Sensitivity Evaluations of Responses with Gamma Shield using SAMPLER

Kyoon-Ho Cha*, Min-Chul Kim, Seo-Jeong Lee
Korea Hydro & Nuclear Power Co., Ltd. 1312, Yuseong-daero, Yuseong-Gu, Daejeon, Korea, 305-343
*Presenting author: khcha.cri@khnp.co.kr

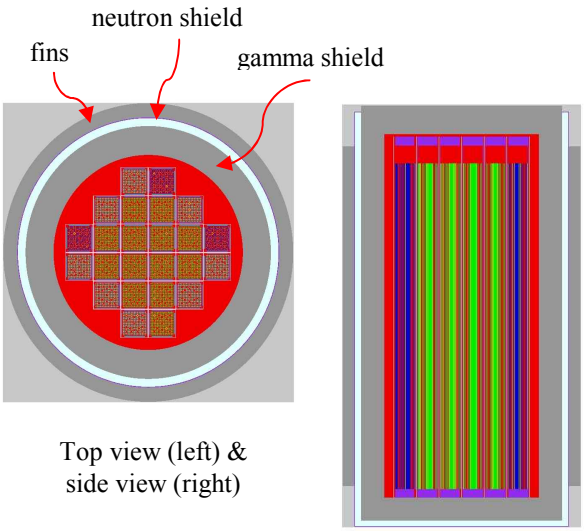
1. Introduction

Sensitivity calculations for shielding analyses of a storage cask were performed using SAMPLER sequence [1] in SCALE6.2. MAVRIC sequence [2] in SCALE was also used for the shielding analyses. Two kinds of sensitivity models using SAMPLER and MAVRIC were made for a storage cask with 24 PWR spent fuel assemblies. First, the gamma dose-rates were calculated by changing the thickness of gamma shield of the cask. Based on the results of the calculations, the thickness of gamma shield of the storage cask was discovered to be determined properly. Next, another gamma dose-rates was also calculated on the cask surface from bottom to top of the cask.

2. Methods and Results

2.1 Analysis Model

The basic model of this analysis is the Westinghouse MC-10 forged-steel storage cask as shown in Fig. 1 [3]. The MC-10 PWR spent fuel storage cask consists of a low-alloy forged-steel body, and is 4.8m long and 2.7m in diameter. The fuel basket within the cask is configured to hold 24 PWR spent fuel assemblies and is constructed of aluminum. The spent fuel assemblies used in this modeling are of a standard WH 15x15 rod design. For gamma dose evaluations, three kinds of fuel assemblies are loaded in the cask.



Top view (left) &
side view (right)

Fig.1 MAVRIC modeling of MC-10 storage cask

Fig. 1 shows the MAVRIC modeling of MC-10 cask to evaluate the sensitivity of gamma responses for the height and thickness of the shields of the cask.

2.2 Computer program and cross section library

Shielding analyses were performed using MAVRIC sequence (MONACO with Automated Variance Reduction using Importance Calculations) in SCALE6.2 which uses multi-group shielding code MONACO and calculates the adjoint flux as a function of position and energy, and combines the results of an adjoint calculation from the 3-D deterministic code TORT with MONACO [4].

MONACO is a new 3-D Monte Carlo code being developed within SCALE code package for shielding calculations. MONACO is the result of a modernization effort combining the multi-group neutron and photon physics of MORSE with the flexibility of the second-order surface SCALE general geometry package (SGGP), which is shared with KENO-VI. MONACO uses the same cross section package as other SCALE modules.

The multidimensional cask calculations in this study were primarily performed with MAVRIC sequence utilizing the SCALE 200-neutron and 47-photon-group cross section based on ENDF/B-VII.1 libraries and ANSI/ANS 6.1.1-1991 fluence-to-dose factors [5].

This paper describes the sensitivity evaluations of gamma responses with gamma shield performed to use the new SAMPLER sequence within the release of the newest version of SCALE code package. SAMPLER is available for the first time in SCALE 6.2. SAMPLER is a “super-sequence” that performs general uncertainty analysis for SCALE6.2 sequences by statistically sampling the input data and analyzing the output distributions for specified responses.

The new SAMPLER sequence within SCALE allows random sampling and perturbation of a wide range of parameters and nuclear data within virtually any sequence currently in the SCALE code package. The user input varies considerably based on the type of perturbation being applied. SAMPLER generates a specified number of perturbed inputs for each case. Identical perturbed values are used in each realization of each case, as specified. Different values are used for cases that are not specified to use the same values

SAMPLER uses a three-step process for executing the required calculations. The first step is the generation of the perturbed inputs. The second step is to execute all

the generated SCALE calculations. After all calculations are complete, SAMPLER is run in a post-processing mode to extract requested information from the generated output

2.3 Sensitivity analysis of the responses

Sensitivity analyses were performed by changing the thickness of the gamma shield and axial position of the cask. SAMPLER calculation provides the expected values of the data and repeats the perturbation for a specified number of samples (set by the user) to obtain the results distribution with its standard deviation and its correlation coefficients. The SAMPLER module has been used coupled with MAVRIC in this study.

