Introduction of Rock-like Oxide fuel in PBR with accumulative fuel loading scheme

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A rock-like oxide (ROX) fuel was introduced in PBR with accumulative fuel loading scheme to improve stability of spent fuel under geological disposal. The core with ROX fuel showed high discharged burnup of 198 GWd/t could be achieved but the core lifetime decrease to around 6.6 years. In addition, to satisfy the safety requirement, a negative temperature coefficient was achieved for ROX fuel throughout the operation period.

Keywords: Pebble bed reactor, accumulative fuel loading scheme, rock-like oxide fuel, high discharged burnup.

1. Introduction

Pebble Bed Reactor (PBR) is one of the candidates for the future nuclear power plant. In this study, PBR with accumulative fuel loading scheme was introduced. At the startup the reactor starts with a large cavity in the core, and pebble ball fuel is loaded continuously little by little until the pebble ball reach the top of the core. A ROX fuel as a once-through type fuel concept was introduced in this reactor type. ROX fuel has several advantages, such as the high stability and easier management for direct geological disposal without reprocessing process. However, the fissile density of ROX fuel is about five times lower than that of UO_2 fuel. In this study, YSZ single-phase, which is one of the candidates of ROX fuel, has been chosen as the fuel in the fuel kernel.

2. Calculation Method

In this study, MVP/MVP-BURN [1] and JENDL-4.0 were used for burnup calculation. A new code based on Fortran Languge has been developed to treat the accumulative fuel loading scheme [2]. Specification of reactor parameter is shown in Table 1. Initial core height was set to 260 cm to accommodate the average power density of 6W/cm^3. Fresh fuel will be added into the core with a stepwise procedure and the calculation will be finished after the fresh fuel reach the top of the core.

Table 1. Specification of reactor and fuel geometry

Parameter	Value
Reactor power (MWt)	110
Core radius (cm)	150
Core height (cm)	1000
Thickness of reflector (cm)	100
Radius of pebble ball (cm)	3.0
Radius of fuel zone (cm)	2.5
Thickness of matrix zone (cm)	0.5
Radius of fuel kernel (cm)	0.03
TRISO layer	Buffer/I-PyC/SiC/O-PyC
Thickness (μm)	60/30/25/45
Kernel density of ROX (g/cm^3)	6.55
YSZ fuel composition	
YSZ (% mol)	81.75
UO_2 (% mol)	18.25

3. Results

The optimum fuel composition of ROX fuel was 5-g HM/pebble with 20% ^{235}U enrichment. With the same amount of HM/pebble, a number of CFPs per pebble ball in ROX fuel are larger than those in UO_2 fuel. The core lifetime can be achieved up to 8.4 years with the average discharged burnup was 178 GWd/t. The maximum power per ball was around 3 kW/pebble, which is much lower than the limit. However, large excess reactivity occurred in the BOL condition. In this study, there are two parameters to suppress the excess reactivity. First, using low enriched uranium at the beginning condition. The uranium enrichment was decreased from 20% to 4.65% to maintain the *keff* at an initial condition almost equal to unity. The other way is by applying the B_4C as burnable poison particles in the initial condition. The results show, reducing the uranium enrichment is more effective to suppress the initial excess reactivity than using burnable poison particles. However, the operation period and discharged burnup could be lower by applying the low enriched uranium.

4. Conclusion

A high discharged burnup could be achieve using ROX fuel in PBR with accumulative fuel loading scheme. The initial excess reactivity was solved using low enriched uranium and burnable poison particle. There are advantages and disadvantages of these two solutions.

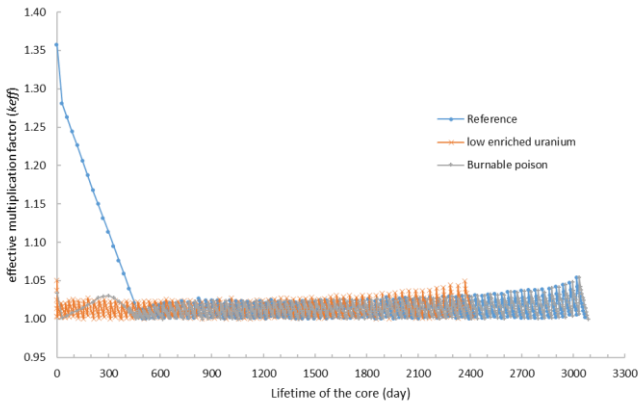

Fig 1. Change of *keff* of Small PBR with accumulative fuel loading scheme using ROX fuel

References

[1] Y.Nagaya et al.," General purpose of Monte Carlo Codes for Neutron and Proton Transport Calculations based on Continuous Energy and Multigroup Method",Japan Atomic Energy Agency, Japan (2004).

[2] Dwi Irwanto and Toru OBARA., Journal of Nuclear Science and Technology., Vol.48, No.11, pp 1385-1395 (2012).