Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 9-10, 2024

Feasibility Study for Spent Fuel Pool Storage of LEU+ fuel

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***Keywords :** Low enriched uranium+ (LEU+), Spent fuel pool, Criticality*

1. Introduction

In recent, accident tolerant fuel (ATF) is being developed for enhancement of safety during design basis accident and severe accident [1]. Major concept of ATF is zirconium alloy with very thin chromium coating and doped pellet for making large grain to decrease fission gas release. However, chromium coated cladding decreases of cycle length by acting as poison material. Utilities do not prefer this because it reduces their profits. To compensate these negative effect, it was considered to create economic benefits from improved safety by adopting ATF. Fuel vendors have conducted research about using low enriched uranium+ (LEU+) of enrichment above 5%. According to U.S. NRC, framatome already got approval for using LEU+ in PWRs and Westinghouse summitted the topical report. Also, domestic nuclear industry considered to use LEU+ in i-SMR and commercial reactors.

However, most of facilities in nuclear power plant was licensed to use enriched uranium lower than 5%. Therefore, it is necessary to analyze the influence of LEU+ in various aspects. Criticality is one of important issue. In particular, new fuel storage and spent fuel pool (SFP) region 1 is important because these are first region where fresh fuel is stored before core loading.

In this study, we calculated the k_{eff} following fuel enrichment which stored in spent fuel region 1 under normal condition to evaluate maximum fuel enrichment with no change of facilities.

2. Modeling

In this study, typical APR fuel assembly and SFP region 1 was modeled (Fig. 1). In general, a lot of fuel assembly is stored in SFP but it is inefficient to model all of fuel assembly with storage cell. Therefore, representative cell with reflective boundary was modeled. Purpose of reflective boundary is to assume that same fuel cells were surrounded infinitely.

For conservatism, couple of assumptions were applied. Pure water with maximum density (ρ=1 g/cm^3) was used although SFP is filled with borated water generally (about 4,000 ppm). Structure materials of fuel assembly except for fuel rod and guide tube were replaced to water (upper fuel assembly with 45 cm and lower fuel assembly with 15 cm).

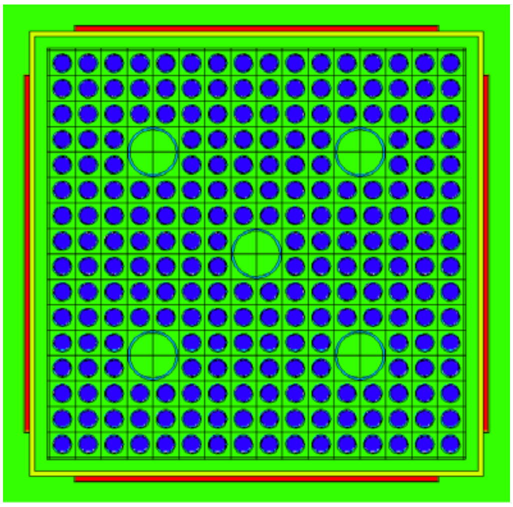

Fig. 1 Representative cell model

Detailed information of this model was shown in Table 1. Two types of fuel assembly were modeled in this study. One was the typical fuel (HANA cladding with UO_2 pellet) as a reference case. The other was ATF fuel (coated cladding with LAS pellet). LAS pellet is doped fuel developed by KNF [1].

Table. 1 Design of fuel assembly

Input data		Type 1	Type 2
Fuel	Type	UO_2	LAS
	Enrichment	5.0 ~7.0 %	
	Stack density	10.313 g/cm^3	
	Diameter	0.81915 cm	
Cladding	Type	HANA6	Cr coated HANA6
	Inner dia.	0.83566 cm	
	Outer dia.	0.9499 cm	
	Coating thickness	15 μm	
Guide tube	Type	HANA6	
	Inner dia.	2.286 cm	
	Outer dia.	2.489 cm	
Assembly	Rod pitch	1.28524 cm	
	Active length	381 cm	

Spent fuel pool rack is made of SUS304. BORAL plate is attached on outside of cell. Detailed information of SFP rack was referred from [2].

