Development of the Phenomenological Uncertainty Analysis Methodology using MELCOR code for the Containment Failure Probability of Level 2 PSA

Suwon Lee [a*], Gunhyo Jung [a], Kwngil Ahn [b], Sooyong Park [b]
[a] *Future and Challenge Technology Co., Ltd., Seoul National University, GwanakRo 599, GwanakGu, Seoul, Korea*
[b] *Korea Atomic Energy Research Institute., DaeDuk-DaeRo 1045, DukJinDong, YuSeongGu, DaeJeon, Korea*
[*] *Corresponding author: swlee@fnctech.com*

1. Introduction

The severe accident considering nuclear power plants has extremely low occurrence probability. But if the severe accident occurs, hazards influenced to public are very large. So it is necessary that quantitative analysis of the severe accident occurrence probability, phenomenological analysis of the accident progression process, and the prediction of outcomes were necessary. Therefore the severe accident analysis using MELCOR code has been performed around the regulatory body, the Korea institute of nuclear safety (KINS). But the severe accident analysis has been done conservatively, because the severe accident phenomena have large uncertainties.

2. Methods and Results

2.1 Procedure of Uncertainty Analysis

Because MELCOR code is comprehensive computer code that simulates the severe accident of a nuclear power plant, a MELCOR model for a specific nuclear power plant is necessary basically [1]. Additionally, accident sequences and severe accident phenomena to be analyzed were defined in advance. An uncertainty analysis scheme posterior to those is divided as 6 steps as seen from figure 1.

- 1^{st} step: First, input parameters, sensitivity coefficients, modeling options that could be target variables for the uncertainty analysis must be reviewed.
- 2^{nd} step: Minimum and maximum available ranges for sensitivity variables that reviewed in the before step must be stipulated.
- 3^{rd} step: Uncertainty variables that seriously affect on the severe accident phenomena must be selected by sensitivity analyses using the stipulated ranges and qualitative expert judgements.
- 4^{th} step: calculation numbers of the uncertainty analysis must be determined, and uncertainty variable combinations must be derived through sampling of uncertainty variables as much as determined numbers.
- 5^{th} step: input decks of MELCOR code following derived uncertainty variable combinations must be prepared, and code calculations using prepared input decks must be carried out.
- 6^{th} step: Conclusions of the uncertainty analysis must be derived through a comparative analysis for uncertainty phenomena that could be seen as each calculation result using all sorts of statistics.

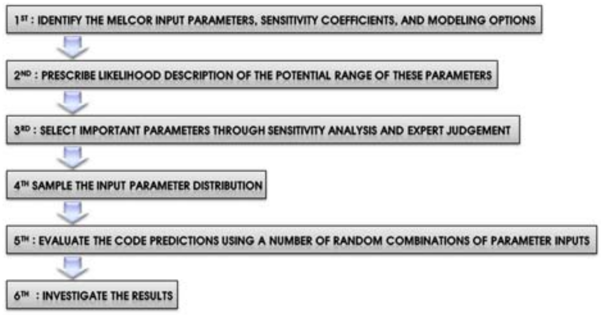

Fig. 1. Uncertainty analysis scheme using MELCOR code

Because the 1^{st} step has a great effect on overall analysis quality as a process that finds variables affecting on a severe accident progress and result for each analysis target phenomenon of an severe accident, it is important that all derivable variables are reviewed through sufficient background studies. Also, stipulations for uncertainty variable ranges by background studies and assumptions are needed in the 2^{nd} step. Uncertainty variables selected in the 3^{rd} step are used in all the left uncertainty analysis steps. The 1^{st}, 2^{nd}, and 3^{rd} steps are the phase that forms the basis for code calculations. So, uncertainty variables which are suitable for the purpose of the uncertainty analysis must be finally selected and ranges of uncertainty variables must be determined in those steps.

Since then, the 4^{th}, 5^{th}, and 6^{th} steps are the phase that prepares the input decks for code calculations, carries out code calculations, and derives the conclusion of the uncertainty analysis through a statistical treatment of calculation results. Monte Carlo random sampling method and Latin Hypercube Sampling (LHS) method are mostly applied in the 4^{th} step.

The uncertainty analysis using MELCOR code by the similar method but not equal to the uncertainty analysis scheme suggested by this paper was performed by Randall O. Gauntt [2].

