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Small Modular PWR Design for TRU Recycling with McCARD-MASTER Two-Step Procedure

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ABSTRACT

In our previous study, a small modular PWR core was designed for TRU (Transuranics) recycling with multi-recycling scheme with a typical two-step procedure using DeCART2D/MASTER code system in which the lattice analysis for producing homogenized group constant was performed by DeCART2D while whole core analysis was conducted by MASTER code. However, the neutron spectrum hardening of the LWR core loaded with TRU requires validating the multi-group cross section library and resonance self-shielding treatment method in lattice calculation. In this study, a new procedure using McCARD/MASTER was used to analyze the SMR core, in which the lattice calculation was performed by a Monte Carlo code called McCARD with a continuous energy library to generate homogenized two-group assembly cross sections. The SMR core analysis was performed to show neutronic characteristics and TRU mass flow in the SMR core with TRU multi-recycling. The result shows that the analyses on the neutronic characteristics and TRU mass flow using the McCARD/MASTER code system showed good agreement with the previous ones using the DeCART2D/MASTER code system. The neutronic characteristics of each cycle of the core satisfied the typical limit of a commercial PWR core and the SMR core consumes effectively TRU with net TRU consumption rates of 8.46~14.33 %.

KEYWORDS: McCARD/MASTER, small modular PWR, TRU multi-recycling

1. INTRODUCTION

Nowadays, one of the most important issues in nuclear industry is safe management and disposal of spent nuclear fuel which contains high level radioactive materials. Several concepts such as CORAIL (COmbustible Recyclage AILot), and CONFU (COmbined NonFertile and Uranium) have been suggested to reduce the inventory and radiotoxicity of spent nuclear fuel by recycling TRUs in PWRs [1-4]. Recently, we have studied the TRU transmutation with a multi-recycling scheme in small modular LWR core [5-7]. Especially, a specialized fuel assembly composed of MOX (Mixed OXide) and FCM (Fully Ceramic Micro-encapsulated) fuel rods was suggested to effectively consume TRUs. With this fuel assembly, the amount of consumed TRU was considerably larger than the amount of produced TRU during depletion. In this concept, only TRU in MOX rod was recycled while the TRU in FCM rod was not recycled due to its high burnup (i.e., high TRU consumption) [5-7]. In the previous study, a deterministic two-step procedure with DeCART2D/MASTER codes was used for the small modular LWR core analysis with multi-recycling of TRU. DeCARD2D [8] has been developed at Korea Atomic Energy

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Research Institute (KAERI) for generating few group homogenized neutron cross section data, which solves transport equation by using MOC with the 47 group flux-weighted neutron cross section library based on ENDF.B-VII.r1. The whole core analysis was performed by MASTER [9] which is the nodal diffusion core analysis code developed at KAERI. When TRU nuclides are loaded in LWR core, which makes the neutron spectrum hardened due to high thermal absorption of TRU, it is needed to validate and verify the multi-group cross section library and resonance self-shielding treatment method in the lattice calculations. In this study, the small modular LWR core analysis was performed by a new two-step procedure with McCARD/MASTER codes in which the few group homogenized fuel assembly cross sections are produced with Monte Carlo depletion calculations and continuous energy cross sections. In this work, we performed the detailed neutronic analysis on the PWR-based SMR core.

2. COMPUTATIONAL METHODS

In this study, two-step procedure was used for analyzing neutronic characteristics of the small modular LWR core with TRU multi-recycling scheme. The lattice calculation for producing few group homogenized neutron cross section data was performed by a Monte Calro code called McCARD [10] in which the few group homogenized fuel assembly cross sections are produced with the continuous energy library. In the calculation using McCARD, the number of particles per cycle and cycles were set to 10,000 and 120 (20 inactive cycle, and 100 active cycle) such that the standard deviation of infinite multiplication factor was within 80 pcm. The whole core analysis was performed by MASTER [9] which has been developed for nuclear analysis and core design using multi-group nodal diffusion methods. The initial TRU feed composition for FCM and MOX fuels corresponds to the PWR spent fuel having 50 MWD/kg burnup and 10 years cooling. Table I shows the initial composition of each TRU nuclides. In this study, the TRU recycling in the SMR core was modeled using a coupling of McCARD, MASTER, and ORIGEN2 [11]. After the depletion calculation of the core using MASTER for each cycle, the average discharge burnups for the discharged fuel assemblies were used in McCARD fuel assembly calculations to estimate the composition of the fuel assemblies and then ORGEN2 were used to determine the TRU composition after cooling time. We assumed a 7 years cooling before loading into the core after discharge and reprocessing including fuel fabrication. Then, new TRU compositions are used in McCARD calculations for the homogenized cross section of the new fuel assemblies which are to be loaded in the core for the next cycle.