First, when the thickness of gamma shield was changed, the other structures which are the neutron shield, fins and boundaries were to be changed. The design thickness of the gamma shield was 25.7cm and was changed from 15.7cm to 35.7cm. It was discretized into 100 shields for sensitivity simulations by changing the thickness of the shield. Fig.2 shows the results of the simulations using SAMPLER. The point of the design thickness of MC-10 cask is 112.4 on the x-axis of the graph. This means that the thickness of gamma shield was designed appropriately.

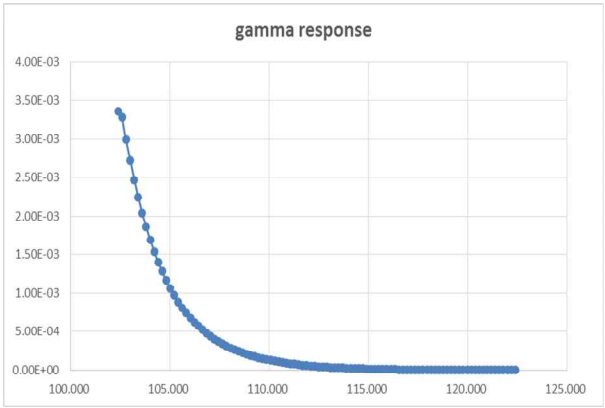


Fig.2. Responses via thickness change of gamma shield

Next, the gamma responses for the axial positions of the cask were calculated. The height of the cask is 473.6cm (-225.6~248.0cm). The number of positions to be calculated was 100 points varied from bottom (-225.6cm) to top (248.0cm) of the cask.

The gamma dose-rates were calculated on every 100 surfaces from bottom to top of the cask using SAMPLER. Fig.3 shows the responses according to the positions of the cask height.

The peaks of responses on bottom and top came from the absent of cooling fins made with carbon steel as shown in side view of Fig 1. And the drop of the response on the top (right side of the graph in Fig 3.) might be stemmed from the reason that there is a space between a test lid on the top of the cask and spent fuel assemblies in the cask.

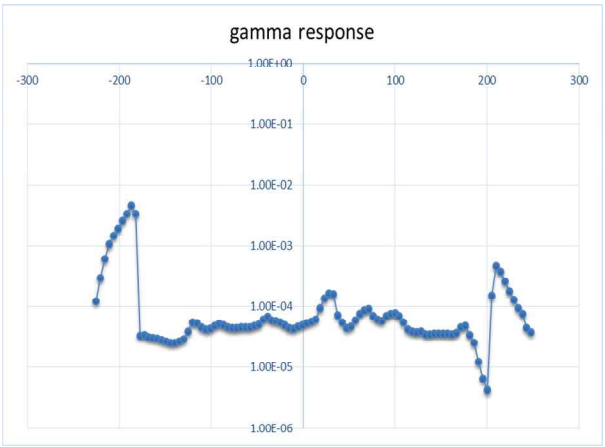


Fig.3. Responses via axial position of the gamma shield

3. Conclusions

Sensitivity calculations for shielding analyses of a storage cask were performed with MAVRIC which uses MONACO Monte Carlo code for shielding calculations and SAMPLER for perturbed thickness of the gamma shield and axial positions of the cask with stochastic sampling techniques. The cask used in this study is Westinghouse MC-10 forged-steel storage cask.

Based on the results of the sensitivity analyses using SAMPLER, it could be discovered for the MAVRIC gamma shielding model to be designed and validated properly.

And additional study is needed in response analysis of neutron shield. After these studies, some optimum shielding calculation models for the determination of design specifications of the gamma and neutron shield for a future storage and transport cask design, if needed, will be established.

REFERENCES

[1] M. L. Williams, et al., “SAMPLER: A Module for Statistical Uncertainty Analysis with SCALE6.2 Sequences,” 2016.
[2] D.E. Peplow and C. Celik, “MAVRIC: MONACO with Automated Variance Reduction using Importance Calculations in SCALE6.2,” 2016
[3] Evaluation of Shielding Analysis Methods in Spent Fuel Cask Environments, EPRI, TR-104329, 1995
[4] D.E. Peplow and C. Celik, “MONACO: A Fixed-Source Monte Carlo Transport Code for Shielding Applications in SCALE6.2,” 2016
[5] ANSI/ANS 6.1.1-1991, “Neutron and Gamma-ray fluence-to-dose Factors”