposition Rate by Region

In the lower compartment regions, there is a great difference for the deposited aerosol mass as shown in Figure 4. If the deposited regions are re-classified in the detailed model, the large amounts of aerosols are shown to be deposited in the steam generator compartment, and Refueling pool compartment having a relatively large volume of the control volume as shown in the Figure 5.

The annular compartment regions are for the outer regions of lower compartment in the containment, and actually, there are so many rooms which can affect the deposition of FP including aerosols.

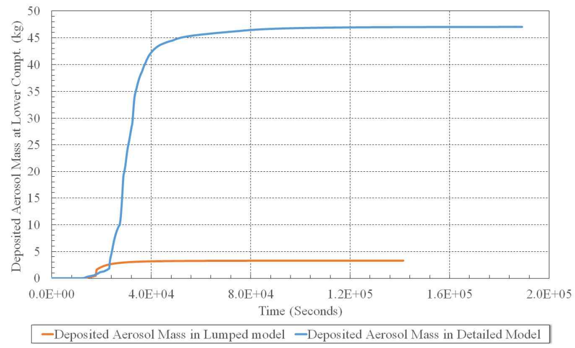

Fig. 4. Comparison of Aerosol Deposition in Lower Compartment Region

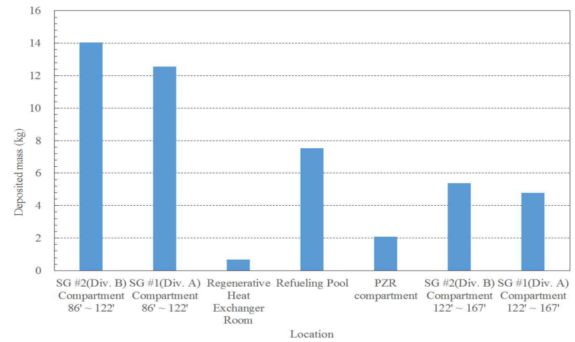

Fig. 5. Distribution of Aerosol Deposition in Lower Compartment

In the annular compartment regions, there is also a great difference for the deposited aerosol mass as shown in Figure 6.

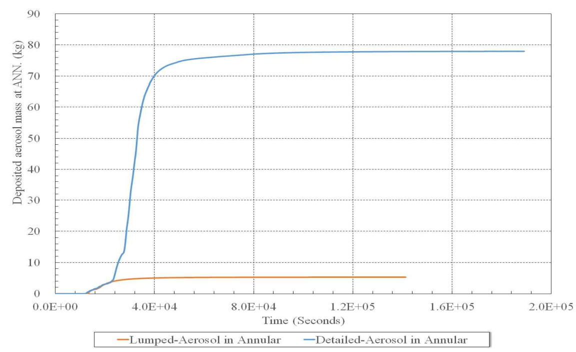

Fig. 6. Comparison of Aerosol Deposition in Annular Compartment Region

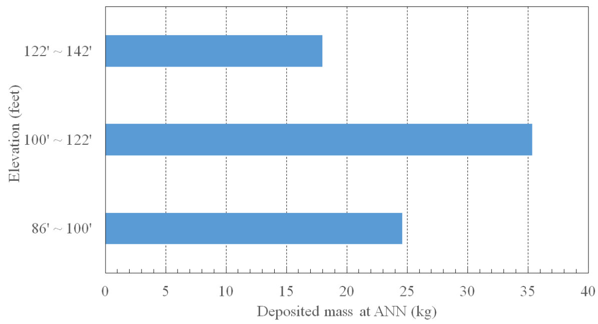

Fig. 7. Distribution of Aerosol Deposition in Annular Compartment

If the deposited regions in the annular compartment are re-classified in the detailed model, the large amounts of aerosols are shown to be deposited in the compartment at 100 ~ 122 feet as shown in the Figure 7.

3.2 Comparison of Radioactive Material Release

The fission products release can be affected by so many factors such as accident progression, and mitigations measures, and chemical reactions in the containment. Therefore, we select the change of aerosols mass in order to find the change of FP in the containment due to the application of detailed model. The amount of FP release to the environment is most important factor for the safety goal. In particular, the Cesium (Cs) release is generally recognized as the major long-term contamination factor to the soil. So, the regulatory body strongly requires the strict control of Cs release to the environment.

In the MAAP5 code, Cs release is simulated as 3 radioisotopes group such as CsI, CsOH, and Cs2MoO4. So, in this analysis, the total amount of Cs is calculated as the sum of CsI, CsOH, and Cs2MoO4.

In Figure 8, the total amount of Cs released to the environment using the simple nodalization model and the detailed nodalization model is compared. At the shortly after containment failure, In case of the simple model, the total amount of Cs released to the environment is more than twice times as in the case of detailed model. Even after 72 hours after the containment failure, the amount of released Cs of the simple model was 13% more. That is to say; the simple model calculates the Cs release more conservatively.

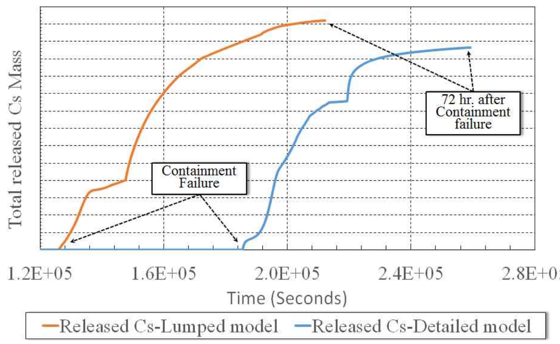

Fig. 8. Comparison of the Total Amount of Cs Release

4. Conclusions

In this analysis, we can identify the differences and trends of aerosols deposition according to the containment Nodalization. And also, the assessment of radioactive materials release to the environment can be different according to the detailed level of nodalization. As a conclusion, we can get the two insights as bellows.

First, from the viewpoint of aerosol deposition, if the containment nodalization is more realistic, the number of junctions and compartment heat sinks that FP can be deposited will be increased. This is the major factor for the increase of aerosols deposition in the detailed model, and the release of FP should be decreased.

Second, it is necessary that the containment nodalization should be made more realistically, since the actual containment has a complex compartment structure. In this analysis, the results of the deposition mass for each compartments in the containment showed a significant difference by nodalization. And also, it was shown that the distribution of radioactive material deposition is different according to the nodalization, and the release amount of FP can be varied. Therefore, the detailed models reflected the actual in-containment structures are necessary for the reduction of uncertainty for severe accidents analysis. If the fission product characteristics are analyzed through the benchmark study, more detailed verification is possible. However, it is difficult to implement benchmark study using the actual detailed nodalization model since the comparable experimental data is not sufficient yet.

Therefore, the additional study for the behavior and characteristics of FP such as the experiments and code improvements should be needed. And these efforts should be a great help to reduce the uncertainty in the severe accident analysis

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