Transactions of the Korean Nuclear Society Spring Meeting

Jeju, Korea, May 17-18, 2012

Optimization of Radiation Diffusion Factor to Environment – Considering Gaussian models for coastal and complex terrain

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1. Introduction

Atmospheric dispersion model is typically considered to evaluate the site condition on Nuclear Power Plant Planning and design. This objectives are (1) to derive short term (a few hours) normalized concentrations and deposition values in order to assess the probability of occurrence of high normalized concentrations and contamination levels due to postulated accidents, (2) to derive longer term (up to one month) time integrated normalized concentrations and deposition values for postulated accidents, and (3) to derive long term (about one year) time integrated normalized concentrations and deposition values for routine operations[1].

Once a radioactive gas or aerosol becomes airborne, it travels and disperses in a manner governed by its own physical properties and those of the ambient atmosphere into which it is discharged. To evaluate the dispersion activity precisely, the models employed should account for the atmospheric condition and flow characteristics affected by terrain or near obstacles.

However, the methods for siting or safety analysis of Korean nuclear power plant cannot be considered the actual condition, historically, because of securing the conservativeness on the licensing stage due to raw data storage. The Gaussian plume model is generally used to estimate atmospheric dispersion of gaseous effluents released to environment during normal operation and accident without considering the topographical effect. It is universally applicable that the result of Gaussian modeling is more conservative than PUFF or numerical 3D dispersion model at flat terrain.

Because the all nuclear power plants of Korea are located in the coastal area with complicated terrain features, the Gaussian model for dispersion of gaseous effluent is not appropriated through the liming assumptions of Gaussian distribution in the strict sense.

2. Limitations of Gaussian model in case of Korea NPP

The Gaussian model is based on the steady state at the flat terrain with unique direction and magnitude of wind to disperse the gaseous pollutant. Therefore, the pollutants or gaseous materials are distributed to Normalized Gaussian distribution form on the receptor point. However, the real vertical wind profile shows dramatically change near the coastal area and complex terrain with time and height due to sea-land breeze and mountain-valley wind as shown in the Figure 1.

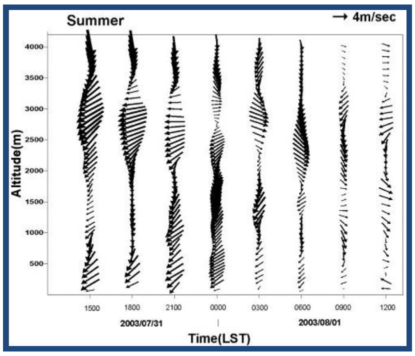

Figure 1. Observed vertical wind profile at the Kori NPP site

And we used the old horizontal and vertical dispersion coefficient (σ_y and σ_z) corresponding to atmospheric stability and distance of receptor point for the Gaussian model of US NRC code on the licensing stage which was provided by experiments at flat terrain condition of USA in 1972.

Now, we were trying to optimize the radiation diffusion factor with new horizontal and vertical dispersion coefficients are to make for simple Gaussian model of US NRC (Nuclear Regulatory Committee) code via consideration of complex terrain condition.

3. Optimization of radiation diffusion Factor in the Gaussian model

The scope and procedures are shown in the Figure 2.

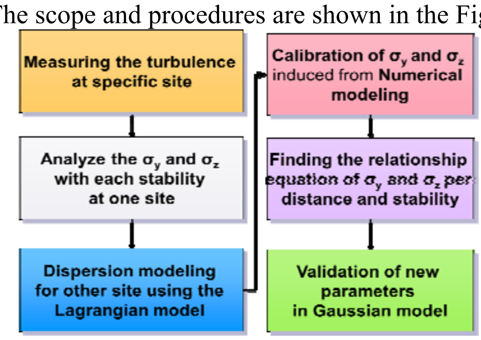

Figure 2. Flow chart to produce the new parameters in

Gaussian model

3.1 Description of experiments

The experiments were performed by turbulence measurement for one month at the YGN, Uljin, Wolsung and Kori site using a 3D ultrasonic anemometer to capture the atmospheric stability and σ_y and σ_z of horizontal and vertical dispersion coefficients[2]. And the Taylor thesis are used to calculate the horizontal and vertical dispersion coefficients with each stability to far distance of receptor point, which used the measured at downward one point of 500m[3]. Optimized new diffusion factors are determined by extracting the σ_y and σ_z from the analysis of Lagrangian model based on the Thomson's method, which is basically supposed the bi-Gaussian distribution and mono-Gaussian type according to the atmospheric stability[4].

