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TRU Transmutation Core Design of KALIMER-600

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1. Introduction

In the early stage of development of fast reactor, main purpose was the economical use of uranium resource but nowadays in addition to the maximum use of uranium resource, the transmutation of the high level radioactive waste is taken an interest for the harmony of environment. It also is estimated that the low and intermediate level radioactive waste storage of our country will be full in 2008. To resolve these problems, transmutation using the fast reactor is considered as a promise option.

In this paper, the conversion of KALIMER-600 core into burner is performed and evaluated. For this, we tried to maintain the fuel design of the KALIMER-600 breakeven as much as possible and to increase the number of the non fuel rods to reduce the breeding ratio.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

For this study, the KALIMER-600 (Korea Advanced Liquid Metal Cooled Reactor) having the breakeven breeding characteristics[1] is used as a reference core. In the KALIMER-600 core design, the power peaking control under single enrichment fuel was achieved by the special fuel assembly designs where non-fuel rods such as moderator rods, B_4C absorber rods, and neutron streaming tubes are used to replace some of fuel rods.

In this study of transmutation core, the neutron streaming tubes and moderator rods are removed while the B_4C absorber rods are added to control power peaking. The reduction of the breeding ratio in order to increase the transmutation rate is done by increasing the number of B_4C absorber rods

Table 1 summarizes the basic design parameters used in the transmutation core. The hexagonal driver fuel assembly consists of 271 rods within a duct wrapper. The rod outer diameter is 0.85cm and the wire wrap diameter is 0.14mm. The duct wall thickness is 3.7mm and the gap distance between ducts is 4mm. These design values give the assembly pitch of 17.878cm. Figure 1 shows the selected core configuration. The core configuration is a radially homogeneous one that incorporates annular rings with a single enrichment. The active core consists of three driver fuel regions (i.e., inner, middle, outer core regions) and three annular core regions have 114, 114, and 108 fuel assemblies, respectively. To suppress the power peaking factor and reduce the breeding ratio, 57 B_4C absorber rods are introduced in the inner core and 39 B_4C absorber rods are applied to the middle core. In the outer core, 27 B_4C absorber rods are introduced.

Table 1. Basic Design Parameters

Parameters	Design value
Fuel type	TRU-U-10Zr
Number of rods/FA	271
Number of fuel rods/FA (Inner/middle/outer core)	(214/232/244)
Number of moderator rods/FA (Inner/middle/outer core)	(57/39/27)
B_4C region height (cm)	58.8
Structural material	HT-9M
Active core height (cm, hot(cold))	105(100)
Assembly pitch (cm)	17.88
Rod outer diameter (mm)	8.5
Cladding thickness (mm)	0.53
Pin pitch (mm)	10
Pin P/D ratio	1.176

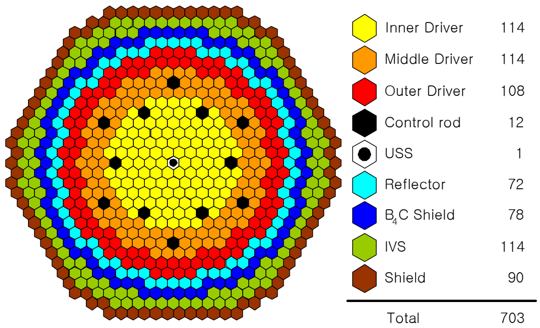

Figure 1 Core configuration

2.2 Core Performance Analysis Results

The REBUS-3[2] equilibrium model with a nine group cross section was used to perform the core depletion analysis. The cycle length is 517EFPD and the refueling interval is 20months with a capacity factor of 85%. The 5 batch fuel management scheme is used to increase the fuel discharge burnup.

Table 2 shows the summary of the core performance analysis results. The burnup reactivity swing and the conversion ratio over one cycle were estimated to be 1401pcm and 0.766, respectively. This relatively large value of burnup reactivity swing is due to the small breeding. The average fuel discharge burnup was estimated to be 86MWD/kg and this core can transmute 265kg/cycle of TRU that corresponds to the TRU amount produced from one LWR of the same power. The uranium consumption rate was estimated to be 550kg/cycle.

