Comparison between Uranium Fuel Cycle and Thorium Fuel Cycle in Proliferation Resistance Aspects

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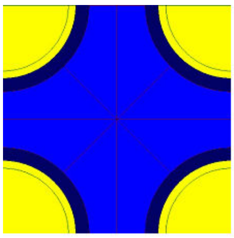
1. Introduction

The operation nuclear power plants around the world have a fuel cycle which based on uranium fuel mostly. Since uranium natural resource are limited, the development of new energy source which can change uranium fuel cycle need. This new energy source must have advantages in non-proliferation and efficient utilization. The research about thorium fuel cycle has been studied as a new energy research during a few decades. Therefore this paper tried to compare with thorium fuel cycle and uranium fuel cycle in proliferation aspects.

2. Calculation Models

It was evaluated uranium fuel-based cycles in Combustion Engineering Standard System 80 Plants to determine the proliferation and feasibility of once-though thorium-based fuel. The calculation models are based on Yeong-kwang 3,4 unit and KTF (Kyung-hee Thorium Fuel) core design [1] as each reference.

About 2X2 unit lattices it accomplished Color-set calculations. To do Color-set calculations it was more efficient to seen the characteristic of that fuels than whole core calculation. giving neutron current is zero at the each boundaries. it was assumed an unit lattice infinitely.



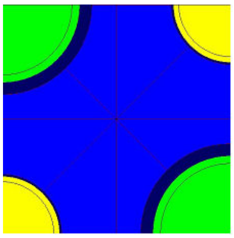


Fig1 All UO_2 Assembly   Fig2. ($UZr+ThO_2$)Assembly

This figures show the color-set of uranium based fuel cycle model and thorium based fuel cycle model graphically. Left one is All UO_2 assumed infinite lattices. Right one is Seed/Blanket assumed infinite lattices. Coolant is same material as the Light Water. Yellow color means uranium material, green color means Thorium material.

Before comparisons are evaluated, it is arranged to have the same burnup length for the equivalent comparison. The enrichment and the volume fraction of the thorium fuel assembly were modified to have the same burnup with uranium fuel assembly.

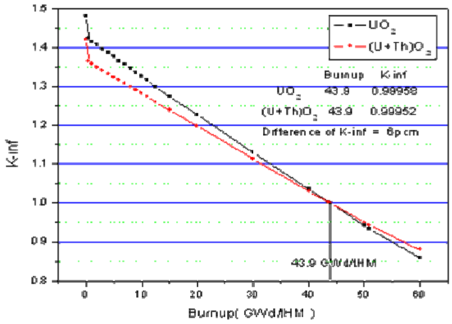


Fig3 Decision of the cycle length

One of the blanket-seed designs presented in this work is to decrease Pu production of the thorium based fuel sub-lattice, which will be loaded in the core during one operating cycle. Finally it is found that blanket composition that will not only have the same cycle length but also improve the non-proliferation at 43.9 burn-up.

Burnup(GWd/tHM)	K - inf	
	UO_2	$(U+Th)O_2$
43.9 GWd/tHM	0.99952	0.99958
△ K	6 pcm	

Table1 Decision of the cycle length

The seed is U/Zr metal fuel. Enrichment is 5 w/o. The blanket fuel decided is a lattice of mixed oxide fuel of the thorium and uranium. The uranium enrichment is 15 w/o. The blanket fuel is a ThO_2-UO_2 of theoritical density consisting of 74.8 v/o ThO2, 25.2 v/o UO_2 on whole fuel basis, with the latter enriched to 15w/o U-235, to give a blanket enrichment of about 3.8 w/o.

3. Utilization of the Code System

HELIOS code system [2] was used for evaluation the comparison. MCNP code [3] and MONTEBURNS code [4] were used to benchmark HELIOS code system. MCNP code was used for criticality comparison between different depletion chains of each HELIOS and MONTEBURNS. As a result of benchmarking, the variation of criticality showed a small difference about 200 pcm, and the number density had a difference about 6~7 percent. This results means that the calculation results of the HELIOS code system can be simulated correctly in both fuel cycle.