MCNP6 code was used to calculated k_{eff} of each fuel types [3]. Composition of HANA6 and LAS was obtained from KNF and composition of structural materials (SUS304, concrete) were referred from [4]. ENDF/B-VII nuclear data was used for making cross section data [5].

Neutrons were generated uniformly from UO_2 pellet region. 10,000 neutrons were used over 1,200 generations to minimized statistical uncertainty. In addition, initial 200 generations of k_{eff} value were ignored to exclude the influence of the bias caused by the initial value in the finial k_{eff} evaluations. This value was determined to pass the source entropy convergence check in MCNP code.

3. Results

Fig. 2 shows k_{eff} of each type of fuel assemblies. Regulatory criteria of SFP criticality under normal condition is lower than 0.95. The k_{eff} of both fuel type was higher than 6 %. This means that enrichment over 6 % fuel cannot stored in SFP region 1 if we use current criticality analysis methodologies.

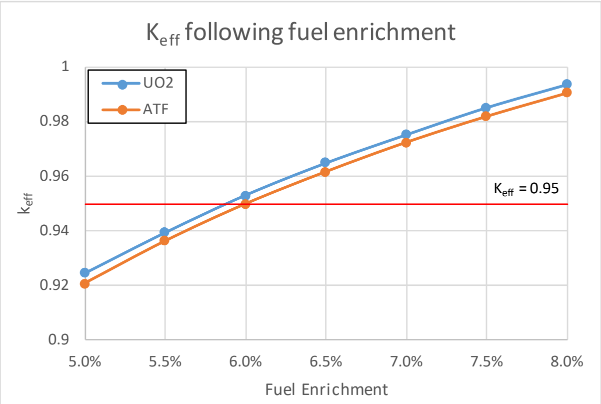

Fig. 2 k_{eff} following fuel enrichment

To identify possibility of storing fuel assemblies in SFP region 1, additional analysis was needed. As mentions previously, SFP was operated with borated water. Therefore, criticality analysis was conducted to confirm minimum boron concentration to store fuel assemblies in region 1. Fig. 3 shows k_{eff} following fuel enrichment and boron concentration. 1000 ppm of borated water was enough to maintain subcriticality if 6% of UO_2 is stored in SFP. However, it seems that 2000 ppm of borated water was needed to store 7% of UO_2 when we considered uncertainties and bias although the result of 1500 ppm was lower than 0.95. In case of 8% of UO_2, except for 2500 ppm of borated water, k_{eff} was exceeded 0.95 for all cases. Nevertheless, additional assumption is needed for 8% of UO_2 to accommodate uncertainties.

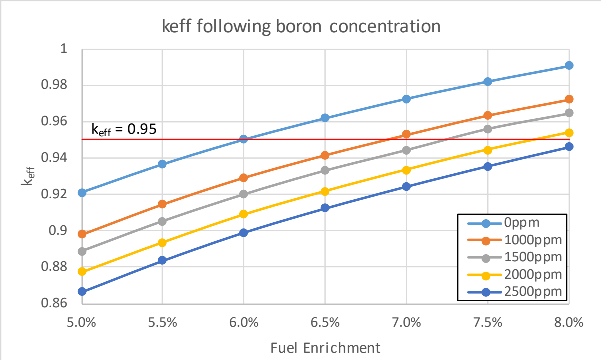

Fig. 3 k_{eff} following boron concentration

4. Conclusion

In this study, criticality analysis was conducted to evaluate feasibility of storing LEU+ fuel in SFP. It is hard to satisfy criticality criteria of LEU+ fuel if we use existing methodology, borated water was additionally considered. It is deduced that 2000 ppm of borated water was demanded for 7 % of LEU+ and additional assumption was needed for 8 % of LEU+.

Acknowledgement

This work was supported by the research and development program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Ministry of Trade, Industry and Energy (MOTIE; 20217810100050).

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