Table I. Initial TRU composition corresponding to burnup of 50 MWD/kg and cooling time of 10 years

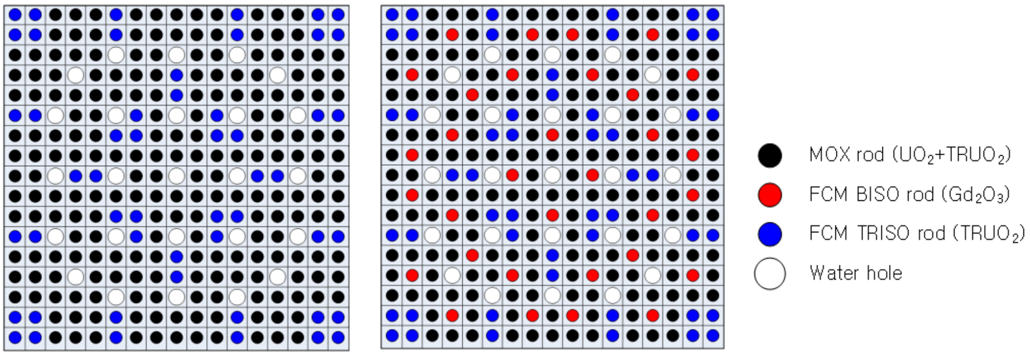
TRU nuclides	Composition (wt%)
NP237	6.92976
PU238	2.52569
PU239	46.24361
PU240	18.16532
PU241	9.99770
PU242	7.22376
AM241	6.60611
AM242M	0.01900
AM243	1.79111
CM242	0.00005
CM243	0.00535
CM244	0.45795
CM245	0.03028
CM246	0.00431
Total	100.00

3. DESIGN AND ANALYSIS OF FUEL ASSEMBLY

Table II shows the design features of the fuel assemblies composed of MOX rods and FCM. The fuel assemblies were designed based on WH 17×17 fuel assembly. There are four types of fuel assemblies having different amount of burnable absorbers. The B0 fuel assembly having no burnable absorber consists of 212 MOX rods and 52 FCM TRISO rods. The B1^B3 fuel assemblies are loaded with the burnable absorber of FCM BISO particle having Gd_2O_3 kernel. In these fuel assemblies, 32 MOX rods are replaced with FCM BISO rods in order to reduce the amount of initial HM (Heavy Metal) loading, which results in neutron spectrum softening and improving the effectiveness of burnable absorber. The packing fractions of BISO particles vary from 2 to 18%. In MOX rods, the fuel pellets are composed of UO_2-7.31 wt% $TRUO_2$-2.50 wt% Mo. The 4.95 wt% enriched uranium was used in the MOX fuels. Molybdenum is admixed in pellets in order to have the accident tolerance by improving the thermal conductivity and fission product retention capability of the pellets [12]. In FCM TRISO rods, the kernel consists of only $TRUO_2$ for deep burning of TRU nuclides. The pellet densities for MOX and FCM TRISO rod fuels were determined based on the 96% TD of UO_2 fuel. The configuration of the fuel assemblies are depicted in Fig. 1.

