Conceptual neutronic simulation in Westinghouse small modular reactor with TRU fuel

Keon il Cha[a] and Chang Je Park [a]*
[a]*Nuclear Engineering Department, Sejong University, 209 Neungdong-ro, Gwangjin-gu, Seoul 143-747, Republic of Korea*
**Corresponding author: parkcj@sejong.ac.kr*

1. Introduction

Currently, 24 reactors were in operation in South Korea, Since the Fukushima accident, there have been doubts about the stability of nuclear power plants in Korea. In addition, despite the installation of dense racks and storage between near units, saturation of the capacity of the spent nuclear fuel reservoir became very close. Efficient fuel and recycling should be considered important when using nuclear fuel [1-3]. Using thorium fuel in reactors and recycled TRU actinides would be an attractive alternative. However, it is known that there are technical problems in recycling TRU in PWR, high radioactivity and heat generation from used fuels, and the rate of TRU consumption. The development of fuel processing and manufacturing technology must be resolved. In this paper, several studies to examine the difference between TRU nuclides and UO_2 fuels are discussed.

2. W-SMR Design

Its standalone reactor unit operates at 800 MW thermal power and delivers 225 MW electric power output. The core contains 89 robust fuel assemblies in a 17 × 17 square arrays, with each assembly loaded with 264 fuel rods, 24 control rod channels and one instrumentation thimble. The fuel assembly is a 17 x17 lattice containing UO_2 fuel pins, guide tubes for the insertion of control rods, instrumentation positions for burnable poisons. The design considers two types of burnable poisons namely the Integral Fuel Burnable Absorber (IFBA), occupying fuel rod positions, and the Pyrex burnable poison, occupying typical control rod positions [4].

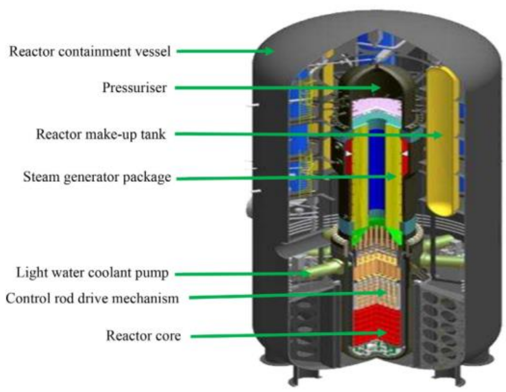

Fig. 1. Sectional view of the Westinghouse SMR

3. Methodology

In this paper, the values of $(TRU\text{-}Th)O_2$ fuel are compared and analyzed compared to the existing UO_2 fuel. The model used a W-SMR **(Fig.3.)**, and only the core was implemented and experimented. In the W-SMR, uranium enrichment was mixed into three types (2.35wt%, 3.40wt%, 4.45wt%). In the experiment, TRU (30wt%) will compare. TRU isotopes are shown in **Table.1.**

The criticality (KCODE) calculation was performed using 15 million histories (15×10^6) in 50,000 initial sources, 300 active and 50 inactive cycles, 1.0 initial criticality guess. four different hot full powers of 600, 900, 1200 and 2500 K equivalent to 71c, 72c, 73c and 74c temperature continuous cross-sections, respectively. ‘c’ stands for temperature dependent cross section library. The selection of gadolinium for reactivity control was based on a thermal neutron absorption cross section suitable as a boron-free core reactivity control material at the beginning of the cycle in which a rapid increase in reactor power is expected. Here, 8.6wt% of Gd_2O_3 was mixed with 3 different fuels as an integral fuel burnable absorber (IFBA) and placed in some designated fuel rods. The number of gadolinium fuel rods per fuel assembly depends on the proposed number per fuel assembly [5] **(Fig.2.)**.

