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Comparative Study on Atmospheric Dispersion Module of Level 3 PSA

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1. Introduction

Some regulation documents such as Regulatory Guides and NUREG publications from the U.S. Nuclear Regulatory Commission (NRC) have influences on domestic radiation environmental analyses. As renewal versions of NUREG-0800 and NUREG-1555 have issued lately, the assessment for Severe Accident (SA) with Probabilistic Safety Assessment (PSA) should be added to Safety Analysis Report (SAR) and Radiation Environmental Report (RER) [1]. Because these reports are the required documents for obtaining the construction permit and operating license, it is important to understand the PSA methodology and it needs to improve the site-specific input data of L3PSA codes for SA.

First, our review focuses on the atmospheric dispersion and deposition related input data of L3PSA code in this paper. Then we will continue to review the improvements of other input data.

2. PAVAN and ATMOS

For review of atmospheric dispersion and deposition related input data, we chose two codes, PAVAN and MACCS2.

PAVAN is a code evaluating the atmospheric dispersion of radioactive materials released from the design basis accident of nuclear power plants. ATMOS is a module of MACCS2(MELCOR Accident Consequence Code System, Version 2) code and evaluates the atmospheric transport, dispersion and deposition.

2.1 PAVAN program

PAVAN is used by the U.S. NRC to estimate relative ground-level air concentrations(X/Q) for potential accidental releases of radioactive material from nuclear facilities[2]. The program implements the guidance provided in Regulatory Guide 1.145, " Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants." [2]

The input of PAVAN code consists of 3 parts, weather conditions, construction information, and receptor location, which are selected differently input depending on the input option.

PAVAN code is supplemented the excessive conservatism of the deterministic analysis by considering the plume meander, building wake effects, and recirculation.

2.2 ATMOS module of MACCS2 code

ATMOS calculates the dispersion and deposition of material released to the atmosphere as a function of downwind distance[3]. It utilizes a Gaussian plume model with Pasquill-Gifford dispersion parameters[3]. The ATMOS evaluates the building wake effects, buoyant plume rise, plume dispersion during transport, wet and dry deposition, and radioactive decay in growth[3]. Input data of ATMOS consists of the information of geometry, released radionuclides, wet and dry deposition, dispersion, plume meander, building wake effects, facility, and meteorological sampling.

2.3 Difference between PAVAN and ATMOS

One of the important differences is the evaluation range of two codes. PAVAN calculates the annual average X/Q value and uses the method described in XOQDOQ with several simplifying assumptions made to assure conservative χ/Q estimates[2]. These assumptions include no plume rise, no deposition or depletion, and no radioactive decay[2]. Even though PAVAN calculates not only the annual average χ/Q but also short-term χ/Q value, it does not concern the wet and dry deposition. However, SA assessment would consider the effect of deposition. Especially in long-term analysis, the food intake is an important exposure pathway and therefore the dry or wet deposition would be the required input. The code evaluator can choose the period option: short- and long-term, and will exclude the deposition analysis and the radionuclides information since the slight deposition effects is negligible in short-term analysis.

Another difference is whether consider the radionuclide information or not. ATMOS consider the name, amount, chemical characteristics of the released radionuclide, but PAVAN does not consider it because this code was modeled as the weather condition is the most dominant of factors affecting to the atmospheric transport and dispersion.

The final difference is how to deal with the meteorological input. PAVAN use the Joint Frequency Data(JFD) pre-processed using the entire raw data, wind direction, wind velocity, temperature, humidity, stability, and so on. The JFD may be inputted as a percent frequency of occurrence or as total frequency of occurrence[4]. However, ATMOS use the only sampling data of the entire raw data. There are five sampling method of atmospheric data in ATMOS module, fixed start time in the weather file(day, hour), weather bin sampling, 120 hr of weather supplied by the user, constant weather conditions (use boundary weather), stratified random sampling from equally spaced intervals[3].

Table 1 shows the atmospheric dispersion factor values evaluated by applying various sampling methods. This evaluation was carried out using ATMOS input of sample problem B(NUREG/CR-4691) distributed with MACCS2 code[3]. MEAN values generally showed conservative result in case of using option 2(weather category BIN sampling) or option 4(stratified random samples for each day of the year). For PSA of SA, it is reasonable to use the atmospheric data created using random sampling method but not deterministic method. However, the researcher could choose the option and the result according to analysis purpose because it is different depending on sampling method, calculation method, period option, and etc.

Table 1. Atmospheric dispersion factor evaluated by ATMOS module

Parameter	Distance (km)	Option1	Option2	Option3	Option4
Ground-Level Dilution, χ /Q (sec/m^3)	4.8~5.6	9.02E-08 1)	4.49E-06 1) 1.61E-05 2)	1.38E-06 1)	4.52E-06 1) 1.60E-05 2)
	5.6~8.1	7.05E-08 1)	3.37E-06 1) 1.26E-05 2)	9.26E-07 1)	3.35E-06 1) 1.18E-05 2)
Plume Sigma-y (m)	4.8~5.6	1.04E+03 1)	4.96E+02 1)	4.24E+02 1)	4.91E+02 1)
	5.6~8.1	7.68E+02 1)	6.34E+02 1)	5.38E+02 1)	6.26E+02 1)
Plume Sigma-z (m)	4.8~5.6	1.33E+03 1)	2.66E+02 1)	1.09E+02 1)	2.85E+02 1)
	5.6~8.1	7.68E+02 1)	3.38E+02 1)	1.28E+02 1)	2.73E+02 1)

1) MEAN value
2) 95TH value

Option1 : METCOD=1, User specified day and hour in the year (from MET file)
Option2 : METCOD=2, Weather category BIN sampling
Option3 : METCOD=4, Constant MET (Boundary weather used from the START)
Option4 : METCOD=5, Stratified random samples for each day of the year

Recently, DOSE module, which is the off-site dose evaluation module, was added to improved MAAP5 code[5] and reads the atmospheric dispersion factor taken from FSAR or calculated using other codes. It would be continually reviewed which data is suitable for the input of MAAP5 model.

3. Conclusions

Two atmospheric dispersion models, which are PAVAN developed for design basis accident and ATMOS of MACCS2 code developed for SA, were reviewed in this paper.

L3PSA deals with the effects of severe accidents and basically includes the evaluation of both short- and long-term effects. Therefore, both the deposition effects and nuclide information(type, amount, and chemical characteristics of released radionuclide) would be considered as the input parameters of atmospheric dispersion model for L3PSA. Additionally, the meteorological data would be sampled randomly to meet the purpose of probabilistic method. However, the sampling method would be selected according to analysis purpose.

After review, ATMOS module and its input data are suitably developed for the atmospheric dispersion analysis of L3PSA. However, ATMOS module was developed using the site-specific terrain and environment characteristics. For the domestic application, it needs to study the input data reflecting the Korean terrain and environment characteristics. It would be also continuously improved in response to the time- and site-specific changes of weather, released nuclides, environment and etc. Additionally, the development of the connect or converter module is also required for the application of the ATMOS module to DOSE module of MAAP5 code or the related module of other codes developed in a similar purposes.

REFERENCES

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[5] EPRI, MAAP5 User Manual Volume 4: Graph & Dose, Calculation of In-Plant and Ex-Plant Dose and Dose Rates, 2012.