Table II. Design specifications of the fuel assemblies composed of MOX rods and FCM rods

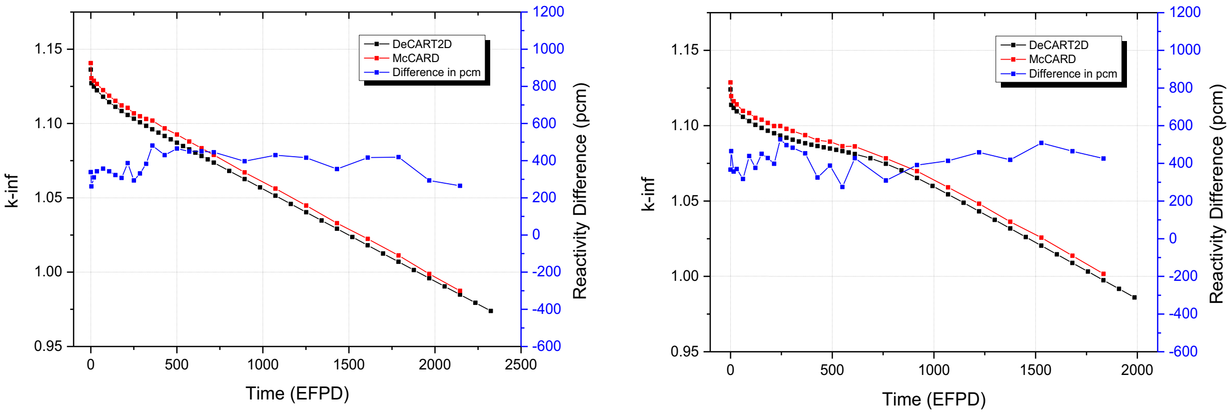
Parameter	B0	B1	B2	B3
Rod array	17×17			
Pellet radius (cm)	0.4095			
Clad. thickness (cm)	0.0655			
Rod diameter (cm)	0.95			
Clad. material	Zircaloy-4			
Pin pitch (cm)	1.2234			
Assembly pitch (cm)	20.879			
Pitch to diameter ratio	1.288			
MOX rod				
The number of rods	212	180		
Pellet material	UO_2–$TRUO_2$ (7.31 wt%)–Mo (2.5 wt%)			
U enrichment (wt%)	4.95			
Density (g/cm^3)	10.392			
FCM TRISO rod	-			
The number of rods	52	52		
Kernel material	$TRUO_2$			
Density (g/cm^3)	10.430			
Kernel diameter (μm)	800			
Buffer thickness (μm)	80			
IPyC thickness (μm)	20			
SiC thickness (μm)	35			
OPyC thickness (μm)	20			
Packing fraction (%)	40			
FCM BISO rod	-			
The number of rods	0	32		
Kernel material	-	Gd_2O_3		
Kernel diameter (μm)	-	500		
Buffer thickness (μm)	-	18		
OPyC thickness (μm)	-	23		
Packing fraction (%)	-	2	18	20



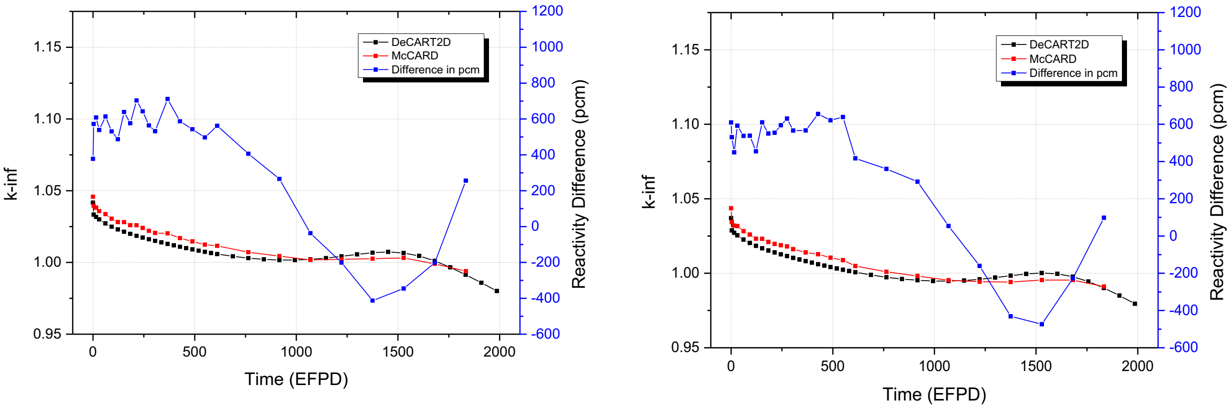
(a) B0 **(b) B1-B3**

Figure 1. Configuration of the 17×17 fuel assemblies composed of MOX rods and FCM rods

