Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Conceptual Core Design of a 20 MW Research Reactor Using the HANARO Fuel Assembly

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1. Introduction

Since its first criticality on Feb. 8th of 1995, the HANARO research reactor has been operated successfully and the number of users and utilizations has been increased rapidly. The demand for the utilizations is expected to exceed the capability of HANARO in the near future. Moreover, the number of research reactors available in the world is expected to be reduced to about 1/3 between 2010 and 2020, and thus the need for new research reactors will increase gradually. It is necessary to prepare in advance for the future domestic and overseas demands for new research reactors. Therefore, based on the HANARO experiences through design to operation, the development of an Advanced HANARO research Reactor (AHR) was launched in 2003 [1]. This paper presents one of the conceptual cores with a high performance.

2. Physics Design

We are considering a 20 MW multi purpose reactor with a high performance. The basic design principles are as follows:

. Multi purpose research reactor with medium power,
. Adaptation of HANARO concepts,
. High neutron flux,
. High safety and economics aspects,
. Improvement of the operability and maintainability, and
. Sufficient space and expandability of the facility.

The core design will satisfy the basic design principles while achieving a high neutron flux that is most important in a research reactor.

2.1 Nuclear fuel

Research reactors use rod or plate type fuel. Plate type fuel is popular in research reactors thanks to their outstanding thermo-hydraulic characteristics. The rod type fuel was selected for HANARO. The uranium density of the HANARO fuel was the highest available in the world at the design stage. The HANARO fuel is in the form of U_3Si dispersed in an Al matrix with a loading density of 3.15 gU/cc. The AHR requires a higher uranium density fuel for a higher performance. A necessity for a high uranium density fuel was raised from the result of the conceptual AHR core design. We are considering a HANARO core conversion by using the U-Mo fuel of a high density for more irradiation holes and a longer cycle length [2]. The U-Mo fuel showed some problems from several irradiation tests, which were caused by the reaction between the U-Mo particles and the Al matrix. The AHR adopts U_3Si_2-Al fuel of 4.0 gU/cc as a reference fuel, which is under the irradiation test at HANARO, and the U-Mo fuel is considered as an alternative if it is available. At the current design stage, we are going to use HANARO fuel assemblies with U_3Si_2 dispersion fuel particles as the AHR fuel. There are two types of fuel assemblies comprising of the hexagonal and circular fuel assemblies as shown in Fig. 1.

Fig. 1. HANARO Fuel Assemblies

2.2 Core Configuration

The core configuration should be optimized according to its purpose. As the AHR is a multi purpose research reactor, the flux level should be high both at 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. Reactor core should be as compact as possible to obtain a high neutron flux at the reflector region. The sites of the Control Absorber Rods (CARs) are restricted by the cooling method and the position of the control driving units. An upward forced convection cooling system will be applied to AHR. The CARs are located at the periphery of the core. The number of the fuel channels should be optimized for the reactor power. Various options for the reactor core have been studied and the core model in this paper is selected as in Fig. 2. 14 channels are loaded by the hexagonal fuel assemblies, and four channels are loaded by the circular fuel assemblies, and one channel is devoted to the central flux trap. The core reactivity is controlled by four CARs made of hafnium which are used as the first shutdown system. The secondary independent shutdown system will be a heavy water drainage system. The number of vertical irradiation holes and horizontal beam tubes at the reflector region will be determined later. The reactivity effect by the irradiation holes is only considered at this design stage. The reactor power is 20 MW and other design characteristics are similar to HANARO.

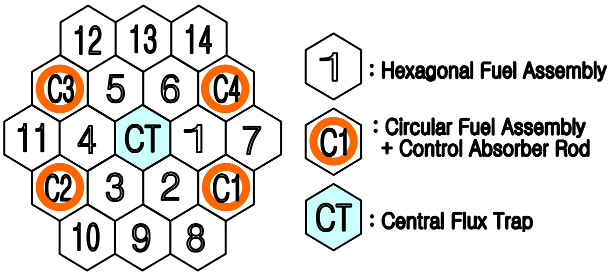

Fig. 2. Core Layout

2.3 Results

The maximum unperturbed thermal neutron flux levels (<0.625eV) at the core and reflector regions are estimated to be about 5.0E14 & 4.3E14 n/cm^2/sec, respectively. The thermal neutron flux distribution is shown in Fig. 3. The fast neutron flux (>1.0MeV) in the central flux trap is estimated to be about 1.7E14 n/cm^2/sec.

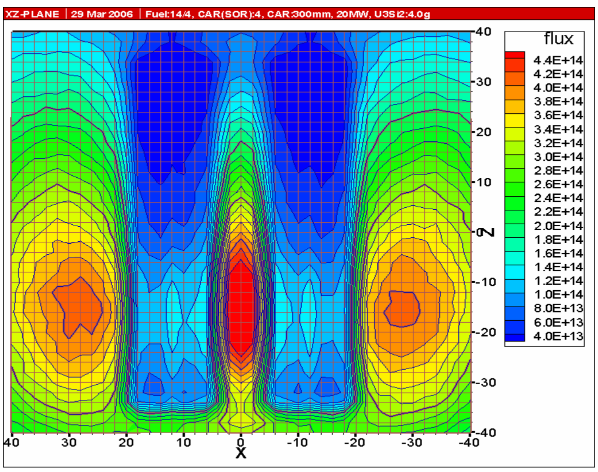

Fig. 3. Thermal Neutron Flux Profile (XZ Plane)

The partially inserted CARs cause the peak linear power to become larger. The peak powers were evaluated over all CARs insertion depths. At the Beginning Of Cycle (BOC), the peak linear power was estimated to be 118.6 kW/m and the total peaking factor was 2.54. The flux levels and the peaking factor were estimated for the fresh clean core. In the equilibrium core, the flux levels become higher and the peaking factor will become lower.

The core excess reactivity up to 123 mk will be provided at the BOC to compensate for xenon, temperature, power, xenon override, fuel burn-up and experimental irradiation loads. The excess reactivity is obtained by loading three new hexagonal fuel assemblies and one circular fuel assembly. The core excess reactivity at the End of Cycle (EOC) will be about 50 mk. The total reactivity worth of CARs is about 205 mk and it meets the shutdown margin at the BOC of the equilibrium core. It is estimated that the reactor can operate at 20 MW without a refueling for 50 days. Regardless of the very long cycle length, the moving span of the CARs was shorter than that of HANARO. The average burn-up values in the equilibrium core at BOC and EOC were about 23 and 35%U-235, respectively. The average discharge burn-up of the fuel assemblies is about 54%U-235.

3. Conclusion

Based on the experiences of the HANARO construction and operation, we succeeded in obtaining a conceptual core with a high performance. This conceptual core provides high fast and thermal flux at the experimental sites. The thermal flux level is the highest among the reactors using the low enriched uranium fuel with a 20 MW power. The cycle length is very long when compared with 28 days of HANARO. The average discharge burn-up is high enough too. The long cycle length and the high discharge burn-up will provide us with a high economic benefit. This core design is based on proven technology through HANARO in principle. We also adopt some new ideas for which we do not have enough experience. We should qualify the 4.0 gU/cc U_3Si_2-Al fuel and test the improved concepts about the core structures. The reactor physics design should be in progress further.

Acknowledgements

This work has been carried out under the nuclear research and development program by MOST.

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