Development of Dispersion Factor Evaluation System for SMR EPZ

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1. INTRODUCTION

This paper aims to establish an atmospheric dispersion factor evaluation system necessary for selecting the Emergency Planning Zone (EPZ) for the conceptual design of domestic SMRs. In the case of NuScale, ARCON96 was applied for the evaluation of atmospheric dispersion factors and received approval. Accordingly, this paper also develops an evaluation code capable of complex sensitivity analysis linked with ARCON96. Currently, the GOD MASTER (Great Off/on sites accident's Dose analysis MASTER) code is equipped with functions to evaluate all types of atmospheric dispersion factors and perform pre-processing and post-processing. Furthermore, it includes a module for analyzing the input and output statements of the accident impact assessment code. Specifically, it has been developed to enable evaluation with ARCON96 as well. The purpose of this study is to modify ARCON96 to develop functionalities that enable sensitivity analysis for atmospheric dispersion factor calculations of SMR. Ultimately, the goal is to build an atmospheric dispersion factor evaluation system that can automate both SMR EPZ selection and sensitivity analysis.

2. METHODOLOGY

2.1. Development of Dispersion Module

The SMR dispersion factor evaluation system consists of creating modules to evaluate atmospheric dispersion factors and incorporating them into executable files.

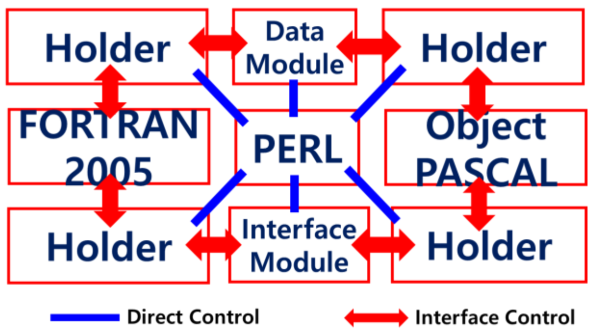

Fig. 1 Code development concept of SMR dispersion factor evaluation system.

Each calculation is performed using modules created in PASCAL and FORTRAN, and the Holder that incorporates these modules is implemented in PERL. The entire evaluation process is designed to be fully controlled through PERL using the Holder and interface modules, allowing for sensitivity analysis.
The detailed structure is illustrated in Figure 1.

Fig. 2 shows the system of GOD MASTER. This code has the function to analyze input/output statements, extract specific parts, and use the extracted information as variables to perform new calculations. Additionally, the newly developed SDF (SMR Dispersion Factor) code will be included as a subroutine within the GOD MASTER code.

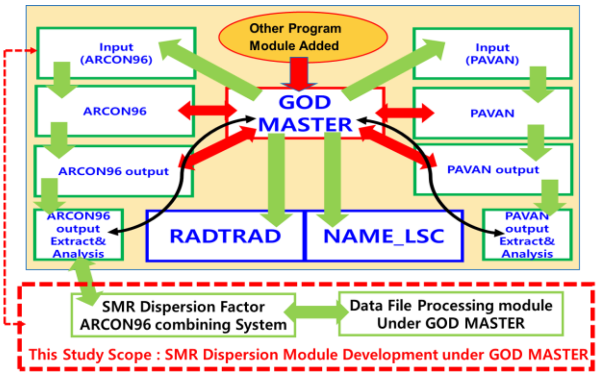

Fig. 2 SMR Dispersion factor system under GOD MASTER code.

2.2. Various Sensitivity Analysis Process in SMR

SMR is a small modular reactor. Therefore, it is assumed that the impact of most accidents will primarily occur in the vicinity. In fact, for NuScale, the maximum impact is also in the vicinity. Additionally, the dispersion factor evaluation must reflect the actual site characteristics. The ARCON96 code, approved by the NRC, is used for this purpose and applies experimental correlations for a range of approximately 1.5 km, including the vicinity. In this study, ARCON96 was modified to enable sensitivity analysis for 16 different directions and distances. This research allows for sensitivity analysis at intervals of 20 meters or 10 meters, generating approximately 1525 input statements (25 directions x 61 distances) for automatic evaluation. The study confirms the generation of these 800 input statements and includes verification for future application in this paper.