Figure 2 compares the evolutions of the infinite multiplication factors (k_{inf}) calculated by DeCART2D and McCARD for each fuel assembly. As shown in the figure, all the k_{inf} values calculated by McCARD are estimated to be large than those of DeCART2D at BOC. The differences of the reactivity at BOC between DeCART2D and McCARD were 338 pcm, 366 pcm, 378 pcm and 610 pcm for B0, B1, B2 and B3 fuel assemblies, respectively. That is, the reactivity difference at BOC increases as the amount of burnable absorber increases. The comparison of the k_{inf} values calculated by DeCART2D and McCARD shows a good agreement each other throughout all the burnup steps.



(a) B0 fuel assembly (b) B1 fuel assembly



(c) B2 fuel assembly (d) B3 fuel assembly

Figure 2. Comparison of the infinite multiplication factors (k_{inf}) for the B0, B1, B2 and B3 fuel assemblies calculated by McCARD and DeCART2D

The excess reactivity was effectively controlled by the Gd_2O_3 burnable absorber in FCM BISO rods. Especially, the B2 and B3 fuel assemblies have extremely low excess reactivity during depletion due to the loading of large amount of Gd_2O_3 burnable absorber. They were loaded in the SMR core in order to flatten the power distribution in the core. Although the B3 fuel assembly has a negative reactivity after 800 EFPD, the degradation of cycle length is minimized by loading a small number of these type fuel assemblies into appropriate positions in the core. Figure 3 shows the comparison of MTCs of the B0, B1, B2 and B3 fuel assemblies calculated by McCARD. The MTCs were estimated to be less negative as the amount of burnable absorber increases. All of the MTCs were shown to be within the comparable range of commercial PWRs.

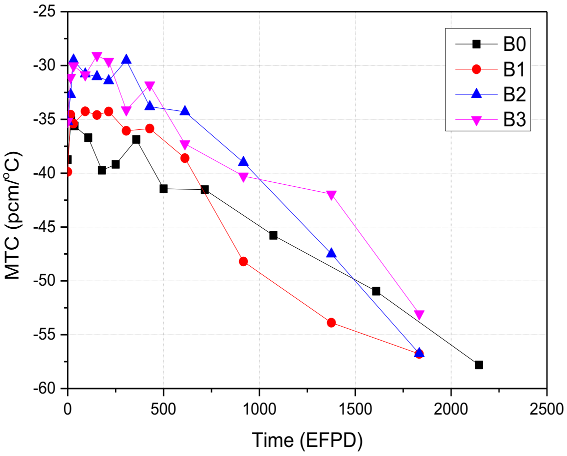


Figure 3. Comparison of the moderator temperature coefficients (MTC) of the fuel assemblies calculated by McCARD

4. SMR CORE DESIGN AND ANALYSIS

The SMR core has the power rate of 330 MWth (100 MWe) and 57 fuel assemblies are loaded in the core. The active core height is 200 cm and all of burnable absorber rods have upper axial cutback region of 20 cm which has no BISO particles in order to flatten axial power distribution. Prior to considering the TRU multi-recycling, a reload core analysis on transition cycles loaded with the four fuel assemblies described above was performed with three batch refueling scheme. In this analysis, TRU recycling are not considered in order to facilitate the search of equilibrium cycle in which the neutronic characteristics are converged from view point of CBC within 10 ppm compared to its previous cycle. Finally, the 5th cycle was determined as the equilibrium cycle at which 20 fresh fuel assemblies are charged at BOC and 20 fuel assemblies (3 twice-burnt, 17 thrice-burnt) are discharged at EOC. Figure 4 shows the core loading pattern of 5th equilibrium cycle at BOC.

