Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 8-10, 2024

The effect of random displacement in spent nuclear fuel cask criticality safety analysis

Seok Geun Cho, Keon Il Cha, Kyoon Ho Cha*
Nuclear Engineering Dept., Sejong Univ., 209 Neungdong-ro, Gwangjin-gu, Seoul 143-747, Korea
**Corresponding author: khcha@sejong.ac.kr*

1. Introduction

During the transportation of nuclear fuel, it is necessary to comply with international regulated safety standards. The casks used for transportation must pass stringent technical requirements to satisfy these standards. The NRC's regulatory requirement 10CFR PART 71[1] refers to subcriticality for packaging and arrangements that will result in a maximum neutron multiplication under normal and accidental conditions of transportation.

A critical safety analysis is critical to the prevention of safety problems in the transportation of nuclear fuel. The safety analysis must objectively consider the effects of possible deviations from the designed arrangement of the fuel assemblies and the possibility of errors during transportation that could result in an arrangement of the fuel assemblies that is smaller than expected. The Standard Review Plan for Transportation Packages for Spent Nuclear Fuel (NUREG-2216) [2] is followed for the transportation of spent fuel. In reference Section 6.3, states that the sum of the effective neutron multiplier (k-effect), the two standard deviations (95% confidence), and all bias and bias uncertainties should not exceed 0.95 to prevent the detection of a computational unweighting.

In this study, a critical safety analysis was performed to investigate potential safety issues associated with the transportation of spent fuel casks with 5000 randomly displaced assemblies.

2. Methodology

The study utilized PLUS7 [3] assemblies enriched to 5% U-235. Fresh fuel was used with no consideration of burnup credits, and it was assumed that the spent fuel assembly cask would be completely flooded with water.

MCNP6 [4] was used to simulate the fuel assembly and the spent fuel cask. **Figure 1** shows the fuel assembly designed with MCNP6 and **Figure 2** shows the spent fuel cask. The fuel assembly is located in the center of the basket, called the "normal case".

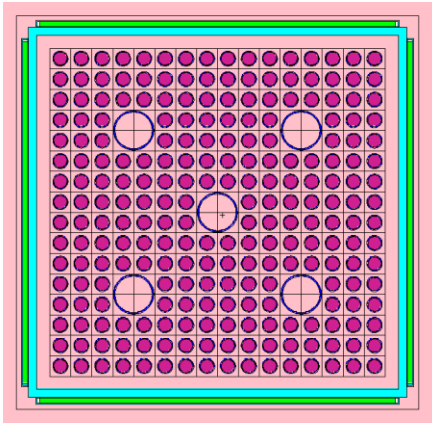

Figure 1. X-Y cross-sectional view of PLUS7 fuel assembly in fuel basket

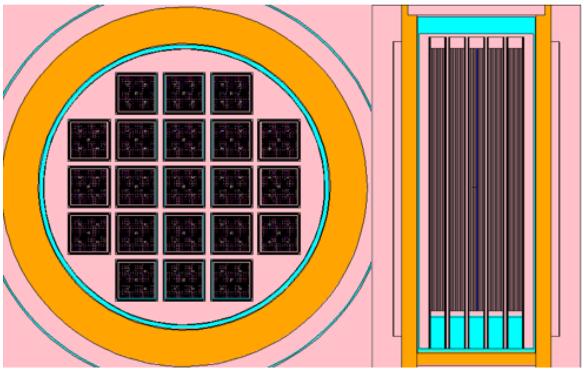

Figure 2. X-Y cross-sectional view of spent nuclear fuel cask

As shown in **Figure 3**, the fuel assembly can move in the X and Y directions within the fuel basket. The range of displacement is limited to -0.8184 cm and +0.8184 cm each. To simulate this movement, a PYTHON module randomly shifted each of the 21 fuel assemblies in the X and Y directions and generated 5000 MCNP input files.