2.2 Tools for Uncertainty Analysis

To use uncertainty analysis tools provided with MELCOR code would pave the way for the uncertainty analysis using MELCOR code. Tools for the uncertainty analysis using MELCOR code are shown in figure 2.

Uncertainty Analysis Engine (Melcor version) can be used to sample uncertainty variables in the 4th step, Batch Melcor can be used to execute automatically and continuously MELCOR code following the MELCOR input decks generated by Uncertainty Analysis Engine in 5th step, and Variance and Distribution can be used to perform a statistical treatment of calculation results [3].

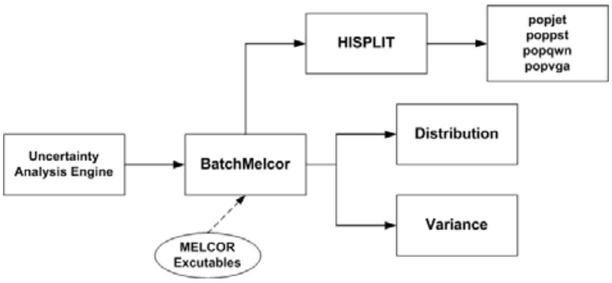

Fig. 2.Tools for the uncertainty analysis

Uncertainty Analysis Engine is a tool for the uncertainty variable sampling provided by Sandia National Laboratories (SNL) in 2004. An extra input deck is needed to sample using Uncertainty Analysis Engine.

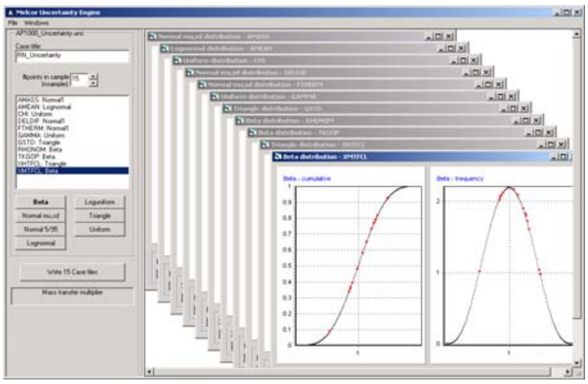

Fig. 3. Graphical user interface of the Uncertainty Analysis Engine (MELCOR version)

Available sampling number of Uncertainty Analysis Engine is from 5 to 500. Available distributions applied to sample each uncertainty variable are normal distribution, lognormal distribution, uniform distribution, logunform distribution, beta distribution, and triangle distribution. Table 1 shows input distribution name and input variables of uncertainty variables.

Table I: Input Variables of Uncertainty Analysis Engine

Distrubution	Input variables			
Beta	P	q	xlow	xhigh
Normal 1	mean	sd		
Normal 2	x05	x95		
Lognormal	mean	geo sd		
Loguniform	xlow	xhigh		
Triangle	xlow	xmidpt	xhigh	
Uniform	xlow	xhigh		

In case the uncertainty analysis would be performed using MELCOR code, SNL was recommended that a sampling number might be determined by a following formula.

$$C = 1 - n \cdot p^{n-1} + (n+1) \cdot p^{n}$$

After code calculations by Batch Melcor execution, calculations results must be collected. Distribution can be used to make cumulative distribution functions at regular intervals and Variance can be used to perform a regression analysis. Distribution and Variance are provided as execution files and executed in DOS mode.

3. Conclusions

If various phenomenological uncertainty analyses using the established uncertainty analysis structure in this report would be perform, uncertainties of the severe accident could be reduced, reasonable conservatism could be applied to the safety analysis of the severe accident, and the accident management strategy and design of severe accident Mitigation equipments could be optimized. Also, through the reduction of uncertainties of the level 2 PSA, the quality of the PSA could be improved and RIA could be promoted.

REFERENCES

[1] Randall O. Gauntt et. al., MELCOR Computer Code Manuals, Version 1.8.6, Users Guide and Reference Manual, NUREG/CR-6119, SAND2005-5713, U.S. Nuclear Regulatory Commission, 2005.

[2] Randall O. Gauntt, Uncertainty Analyses Using the MELCOR Severe Accident Analysis Code, Workshop on Wvaluation of Uncertainties in relation to Severe Accidents and Level 2 Probabilistic Safety Analysis, Sandia National Laboratories, 2005.

[3] Randall O. Gauntt et. al., User Guide for Uncertainty Analysis Engine: Melcor version, Sandia National Laboratories, 2004.