Table 2. Summary of the core performances

Performance parameter	Value
Refueling intervals (EFPD)	517
Average conversion ratio	0.766
Burnup reactivity swing (pcm)	1401
Number of fuel management batches	5
Average discharge burnup (MWD/kg)	86.1
Peak discharge burnup (MWD/kg)	113.8
Average TRU wt% in HM BOEC/EOEC	23.9/23.7
Pu inventory (kg, BOEC/EOEC)	7360/7128
MA inventory (kg, BOEC/EOEC)	857/825
HM inventory (kg, BOEC/EOEC)	34407/33592
TRU consumption rate (kg/cycle)	264.7
U consumption rate (kg/cycle)	549.9
Supporting ratio	~1.2
Average power density (W/cc)	152.4
Average linear heat rate (W/cm, BOEC)	186.6
Peak linear heat rate (W/cm, BOEC)	245.5
Peak fast neutron fluence (n/cm^2)	3.01x10^{23}

The peak discharge fast fluence is estimated to satisfy the design limit of 4.0x10^{23}. The average linear power rate is 186.6W/cm and the peak linear power of 245.5W/cm occurs in the BOEC. The average TRU content in the heavy metal (HM) of the fuel is maintained below 30wt%.

Table 3. Inventories(kg) of the heavy metal isotopes

Isotopes	BOEC	EOEC	Increase
^{234}U	49.4	48.7	0.7
^{235}U	18.8	17.7	1.1
^{236}U	16.7	16.7	0.0
^{238}U	26104.0	25555.9	548.1
Total U	26188.8	25638.9	549.9
^{238}Pu	247.9	243.8	4.1
^{239}Pu	3762.3	3627.8	134.5
^{240}Pu	2459.5	2405.2	54.3
^{241}Pu	401.7	372.9	28.8
^{242}Pu	489.2	478.8	10.4
Fissle Pu	4164.0	4000.7	163.3
Total Pu	7360.6	7128.6	232.0
^{237}Np	154.0	139.7	14.2
^{241}Am	320.5	306.7	13.8
^{242m}Am	22.1	22.1	0.0
^{243}Am	188.1	181.4	6.7
^{242}Cm	7.2	9.2	-2.0
^{243}Cm	0.6	0.6	0.0
^{244}Cm	113.7	113.9	-0.2
^{245}Cm	34.3	34.1	0.1
^{246}Cm	17.5	17.5	0.0
Total MA	857.9	825.2	32.7

Table 3 shows the inventories of the heavy metal isotopes at BOEC and EOEC and an increase(EOEC-BOEC). As shown in Table 3, the changes of the Pu and MA inventories over a cycle are considerable. For uranium, the inventories are decreased by 550 kg which are caused mainly by conversion ^{238}U to ^{239}Pu. The amount of transmuted uranium is externally supplied with the depleted uranium. For the plutonium isotopes, the total plutonium inventories were decreased by 232kg. The inventories of all the plutonium were decreased. For the minor actinide isotopes, the total minor actinide inventories were decreased by 32.7kg. The most mass of the isotopes were decreased but the isotope ^{242}Cm, ^{243}Cm and ^{244}Cm is increased a little bit.

3. Conclusion

In this paper, the conversion of KALIMER-600 core into burner is performed and evaluated. For this, we tried to maintain the fuel design of the KALIMER-600 breakeven as much as possible and to increase the number of the non fuel rods to reduce the breeding ratio. The core performance analysis results show that the transmutation core has its TRU supporting ratio of ~1.2 that corresponds to the TRU amount produced from one LWR of the same power.

Acknowledgement

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[2] B. J. TOPPEL, "A User's Guide for the REBUS-3 Fuel Cycle Analysis Capability," ANL Report, Argonne National Laboratory 83-2, March (1983).