Effect of Reflector Material on the Neutronic Characteristics of the Small Sodium-cooled Fast Reactor

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1. Introduction

The sodium-cooled fast reactor (SFR) has been chosen as a candidate for the Gen-IV Nuclear Energy Systems Initiative due to the advantages in utilization of uranium resources and reduction of radioactive wastes. Recently, the uranium blanket concept is omitted for a purpose of the non-proliferation, hence the reflector material plays a more important role in reactor core design. Moreover, especially in the Korean prototype SFR, the initial core should startup with low-enriched uranium (≤ 20 w/o) for 100 ~ 150 MWe power. This restriction causes significant difficulties to achieve sufficient excess reactivity. Thus, in this paper, core characteristic studies of various reflector materials (HT9, BeO, MgO, and $ZrH_{1.6}$) [1] are performed to enhance the initial core excess reactivity.

2. Characteristic Studies of the Small SFR Core

The small SFR core [2] is composed of a single type fuel assembly with the pitch of 13.307 cm and 0.37 cm in fuel pin radius. The detailed configurations are shown in Fig. 1.

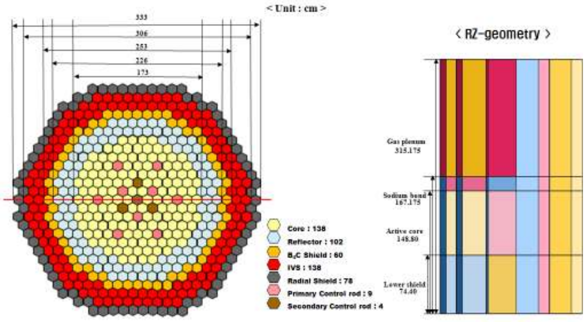

Fig. 1. The configurations of the 100MWe small SFR core

The small SFR core was modeled as both heterogeneous and homogeneous configurations by using MCNP5 and TWODANT code, respectively. The MCNP calculation was carried out with pin-by-pin description of assembly with ENDF/B-VII.0 library. The change of excess reactivity was investigated by replacing reference the reflector material (HT9) to alternative ones, BeO, MgO, and $ZrH_{1.6}$. The MCNP5 results were also compared with 150-group TRANSX/TWODANT [4] results and shown in the Table I.

Table I: The eigenvalues with various reflector materials

Reflector	Reference HT9	MgO	BeO	$ZrH_{1.6}$
MCNP5 (Hetero.)	1.08360 0.00005*	1.10845 0.00006	1.10908 0.00005	1.06287 0.00005
TWODANT (Homo.)	1.07647	1.10469	1.11077	1.06351

*: 1 standard deviation of eigenvalue

The TWODANT calculation tends to underestimate the eigenvalue for the reference reflector (HT9) compared with that of MCNP5 while its difference decreases for the MgO reflector and is reversed for the BeO and ZrH reflectors. The discrepancies of neutron spectrums between the outermost fuel assembly and reference assembly (innermost fuel assembly with reference HT9 reflector) are shown in the Figs 2.

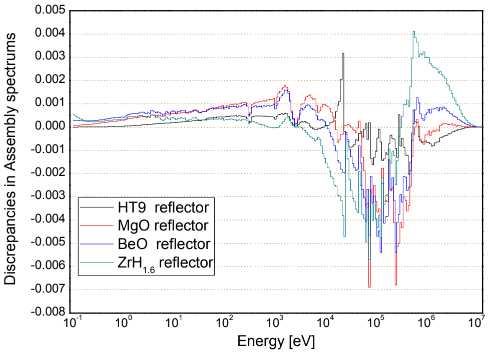

Fig. 2. The discrepancies of neutron spectrum between outermost fuel assembly and reference assembly

The $ZrH_{1.6}$ reflector shows the most soft spectrum in the peripheral fuel assembly and the spectrum softening effects are decreased in other BeO, MgO, and HT9 reflectors, respectively. Since the 150-group cross section library was weighted by the fast neutron spectrum in the NJOY process, the TWODANT results tends to overestimate eigenvalues as the neutron spectrum gets soften, especially for the BeO and ZrH reflectors. The discrepancies in neutron spectrum with respect to the assembly locations are shown in the Figs 3. The spectrum softening effect due to the MgO reflector is negligible in the inner layer fuel assemblies.

