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A Preliminary Calculation of Annular Core Design for a High-flux Advanced Research Reactor

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1. Introduction

Many of research reactors in operation over the world become old and the number of research reactors is expected to be reduced around 1/3 within a next decade. So it may be necessary to prepare in advance for the future demands of research reactors with a high performance. Therefore, based on the HANARO experiences through design to operation, a concept development of an improved research reactor is under doing. In this paper, 10 MW conceptual annular core is proposed and its basic characteristics were analyzed as a preliminary step.

2. Design Description

Neutron flux is one of the important factors to evaluate the performance of a research reactor. So the primary goal of a research reactor core design is to achieve a high neutron flux in the reactor core and reflector region, depending on the purposes. In order to obtain high thermal neutron flux in the reflector region, an annular-core concept that fuel assemblies with rod type low enriched uranium (LEU) fuels are arranged in a ring-shaped manner is proposed. In this work, we mainly focused our target on the neutron flux and MCNP code was used core in the analysis.

2.1 Fuel Assembly

In general, research reactors use various types of fuels such as rod, plate and tube. Plate or tubular type fuel is popular in research reactors due to their outstanding thermo-hydraulic characteristics comparing with the rod type fuels. In this study, the rod type fuel of HANARO is chosen as an advanced research reactor fuel because one of the most important safety principles for nuclear installations is to use proven technology. The basic design data of a fuel assembly containing the 54 fuel rods with a 12 mm hexagonal pitch represented in Table 1. And Fig. 1 shows a cross sectional view of a fuel assembly using LEU with density of 4.8 gU/cc. A cylindrical absorber rod is inserted outside its fuel assembly as shown in Fig. 1.

Table 1 Basic data of fuel assemblies

Fuel meat	U_3Si_2
Number of fuel rods	54
Fuel meat radius	3.175 mm
Pitch	12 mm
Cladding thickness	1.003 mm
Absorber thickness	4 mm

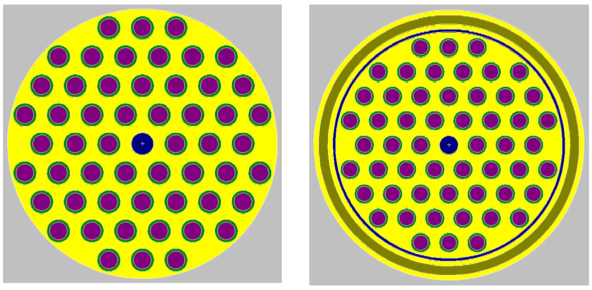

Fig. 1 Cross sectional view of fuel assemblies

2.2 Core Configuration

Using the fuel assemblies with the rod type LEU fuels, annular core arranged in a ring shaped manner. The basic data and the cross sectional view of annular core are presented in Table 2 and Fig. 2, respectively. And Fig. 2 shows a cross sectional view of the core. As shown in Fig. 2, the core has 6 fuel assemblies with two control absorber(CAR), and one shut-off absorber(SOR). Considering the T/H characteristics of the HANARO fuel performance, the thermal power capacities would be 10MW. H_2O and D_2O were used as a coolant and reflector, respectively. The annular type core can obtain relatively high thermal neutron flux in reflector region by maximizing the fast neutron leakage from the core.

Table 2 Basic design data of core

Parameter	Value
Thermal power	10 MWth
Total U loading	34.5 kg
Number of fuel sites (std/rdc)	3/3
Core radius (inner/outer)	6.2/18.3 (cm)
Number of absorber (CAR/SOR)	2/1

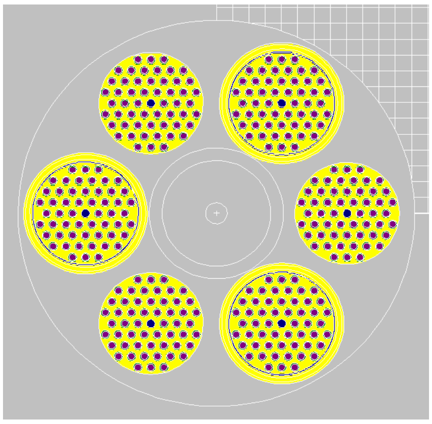

Fig. 2 Cross sectional view of core

2.3 Results

Nuclear characteristics of annular core are represented in Table 3. The flux to power ratio including perturbed effect are compared with those for other research reactors in Table 4. If the perturbed flux is assumed as about 70% of unperturbed flux in usual research reactors, the flux to power ratio would be 2.1E13 (n/㎠•s/MW) at the reflector region of annular-core.

Table 3 Results of nuclear characteristics for annular core

Parameter	Value	
K-eff	BOC	EOC
	1.22	1.05
All CAR in	0.94381	
All rods in	0.72020	
Effective burnup cycle	172 days *	
Max thermal neutron flux	3.0E14 n/㎠•s**	

* The entire core is refueled at one time
** Unperturbed neutron flux

Table 4 Comparison of flux to power ratio

	Flux to Power Ratio in reflector (n/㎠•s/MW)
JRR-3M (Japan)	0.6E13 (20MW)
HANARO (Korea)	0.7E13 (30MW)
CARR (China)	1.3E13 (60MW)
OPAL (Australia)	1.6E13 (20MW)
ORPHEE (France)	2.1E13 (14MW)
Annular Core	**2.1E13 (10MW)**

It was shown for Table 4 that the performance of annular core would be better than other research reactors in the world in the neutron flux point of view.

3. Conclusion

In order to prepare the expected future needs for a research reactor, a study on the concept of advanced research reactor has been performed based on the experiences of HANARO construction and operation. A 10 MW annular core using rod type fuel of low enriched uranium is proposed as a candidate. The performance of the annular core is judged to be good from the high ratio of power to thermal neutron flux.

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