Burnup analysis of Rotational Fuel-shuffling Breed-and-Burn fast reactor with lead-bismuth coolant

*Xucheng Zhao[1], Jun Nishiyama[1], Toru Obara[1]

[1]Laboratory for Zero-Carbon Energy, Institute of Innovative Research, Tokyo Institute of Technology, Ookayama 2-12-1-N1-19, Meguro-ku, Tokyo 152-8550, Japan

Abstract

The purpose of the study was to clarify the feasibility of lead-bismuth cooled rotational fuel-shuffling reactor (RFBB) with nitride fuel by analyzing for equilibrium burning conditions. The SERPENT code with ENDF/B-VII nuclear data library was used to perform the neutron transport calculation and burnup calculation in this study. The results showed that the 750 MW RFBB core attained criticality at the equilibrium state and the maximum DPA of discharged fuel is 656 dpa.

Keywords: RFBB, nitride fuel, lead-bismuth coolant, Breed-and-burn fast reactor

1. Introduction

Small Breed-and-Burn fast reactor(B&B) uses natural uranium or depleted uranium as fuel, fissile material is produced in the core and consumed by itself, and a lot of energy from a small amount of uranium. Compare with other types of reactor cores, the B&B fast reactor is hard to maintain criticality. To use natural uranium resources effectively without reprocessing facility, the concept of rotational fuel shuffling Breed-and-Burn fast reactor (RFBB) has been proposed [1]. The purpose of the study is to clarify the feasibility of lead-bismuth cooled nitride fuel RFBB.

2. Methodology

Table.1 shows the core design in the preliminary analysis. Natural uranium fuel is loaded in the initial core, and the burning and shuffling were repeated until the burning becomes an equilibrium condition. The calculation was performed by using SERPENT 2.1 code with ENDF-B/VII nuclear data library. The rotational shuffling strategy is treated by the Python program. The concept is that natural uranium is loaded from the periphery region and moved toward the center along a zigzag path, then discharged at the center of the core.

Table 1 Core design parameters

Parameter	Value
Fuel type	N15 isotope 99% enriched UN(UN99)
Cladding material	ODS
Coolant	LBE
Number fuel assemblies	168+1(coolant channel)
Fuel pins in an assembly	271
Radius of fuel[cm]	0.45
Outer radius of cladding[cm]	0.51
Pin pitch[cm]	1.2
Assembly pitch[cm]	20.09
Core active height[cm]	140
Core equivalent radius[cm]	133
Smear density of fuel	85%
Average fuel temperature[K]	800
Average cladding temperature[K]	700
Average coolant temperature[K]	700
Top and bottom thickness of reflector[m]	1
Outer radius of reflector[m]	1.5
Reflector material	LBE

3. Results and discussion

The change of k_{eff} in the equilibrium states is 1.003 which is an almost constant value, the reactor can be operated at critical in the equilibrium condition, and the radial distribution power density at Beginning Of the Equilibrium Cycle(BOEC) and End Of the Equilibrium Cycle(EOEC) are almost unchanged. It can be seen from the results that there is not much difference between the average neutron flux and average power density of the BOEC and EOEC. The maximum DPA of discharged fuel is 656. The results show the RFBB with nitride fuel and LBE coolant is feasible from the neutronic point of view.

4. Conclusion

The neutronic analysis was performed for 750MW RFBB-NLB. The reactor can be critical in the equilibrium burning condition with high discharge burnup.

Reference

[1] T. Obara, K. Kuwagaki, J. Nishiyama, *Proc. of FR17*, IAEA-CN245-051(2017)