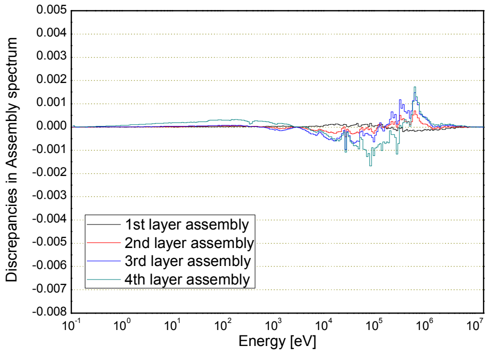

Fig. 3. The neutron spectrum discrepancies vs. reference assembly spectrum

The pin power distributions in the outermost fuel assemblies according to the reflectors are shown in Fig. 4 to Fig. 7.

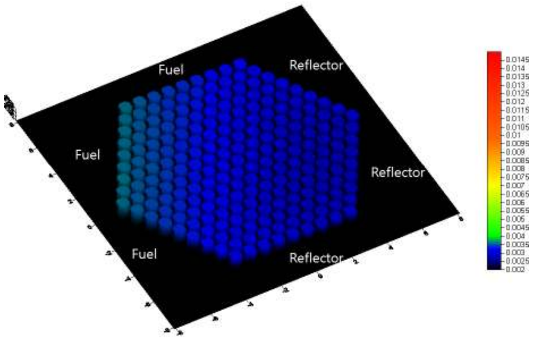

Fig. 4. The pin power distribution in the 5th layer fuel assembly with HT9 reflector

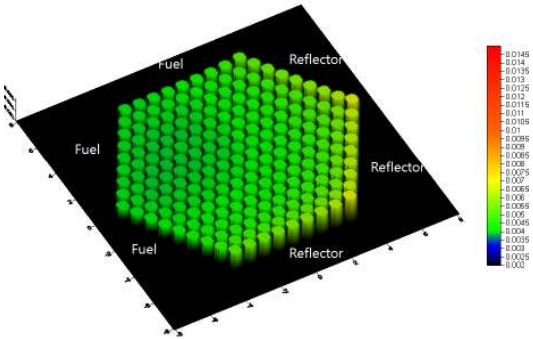

Fig. 5. The pin power distribution in the 5th layer fuel assembly with MgO reflector

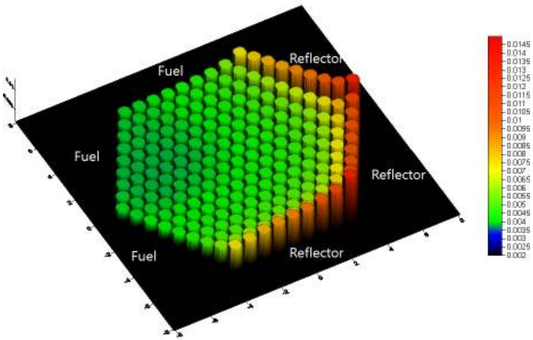

Fig. 6. The pin power distribution in the 5th layer fuel assembly with BeO reflector

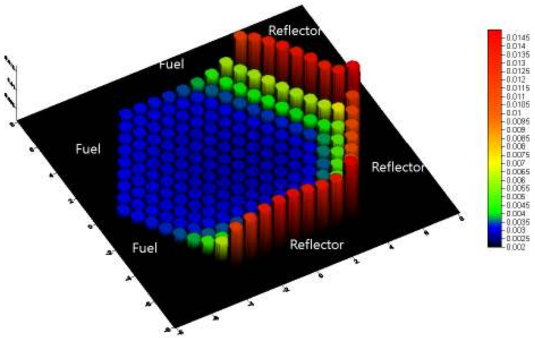

Fig. 7. The pin power distribution in the 5th layer fuel assembly with $ZrH_{1.6}$ reflector

The peak pin power factors within the outermost fuel assembly are 1.153, 1.536, 2.516, and 3.649 for HT9, MgO, BeO, and $ZrH_{1.6}$ reflectors, respectively.

3. Conclusions

The effect of reflector material on the core characteristic was investigated in aspects of the core eigenvalues and pin power distribution. By the change of reflector material from HT9 to MgO, the excess reactivity gain (~2500 pcm) can be achieved. However, the softer neutron spectrum in the peripheral fuel assemblies cause drastic increase of pin power and those are more significant as the slowing down power is increased. The MgO reflector showed less softened neutron spectrum (softened to the epithermal range) in the peripheral fuel assemblies, hence showed acceptable pin power peaking while taking 2485 pcm excess reactivity.

For reflector materials tested, the neutron spectrum in the inner core region (core region without last layer fuel assembly) did not show meaningful changes, in other words, the core characteristics would not change significantly.

The optimization of reflector materials and its configurations is planned as a further study.

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