4. Proliferation Resistance Evaluation

After benchmarking of HELIOS, it is performed that the comparison of proliferation resistance between the thorium fuel cycle and the uranium fuel cycle using three performance indices – BCM (Bare Critical Mass), SNS (Spontaneous Neutron Source rate), and TG (Thermal Generation rate) which are suggested at LANL (Los Alamos National Laboratory). Plutonium isotope fractions of each spent fuel are major parameter to verify proliferation resistance. Using these fraction, BCM calculation was accomplished by MCNP code in bare spherical geometry and SNS and TG calculation were also achieved by ORIGEN-II code [5].

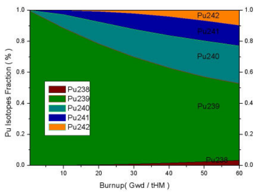


Fig4 Uranium fuel cycle

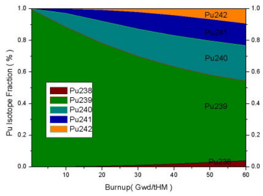


Fig5 Thorium fuel cycle

As a comparison results of non-proliferation, there are no longer big differences between thorium fuel cycle and uranium fuel cycle because of similar plutonium fractions between two fuel cycles.

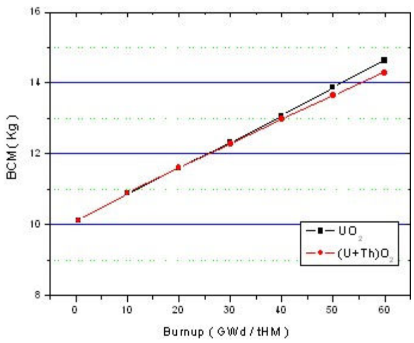


Fig6 Using Pu fraction

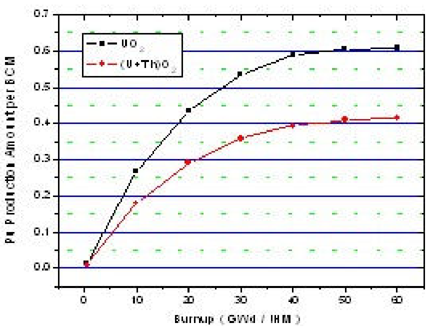


Fig7 Using Pu amount

However, thorium fuel cycle showed higher proliferation resistance than uranium fuel cycle at the variation of the production amount of the plutonium isotopes. because the total plutonium production mass in thorium fuel cycle was 67 % of plutonium mass in uranium fuel cycle.

5. Conclusions

It is tried to compare between thorium-based fuel cycle and uranium-based fuel cycle in proliferation resistance aspects. The calculation models are based on Yeong-kwang 3,4 unit and KTF(Kyung hee Thorium Fuel) core design as each reference. Before comparisons are evaluated, Enrichment and volume fraction of Thorium fuel assembly is modified to have the same burnup with uranium fuel assembly.

HELIOS code system is used for evaluating the comparison MCNP and MONTEBURNS code is used for benchmarking the HELIOS code. In case of benchmarking of criticality, there are difference with 200 pcm. In case of number density, there are difference with 6.5 percent which takes the highest error.

It is used 3 elements of BCM, SNS, TG which are suggested at LANL (Los Alamos National Laboratory). In case of using plutonium fraction, there are no big differences. Other hands, In case of using plutonium mass into spent fuel, there are relatively big differences. Because of contained quantity of uranium-238 is less than uranium fuel model, producted quantity of plutonium in thorium fuel model was about 67 percent of plutonium mass in uranium fuel model.

According to KTF Core design of Kyung Hee University applied the thorium fuel cycle, it was confirmed that thorium fuel cycle was merely high in proliferation resistance aspects..

REFERENCES

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