3.2 Result

As shown in Table 1, the optimized new diffusion factor of horizontal (σ_y) and vertical (σ_z) dispersion are produced for each stability, which are covered the complex terrain for 4 sites.

Table 1. Optimized new diffusion factor of horizontal (σ_y) and vertical (σ_z) dispersion

Basic Equation for new parameter : $y = a + bx + cx^2 + dx^3 + ex^4$						
Stability \ Coefficient		a	b	c	d	e
σ_y	A(Very Unstable)	166.72	0.13	-4.30E-06	5.56E-11	-2.53E-16
	B(Unstable)	117.64	0.10	-3.07E-06	3.95E-11	-1.79E-16
	C(Weak Unstable)	96.11	0.08	-2.53E-06	3.24E-11	-1.46E-16
	D(Neutral)	83.35	0.07	-2.21E-06	2.82E-11	-1.27E-16
	E(Weak Stable)	74.68	0.06	-1.98E-06	2.53E-11	-1.14E-16
	F(Stable)	68.25	0.06	-1.82E-06	2.32E-11	-1.04E-16
	G(Very Stable)	63.25	0.06	-1.69E-06	2.15E-11	-9.67E-17
σ_z	A(Very Unstable)	-74.26	0.15	-4.26E-06	5.48E-11	-2.60E-16
	B(Unstable)	-32.35	0.08	-2.10E-06	2.67E-11	-1.26E-16
	C(Weak Unstable)	-19.73	0.05	-1.40E-06	1.77E-11	-2.73E-16
	D(Neutral)	-13.81	0.04	-3.24E-06	1.33E-11	-6.20E-17
	E(Weak Stable)	-10.45	0.03	-8.50E-07	1.06E-11	-4.96E-17
	F(Stable)	-8.30	0.03	-7.13E-07	8.92E-12	-4.14E-17
	G(Very Stable)	-6.81	0.02	-6.15E-07	2.39E-02	-3.55E-17

And the new parameters are compared with old parameters as shown in the Figure 2.

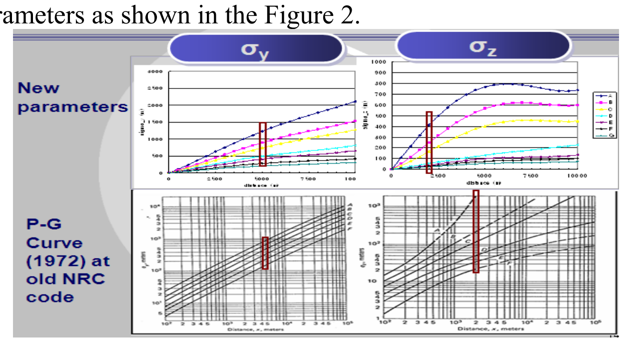

Figure 3. Comparison of the new diffusion factor for the Gaussian model with old NRC code

3.3 Validation of new parameterization

The new parameters are validated using the Model validation kit[5] which is developed by Harmonization within atmospheric dispersion modeling for regulatory purpose group of IAEA. These are the statistical data package to validate the modified Gaussian model, which was provided by field experiments. The validation result is shown in the Figure 4.

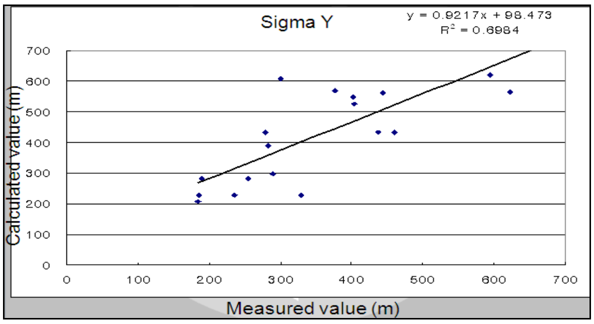

Figure 4. Validation result for horizontal dispersion coefficient

4. Discussion and conclusion

Since the new diffusion factors are based on the field experiments and 3D numerical analysis to consider complex terrain condition, the dispersion assessment of gaseous materials could generally be improved and actualized. The radiation diffusion(X/Q) estimated by XOQDOQ(NRC code) using the new parameters are sharply decreased depending on the distance from the source as 10^{-10} or10^{-11} of magnitude order compared to the old case with order of 10^{-6}.

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