2.3. Essential Parameters of ARCON96 for Sensitivity Analsysis

In onsite dispersion factor, some parameters are used as below:

a. Release height: Onsite dispersion factor includes a middle point between the minimum point and the maximum point of the wind instrumentation heights.
b. Wind direction: North is the reference direction used as either 0 or 360 degrees.
c. Calm condition: calm can be defined as hours with no wind or as very small wind speed.
d. Building area: Building wake factor's key point of X/Q near the building structure.
e. Wind speed: A wind speed group which is distributed by 13 regions and each maximum value of each wind speed group as like 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0.
f. A surface roughness length : 0.1m ~0.2m
g. An angular width : 90 degree(+/- 45)
h. Minimum wind speed: 0.3m/sec, this wind is calm condition and the input hourly meteorological preparing process is checked by a calm-processing subroutine of ARCON96.
i. A sector-averaged width is used for more than 8 hours.
j. 4 standard deviations of a Gaussian plume are used as sector-average default.
k. Horizontal dispersion coefficient and vertical dispersion coefficient are calculated by using standard deviation of a Gaussian plume.
l. The time averaged scale is ranged from 1 hour to 720hours, in which X/Q are averaged and calculated.

Among the various variables introduced above, distance, direction, and wind speed will be used as the main sensitivity variables.

3. RESULTS AND DISCUSSIONS

3.1. SDF Code's Various Output Results

In Chapter 2 of this paper, we examined the generation of input statements for sensitivity variables and the sensitivity variables themselves. Now, based on the above content, we will review various output results of the SDF(SMR Dispersion Factor) code and verify the performance of the sensitivity analysis.

To validate the SDF code, we confirmed the generation of various input files for sensitivity analysis and the creation of an EXCEL dataset summarizing the results along with the output files. Sensitivity analysis input files for atmospheric dispersion factors were generated based on direction, distance, and wind speed, resulting in 1,525 cases. The automated evaluation of these input files produced approximately 3,050 output files. These were organized into an EXCEL file, resulting in 4,575 datasets and files. These results are well presented in Figures 3 to 6, and it was confirmed that the newly developed sensitivity analysis function for SMR atmospheric dispersion factors works perfectly.

As shown in Figures 3, 4, 5, and 6, Figure 3 displays the sensitivity analysis case inputs by direction, and Figure 4 shows the sensitivity analysis case inputs by distance for each direction. Figure 5 presents the output files generated by the atmospheric dispersion factor calculation module for approximately 1,525 sensitivity analysis input files. Figure 6 shows the results of all output files automatically organized into an EXCEL file.

Fig. 3 25 case inputs generation of each direction sensitivity analysis in SDF code module

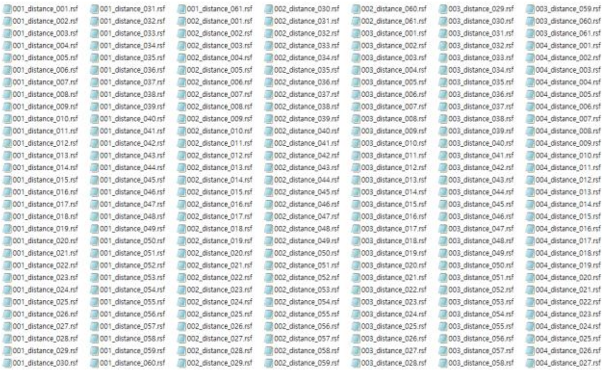

Fig. 4 1525 case inputs generation of each distance in SDF code module.

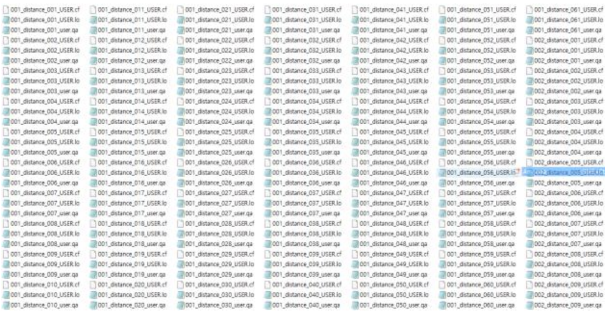

Fig. 5 4575 output results from SDF code module execution.

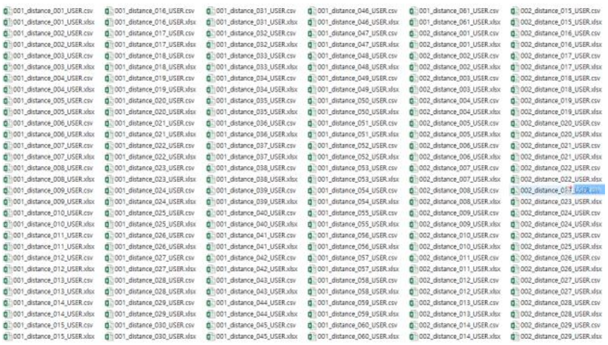

Fig. 6 Final output results from automated EXCEL control module in SDF code module.

3.2. Output Results from SDF Code Execution

To verify the functionality and performance of the SMR Dispersion Factor code, we summarized the most restrictive results at the distance of 500m point from the analysis of 3,050 cases. The summarized results are provided in Table 1 below.