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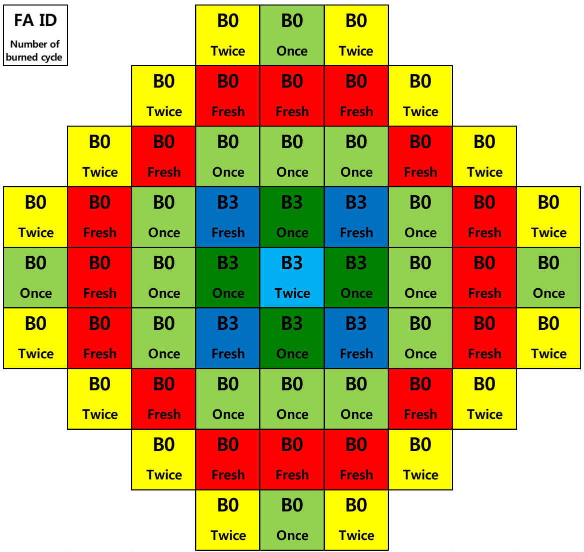

			B0 Twice	B0 Once	B0 Twice			
		B0 Twice	B0 Fresh	B0 Fresh	B0 Fresh	B0 Twice		
	B0 Twice	B0 Fresh	B0 Once	B0 Once	B0 Once	B0 Fresh	B0 Twice	
B0 Twice	B0 Fresh	B0 Once	B3 Fresh	B3 Once	B3 Fresh	B0 Once	B0 Fresh	B0 Twice
B0 Once	B0 Fresh	B0 Once	B3 Once	B3 Twice	B3 Once	B0 Once	B0 Fresh	B0 Once
B0 Twice	B0 Fresh	B0 Once	B3 Fresh	B3 Once	B3 Fresh	B0 Once	B0 Fresh	B0 Twice
	B0 Twice	B0 Fresh	B0 Once	B0 Once	B0 Once	B0 Fresh	B0 Twice	
		B0 Twice	B0 Fresh	B0 Fresh	B0 Fresh	B0 Twice		
			B0 Twice	B0 Once	B0 Twice			

Figure 4. Core loading pattern of 5th equilibrium cycle at BOC

After 5th equilibrium cycle (i.e., from 6th cycle core), the reload core analysis was performed with TRU recycling scheme. The recycling scheme of TRU nuclides is depicted in Figure 5. As shown in the figure, it is assumed that only the TRUs in MOX rods are totally recycled through reprocessing after discharge (5 years cooling and 2 years reprocessing and fabrication). The reprocessed TRUs are loaded into MOX rods of the fuel assembly for the next cycle and the remaining HM amount in the MOX rods are supplemented with 4.95 wt% enriched UO_2. On the other hand, the TRUs in FCM TRISO rods are disposed without recycling and the subsequent FCM TRISO rods are always made up only with external TRU from PWR spent fuel corresponding to the burnup of 50 MWD/kg with 10 years cooling. With this strategy, the amount of reprocessed TRU can be significantly reduced at reprocessing stage by disposing the TRUs in FCM fuel after discharge without recycling. Also, a considerable high TRU consumption rate can be achieved in FCM rods throughout every cycle due to the supplement of the external TRU of high fissile Pu content every cycle.

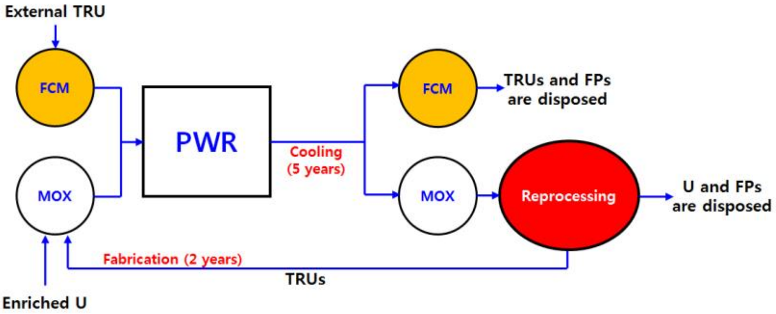

Figure 5. TRU recycling scheme of fuel assembly composed of MOX rods and FCM rods