Table 1 TRU compositions

TRU Nuclides	wt%	TRU Nuclides	wt%
Np-237	1.7152	Am-242	0.2234
Pu-238	3.0176	Am-243	1.1902
Pu-239	50.0963	Cm-242	0.0031
Pu-240	31.9379	Cm-243	0.0103
Pu-241	3.8629	Cm-244	0.7526
Pu-242	3.1988	Cm-245	0.2440
Am-241	3.6076	Cm-246	0.1400

3. Results

Initial reactivity is an important parameter that provides measurement of reactor power when the expected burnup time of the reactor is exceeded and helps to provide the control measures required by the operator. In Table 2, although there was no change in the value of the existing UO_2 even though there was a temperature change, the TRU k_{eff} value decreased as the fuel temperature increased.

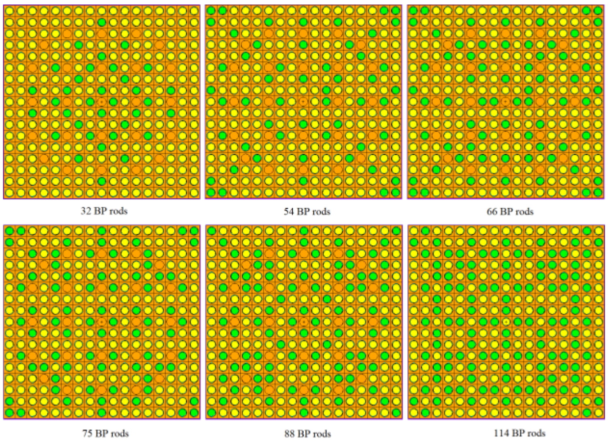

Fig. 2. The position of the fuel rods with burnable poison rod

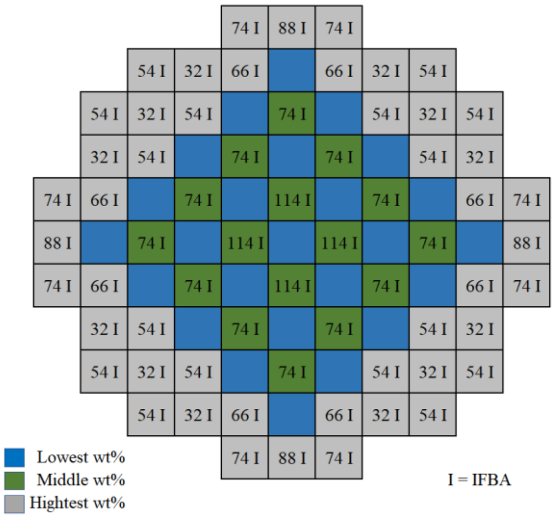

Fig. 3. Layout of the Core

Table 2 Effective multiplication factor

	UO_2	std	$(TRU\text{-}Th)O_2$	std
600K	1.21290	0.00020	1.15985	0.00020
900K	1.21291	0.00022	1.15189	0.00018
1200K	1.21392	0.00017	1.14590	0.00018
2500K	1.21238	0.00017	1.12687	0.00020

Existing UO_2 fuels and TRU were used to investigate and analyze the instantaneous burnup change of the fuel temperature difference. This investigation seeks to see the performance of fuels that may be normal or potentially abnormal. The temperature of the thermal reactor is around 600K. It is impossible to operate at 2500K throughout the entire cycle, but irradiating 2500K may help determine the temperature limit of the fuel considering the safety feedback of the reactor system and thermodynamic factors.

5. Conclusion and Future works

This study measured the k_{eff} and burnup values of the fuel consisting of a single enrichment of TRU fuel and the UO_2 fuel with three fission enrichment zones. As a result, the effective multiplication factor and burnup of the two fuels in common depend on the range and fuel temperature of the fission enrichment zone, which decreased as the fission enrichment and temperature increased. The effect of gadolinium burnable poison rods seems to have the more effective on TRU fuels, except for the possibility of increasing the non-actinide enrichment of spent nuclear fuel. Using external TRU feeds instead of enriched uranium is positive in the direction of TRU consumption. It is suggested to determine the optimal core configuration by analyzing the effect of changes in core flux profile and core composition on the inventory of fission products, since the conventional alternative to UO_2 with $(TRU\text{-}Th)O_2$ is known as a high level of waste reduction. As a future study, the most important burnup calculation will be carried out, and various experiments such as decelerators, fuel temperature coefficients, and safety variables will be conducted.

ACKNOWLEDGEMENT

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