Transmutation Performance of 300MWe PEACER

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1. Introduction

A new fast reactor concept - PEACER (Proliferation-resistant, Environment-friendly, Accident-tolerant, Continual energy producing, and Economical Reactor) have been studied by NUTRECK (Nuclear Transmutation energy REsearch Center of Korea).[1] Primary design goals of this reactor are transmutation of long-lived minor actinides (LLMA) and long-lived fission products (LLFP) and enhancement of proliferation resistance potential.

The first design core of PEACER named by PEACER-550 had 1,560 MWt(550 MWe) power rate and consisted of square lattice fuel assemblies with 14 by 14 fuel pins. Resulting neutronic parameters of this core were acceptable in the aspect of level of reactivity swing, transmutation ability and maximum pin power peaking.[2] However, three modification of reactor design was tried to improve thermal safety margins of PEACER-550 core. For increasing thermal margin of (U,TRU)10%Zr metallic fuel on melting point, core size was reduced as reactor power rate was decreased from 1,560 MWt to 850 MWt(300MWe). Fuel pin size was also reduced by changing lattice array from 14 by 14 to 17 by 17. In order to ensure natural circulation ability under long-term cooling, a water pad cooling system was attached on reactor vessel surface.

The purpose of this paper is a transmutation assessment of the second core design, PEACER-300. The general performance of PEACER-300 core was analyzed by REBUS-3 code system and MONTEBURNS. [3,4]

2. Analysis of PEACER-300 core design

In order to completely transmute LLMA and LLFP reprocessed from PWR spent fuel and spent fuels within a closed cycle, it was assumed that all of uranium, TRU and LLFP be reprocessed and burnt again infinitely within a collocated reprocessing plant. Any uranium and TRU were not discharged from PEACER Park except process tails unrecovered from pyro-reprocessing.[5,6] The PEACER-300 core consisted of LLFP target assemblies, inner core, middle core, outer core, radial reflector and shield as shown in Fig. 1. The shape of core is very flat like a pancake, height is 0.5 meter and radius is about 3 meter.

For an equilibrium cycle simulated by REBUS-3, the excess reactivity was about 3% $\Delta k/k$ at the BOC with annual refueling period at 3 batch cycle. A sufficient shutdown margin could be guaranteed by 20 control assemblies which containing B_4C absorber in the same geometry with fuel assemblies.

Fig. 1. 1/4 Core configuration of PEACER-300

Relative pin power distribution was calculated by MCNP4c2 with corresponding composition densities. Maximum pin peaking was about 1.5. As a preliminary verification process, calculation results from REBUS-3 were compared with those from MCNP4c2 and they agreed well each other within 2 % errors. The effective delayed neutron fraction was also calculated using the MCNP option to turn off the effect of delayed neutrons on criticality.

3. Transmutation ability of PEACER-300 core

3.1 Minor Actinide Transmutation

Fuel cycle strategy used at REBUS-3 calculation was configured as shown Fig. 2. All isotopes of fuel materials were burnt repeatedly in this strategy and loss amounts of fission product produced by depletion and unrecoved actinide from pyro-processing were only fed from LWR spent fuels.

In an equilibrium state, the transmutation capability of PEACER-300 core was assessed by subtracting the amounts of TRU in a discharged fuel by the amount in a fresh fuel. Although reactor size was reduced from PEACER-550, support ratio (SR) of LLMA was maintained over 2.0.

Table 1. Performance characteristics of PEACER-300

		BOEC	EOEC
Multiplication factor		1.03944	1.00094
Effective delayed neutron fraction		0.00329	0.00283
Control rod worth (All rods in)		6.52%	6.82%
Maximum pin power peaking		1.567	1.583
Support Ratio	TRU	2.013	
	LLFP	2.340	

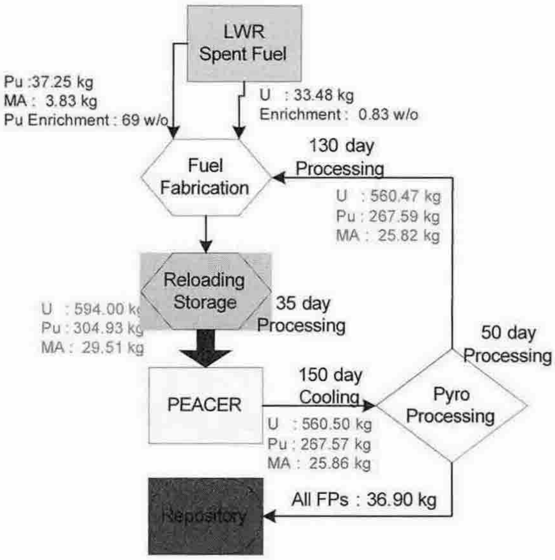

Fig. 2. Fuel mass changes in closed fuel cycle stream

3.2 Long-Lived Fission Products Transmutation

Because of larger capture cross-section of LLFP isotopes, well-thermalized neutron spectrum was profitable to incinerate LLFPs such as Tc-99 and I-129.[7] For transmutation of LLFP, Tc/I target assemblies thermalized by ZrH_2 moderator were adopted in PEACER-300 core design. MONTEBURNS code was used in SR calculation of LLFP because of inconsistency of cross section library used in REBUS-3 system under the thermal spectrum. In the case of 20 Tc/I target assemblies in PEACER-300 core, SR of LLFP was also acquired over 2.0.

4. Conclusion

In this paper the possibility of PEACER core was estimated as a fast reactor transmuter for long-lived radiotoxic isotopes. It was confirmed that PEACER-300 had a good transmutation capability with 2.013, 2.340 of SR about TRU and LLFP respectively. PEACER-300 core also had a sufficient shutdown margin at any point of equilibrium cycle and a equivalent maximum pin power peaking with PEACER-550.

Acknowledgement

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