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Conceptual Nuclear Design of a 10 MW Research Reactor with MTR type Fuel Assemblies

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1. Introduction

Since its first criticality on Feb. 8th of 1995, the HANARO (High-flux Advanced Neutron Application ReactOr) has been operated successfully. Based on the HANARO experiences, we have developed conceptual cores named the AHR (Advanced HANARO research Reactor) [1,2]. While the AHR adopts a rod type fuel like the HANARO, many research reactors use MTR type fuels. As the core design is dependent on a user's requirements, we are preparing other core models with MTR type fuel assemblies. This paper presents a basic core model with the MTR type fuel and its neutronics characteristics.

2. Nuclear Design

We are considering a 10~20 MW multi purpose reactor with a high performance. The conceptual nuclear design of the AHR satisfies all design targets[2], in which a high neutron flux, safety, and economics were preferentially considered. The AHR reference core is a light water cooled and heavy water reflected open-tank-in-pool type multipurpose research reactor with 20 MW. In this paper, a new core with the MTR (Material Test Reactor) type fuel is designed and named the AHR-P10, in which its power level is 10 MW and upgradable to 20 MW. The nuclear design will satisfy the basic design requirements. A core model with 3 in-core irradiation sites is presented and analyzed.

2.1 Core Concept

This core uses the MTR type fuel for which multiple fuel vendors are available. The dimensions of the fuel assembly and the fuel plate were chosen as the standard size. As the AHR-P10 requires a high uranium density fuel for high performance, the AHR-P10 adopts U_3Si_2-Al fuel of 4.8 gU/cc as a reference fuel. The AHR-P10 core is constructed using two types of fuel assemblies, a standard type and a follower type. The nominal core consists of 18 fuel assemblies. Because the reactivity swing of the core is not so large, the fuel assembly does not contain any burnable poison. However, the burnable poison could be required for a longer cycle length or a 20 MW power core. The current design of the fuel assembly is ready to use Cd wire as burnable poison, which is inserted into side plates of a fuel assembly. Total uranium loading of the nominal core is 35.3 kg.

The core configuration should be optimized according to its purpose. As the AHR-P10 is a multi purpose research reactor, the flux level should be high both in the core and reflector regions. A multi purpose research reactor in general provides at least one irradiation hole at the core region, in which the fast neutron flux can be high. The core design is strongly dependent on the number of in-core irradiation sites. Fig. 1 shows a core model with 3 in-core irradiation sites.

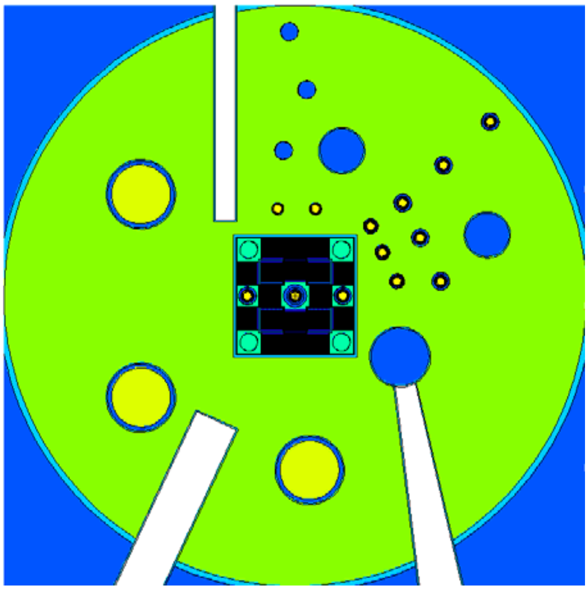

Fig. 1. Cross Sectional View of the AHR-P10 Core

This core is composed of 5x5 lattices with its active length of 60 cm. A heavy water reflector tank of 200 cm in diameter and 120 cm in height surrounds the core. The nominal core consists of 14 standard fuel assemblies and 4 follower fuel assemblies. 3 in-core irradiation sites are used for the fuel and material irradiation tests and for RI production. The reactor regulating system shares its Control Absorber Rods (CARs) with the reactor protection system. The secondary independent shutdown system is a heavy water drainage system. The reflector tank provides sufficient space for the irradiation facilities. The arrangement of the experimental facilities for the AHR-P10 was studied by reflecting the HANARO operating and utilization experiences [3]. The selected model in this paper has 4 tangential beam tubes and a total of 18 vertical irradiation holes with different diameters. The final arrangement of the experimental facilities will be determined later, thus a continuous effort is required for the development of appropriate irradiation facilities.

2.2 Nuclear Analysis

The nuclear analyses are mainly performed for an equilibrium cycle of a reference core. To confirm that the proposed AHR-P10 core satisfies the design performance and criteria, nuclear analyses were performed with two well-known nuclear codes, MCNP and HELIOS. The MCNP code was mainly used to evaluate the nuclear characteristics of the core, which uses continuous energy library based on ENDF/B-VI. The HELIOS code was used for supporting the burnup calculation in the coupled MCNP/HELIOS system [4].

An equilibrium core is dependent on an operation strategy, so there may be various equilibrium cores according to a reactor operating strategy. We selected a full batch core considering a discharge burnup, a cycle length and an excess reactivity at a BOC and an EOC. The equilibrium core is reloaded with one fuel assembly for one cycle operation. As there are many loading patterns, a sophisticated study is required. In this paper, a loading pattern is intuitively selected to minimize a maximum peaking factor. As a loading pattern is determined, a fresh core converges to an equilibrium core by repeated core calculations, in which the MCNP/HELIOS system is used for exact evaluations. For the selected equilibrium core, the cycle length was estimated as 21 days long. The excess reactivity at a BOC was 68.5 mk, and at least 23.7 mk was reserved at an EOC.

The neutron fluxes were evaluated at equilibrium Xe state of the BOC core. The maximum thermal neutron flux ($E_n \leq 0.625$ eV) at target regions of the capsule in CT (Central flux Trap) was estimated to be 2.87E+14 n/cm^2/sec. The maximum fast neutron flux ($E_n \geq 1.0$ MeV) at CT is 7.3E+13 n/cm^2/sec when the control rods are located at 400 mm. The maximum thermal neutron flux at the nose of the tangential beam tube was estimated to be 1.16E+14 n/cm^2/sec.

The assembly average discharge burnup is 58.7% of initial U-235 loading. For evaluating the power peaking factors, all the fuel rods were axially divided into 5 cm each. Linear power was evaluated for every control rod positions because it is sensitive to a control rod's position. The maximum linear power occurred at 300 mm and the maximum total peaking factor Fq is estimated as 2.46. The shutdown margins by the 1st and 2nd shutdown systems were estimated to be 27.4 mk and 23.0 mk, respectively. Both the isothermal temperature coefficient and the power coefficient were negative, so the AHR-P10 core is characterized as being inherently safe.

3. Concluding Remarks

We succeeded in obtaining a new conceptual core with MTR type fuel assemblies. This core design is based on internationally proven technology. Based on this conceptual core design, core models for improved performance will be developed.

REFERENCES

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