Table 1. Calculation results of 500m distance from SDF calculation module in Fig. 6

azimuth	0 ~ 2 hours	0 ~ 8 hours	8 ~ 24 hours	24 ~ 96 hours	96 ~ 720 hours
0	5.14E-05	4.91E-05	1.99E-05	1.99E-05	1.72E-05
22	5.14E-05	4.92E-05	2.01E-05	1.97E-05	1.66E-05
23	5.14E-05	4.92E-05	2.01E-05	1.97E-05	1.66E-05
45	5.14E-05	4.94E-05	2.00E-05	1.95E-05	1.65E-05
67	5.14E-05	4.94E-05	1.87E-05	1.91E-05	1.63E-05
68	5.14E-05	4.94E-05	1.87E-05	1.91E-05	1.63E-05
90	5.14E-05	4.94E-05	1.81E-05	1.86E-05	1.61E-05
112	5.14E-05	4.94E-05	1.64E-05	1.80E-05	1.61E-05
113	5.14E-05	4.94E-05	1.63E-05	1.80E-05	1.62E-05
135	5.14E-05	4.95E-05	1.61E-05	1.83E-05	1.64E-05
157	5.14E-05	4.97E-05	1.70E-05	1.85E-05	1.74E-05
158	5.14E-05	4.97E-05	1.71E-05	1.86E-05	1.74E-05
180	5.14E-05	4.98E-05	1.86E-05	1.93E-05	1.80E-05
202	5.14E-05	4.96E-05	2.10E-05	2.03E-05	1.93E-05
203	5.14E-05	4.96E-05	2.10E-05	2.03E-05	1.94E-05
225	5.14E-05	4.92E-05	2.21E-05	2.19E-05	2.03E-05
247	5.14E-05	4.89E-05	2.08E-05	2.24E-05	2.01E-05
248	5.14E-05	4.89E-05	2.06E-05	2.24E-05	2.01E-05
270	5.14E-05	4.88E-05	2.03E-05	2.21E-05	1.98E-05
292	5.14E-05	4.88E-05	1.96E-05	2.16E-05	1.92E-05
293	5.14E-05	4.88E-05	1.96E-05	2.15E-05	1.89E-05
315	5.14E-05	4.89E-05	1.92E-05	2.07E-05	1.78E-05
337	5.14E-05	4.90E-05	2.00E-05	2.05E-05	1.75E-05
338	5.14E-05	4.90E-05	1.99E-05	2.05E-05	1.74E-05
360	5.14E-05	4.91E-05	1.99E-05	1.99E-05	1.72E-05

Table 2. Maximum Results at the distance 500m in all directions

Item	0~2 hours	0~8 hours	8~24 hours	24~96 hours	96~720 hours
Maximum	5.14E-05	4.98E-05	2.21E-05	2.24E-05	2.03E-05
Minum	5.14E-05	4.88E-05	1.61E-05	1.80E-05	1.61E-05

Table 2 summarizes the maximum and minimum values over time for all directions at the 500m point. These results indicate that the time-based range in each direction at the 500m point does not show significant displacement during the initial elapsed time, but generally shows greater displacement after approximately 24 hours. The atmospheric dispersion factors, when viewed as a closed system for a specific region or section, reveal the typical exponential dilution characteristics. In other words, this demonstrates the significant cumulative impact of dilution over time, with the effect showing a typical exponential change in magnitude over time within a given space.

3.3. Application of Output Results Generated by SDF Code Execution

The numerous sensitivity analysis output results of atmospheric dispersion factors generated by the SDF code serve as key input data for dose assessment or accident impact assessment. All the results generated here simulate the dispersion behavior of fission products according to direction, distance, and geometric characteristics, ultimately playing a crucial role in determining the radiological impact of dose assessment or accident impact assessment for SMRs.

4. CONCLUSIONS

Through this study, the SDF code was developed. As presented so far, the SDF code has demonstrated itself to be a highly efficient tool with substantial file control capabilities and unique computational abilities. Notably, it possesses the powerful capability to provide unlimited sensitivity analyses.

In this study, we confirmed the functionality and performance of the SDF code in supporting detailed sensitivity analysis of SMR dispersion behavior. Specifically, we generated input process supporting detailed sensitivity analysis cases, creating 1,525 sensitivity input files and using them to generate 4,575 analysis files for computation. Additionally, we developed the code to generate files with a separate ‘qa’ extension that provide statistical analysis results.

Through this research, we believe that we have developed a powerful and efficient tool for future SMR EPZ analysis and decision-technology. The many results of the SMR EPZ sensitivity analysis using the SDF code from this study will be presented at future next conferences.

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