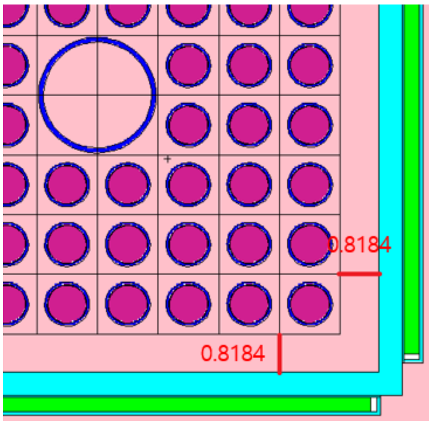

Figure 3. Range of displacement within the fuel basket

An example of random displacement in the spent fuel cask is shown in **Figure 4**. The displacement of the fuel assembly was tracked by plotting its center coordinates in the basket at the center of the spent fuel cask. The MCNP cases ran for 2000 cycles, each with 10,000 neutrons. The first 100 cycles were inactive.

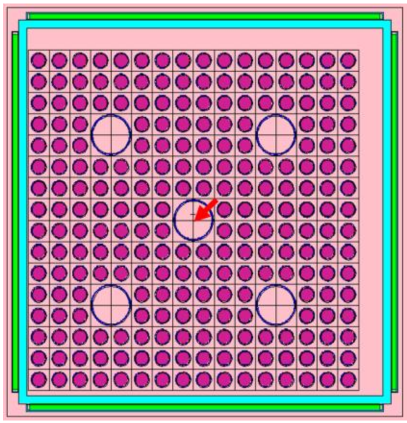

Figure 4. example of randomly displaced assembly in the X and Y direction

3. Result Analysis

Table 1 shows the results of the k-effective values and the standard deviation for the normal case and for the 5000 cases of random displacement. The standard deviation ranges from 0.00018 to 0.00019 for all cases of random displacement. The results show that in most cases the k-effective value is lower than the normal case. However, there are 35 cases where the k-effective value is higher than the value for the normal case. This indicates that he k-effective value may increase due to random displacement. **Figure 5** shows the k-effective value for both the normal case and the random shift cases.

Table 1. k-effective values for random displacement

Cases	k-effecitve	Diff.(pcm)	Std
Normal	0.89747	-	0.00019
RD(Max)	0.89829	+ 82	0.00019
RD(Min)	0.89411	-336	0.00019
RD(AVG.)	0.89597	-150	-

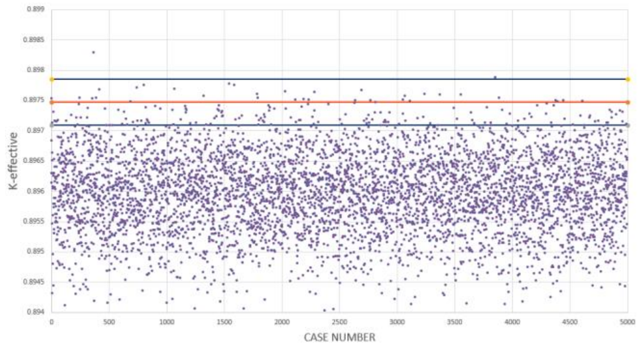

Figure 5. k-effective values for the normal case and random displacement cases

4. Conclusion

The results indicate that random displacement in the spent fuel cask can cause an increase in the k-effective value, which should be considered as a bias. The study found that the k-effective values of 35 cases exceeded the k-effective values of the normal case. These results also indicate that the same phenomenon can be observed in other types of fuel assemblies or in other types of spent fuel casks.

Acknowledgement

This work was supported by Technology Development Project for safe operation of nuclear power plants through the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MTIE) (No.20222B10100040).

REFERENCES

[1] PACKAGING AND TRANSPORTATION OF RADIOACTIVE MATERIAL, NRC, 10 CFR Part 71
[2] Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material: Final Report, NUREG-2216
[3] KEPCO/KHNP, 2014a. Chapter 4: REACTOR, TIER 2 - APR1400-K-X-FS-14002-NP-Rev 0. KEPCO/KHNP. Retrieved from http://www.nrc.gov/docs/ML1500/ML15006A043.pdf.
[4] C. J. Werner, "MCNP User's Manual – Code Version 6.2", LA-UR-17-29981, 2017.