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Equilibrium Core Analysis of Two Types of Cores for the AHR

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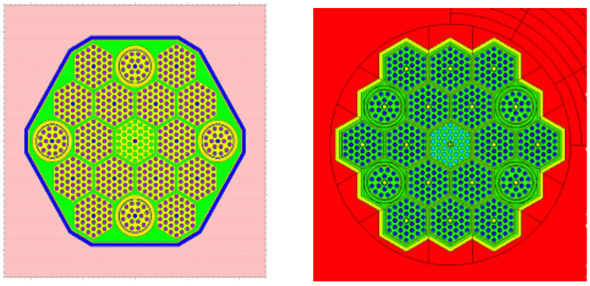
1. Introduction

A preliminary conceptual design of a research reactor core employing a rod type fuel assembly, has been performed. Two types of the reactor core configuration have been developed as a basic core of the Advanced HANARO Reactor (AHR). One is the aluminum block core whose coolant channels are made inside a hexagonal aluminum block for loading the fuel assemblies, the other is a flow tube core by using the same zircaloy flow tubes as the HANARO. Figure 1 shows the aluminum and the flow tube cores. These cores have four control rods of a shroud type. In the control rod sites, 18-element fuel assemblies of a circular type are loaded, whereas 36-element fuel assemblies of a hexagonal type are loaded in the hexagonal sites except the central site. The AHR is designed on the basis that the thermal power is 20MW and the maximum thermal neutron flux is about 4.0×10^{14} n/cm^2/sec in the reflector region.

For these two cores, MCNP calculations have been finished for the condition of loading fresh fuels and no irradiation holes and beam tubes in the reflector region.

For the depleted core, the parameters such as the cycle length, fuel burnup and maximum linear power for the equilibrium core, are evaluated by using the HANARO fuel management code system [1].



Aluminum core　　　　Flow tube core

Figure 1. Aluminum and flow tube core

2. Calculation

Two cores use the same shape of the HANARO fuel assemblies but they are constructed with standard fuel rods, which is comparable with standard and reduced fuel mixes in HANARO case. The fuel meat is U_3Si_2-Al with a density of 4.0gU/cc. A total of 14 hexagonal and 4 circular fuel assemblies are loaded into each core. The reactor core is surrounded by a D2O reflector tank. The irradiation holes and beam tubes in the reflector tank are not considered in this work.

The reactor physics calculation is performed with VENTURE, one of the computer codes of the HANARO fuel management code system. The group constants for the VENTURE calculation are produced by HELIOS. The k-effective values of MCNP and VENTURE for the core with fresh fuel assemblies were different. VENTURE underestimated the reactivity by 10～15mk and the neutron flux by 10%[2].

Before searching the equilibrium core, two types of fuel reloading patterns are considered. One pattern is that 4 fuel assemblies (3 hexagonal assemblies and one circular assembly) are changed at the end of a cycle (EOC), the other is that 3 fuel assemblies (2 hexagonal assemblies and one circular assembly) are changed. The core depletion calculation is performed repeatedly to determine the cycle length along with the fuel reloading pattern. Figure 2 shows the k-effective values for the cycle length of 40, 45, 50 and 55days, when 4 fuel assemblies are changed at EOC.

It is determined that a cycle length is 40days for Al-block core and 45days for the flow tube core. It is desirable that the excess reactivity is more than 40mk through HANARO experience, because the excess reactivity for the irradiation holes and beam tubes in the reflector region needs about 20mk and that for the irradiation material in CT needs about 15mk. Also the reactivity reserve for the Xe override and the calculational uncertainty should be considered.

When 2 hexagonal fuel and one circular fuel assemblies are changed at EOC, one cycle length is determined as 28days for the aluminum core and 35days for the flow tube core.

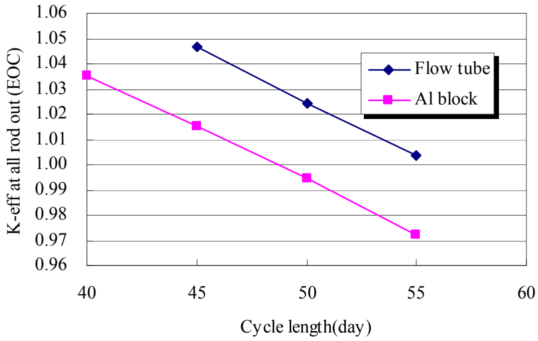


Figure 2 k-effective values with cycle lengths at EOC

3. Results

Table 1 shows the calculation results. For the aluminum core, the discharge burnup of the fuel assemblies at EOC is less than 50%U-235. It is not desirable from the view point of a fuel economy. In the case of HANARO, the discharge burnup of the fuel assemblies is more than 50%U-235.

Table 1. Calculation results for two types of core

		Al core		Flow tube core	
Cycle length(day)		40	28	45	35
Core Avg. Burnup(%U-235)	BOC	18.4	19.74	20.62	24.95
	EOC	27.7	26.26	31.02	32.98
k-eff at EOC(All Rod Out)		1.03496	1.04170	1.04662	1.03463
Max. linear power at BOC (kW/m)		150	132	147	134
Discharge burnup(%U-235)		45,45,38,42	44,44,31	55, 56, 46, 51	55,54,39
Max. thermal neutron flux (reflector area)		4.10E+14	4.15E+14	4.35E+14	4.20E+14

The flow tube core satisfies the discharge burnup to some extent except for the 18-element fuel assemblies.

The maximum linear power is very high for all cases. The maximum linear power is desirable to be less than 120kW/m for the U_3Si_2-Al fuel. The limit of the maximum linear power will be determined after thermal-hydraulic analyses. The thermal neutron flux at the reflector region is satisfied with the target, 4.0×10^{14} n/cm^2/sec.

4. Conclusion

Two types of reactor cores, the aluminum core and the flow tube core, were considered as a candidate of the AHR. The equilibrium cores for the two candidates were searched and their performances were compared.

The performance of the flow tube core is better than the aluminum core. The maximum linear power is high. To reduce the maximum linear power, more fuel assemblies are loaded inside the core to reduce the power of a fuel assembly. If more fuel assemblies are loaded inside the core, the neutron flux in the reflector region becomes low. From now on, a detailed design will be performed with the targets for reducing the maximum linear power.

Acknowledgement

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REFERENCES

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[2] C. S. Lee, et al, The Equilibrium Core Analysis with a Basic Core for the Development of a New Research Reactor using Rod Type Fuel, HANARO Symposium, 2006.