The reload core analysis with TRU multi-recycling was performed up to 14th cycle core in which the fuel assemblies of all batches contain thrice-recycled TRUs at BOC. The core loading patterns of the reload cores with TRU multi-recycling up to 14th cycle are same as the 5th equilibrium cycle. Figure 6 shows the changes of the critical boron concentration (CBC) over the cycles. From Figure 5, it is noted that the cycle lengths considerably decrease as TRU multi-recycling from 665 EFPD in 5th cycle to 443 EFPD in 14th cycle. This is because the quality of TRU as a fuel is degraded as recycling. The neutronic characteristics of the cores calculated by DeCART2D/MASTER and McCARD/MASTER two-step procedures are summarized in Table III. As shown in the table, the difference in cycle length between two code systems was evaluated to be 5 EFPD at the 5th equilibrium cycle and it was evaluated within 20 EFPD throughout all of the cycles from 6th to 14th cycle. The results of two code systems showed good agreements for all neutronic characteristics. All the parameters are within the typical ranges of the PWRs. In particular, it is noted that the MTCs become more negative at BOC as TRU recycling proceeds because the CBC at BOC decreases as recycling.

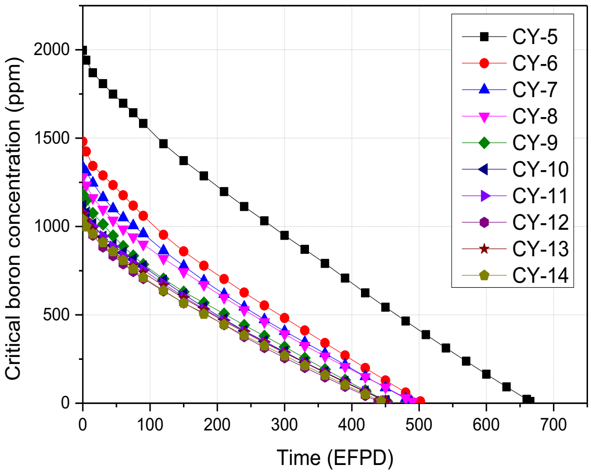

Figure 6. Comparison of cycle-wise critical boron concentration calculated by McCARD/MASTER two-step procedure (5th to 14th cycles)

Table III. Summary of neutronic characteristics from 5th to 14th cycles calculated by McCARD/MASTER and DeCART2D/MASTER two-step code procedures

		CY-5	CY-6	CY-7	CY-8	CY-9	CY-10	CY-11	CY-12	CY-13	CY-14
Cycle length (EFPD)	*M-M	665	502	488	490	452	451	451	439	451	443
	*D-M	671	522	503	500	463	458	457	458	458	460
Max. CBC (ppm)	M-M	1997	1481	1337	1281	1183	1117	1078	1062	1075	1040
	D-M	1936	1343	1189	1154	1023	983	970	957	947	950
AO (%)	M-M	-4.2~ -3.7	-5.1~ -4.3	-5.5~ -4.6	-6.0~ -4.9	-5.8~ -5.0	-6.3~ -5.1	-6.0~ -5.0	-6.1 ~ -5.3	-6.5~ -5.3	-6.5~ -5.3
	D-M	-4.1~ -3.6	-5.1~ -4.5	-6.0~ -5.2	-6.3~ -5.3	-6.4~ -5.5	-6.7~ -5.7	-6.8~ -5.7	-6.8~ -5.7	-6.8~ -5.6	-6.8~ -5.6
Max. Fq	M-M	2.14	2.06	1.96	1.99	1.95	1.97	1.98	2.03	2.01	2.03
	D-M	2.02	2.00	1.97	1.98	1.97	1.95	1.95	1.95	1.95	1.95
Max. Fr	M-M	1.54	1.44	1.45	1.47	1.44	1.45	1.46	1.49	1.48	1.48
	D-M	1.54	1.54	1.46	1.46	1.45	1.43	1.43	1.43	1.43	1.43
MTC (pcm/oC) BOC/EOC at HFP	M-M	-41.56/ -66.02	-48.42/ -65.90	-48.70/ -63.81	-48.83/ -63.61	-49.36/ -64.97	-50.42/ -63.17	-49.27/ -62.98	-50.10/ -64.58	-51.95/ -65.02	-51.87/ -65.45
	D-M	-41.18/ -67.83	-47.69/ -67.11	-49.36/ -66.59	-49.76/ -66.46	-51.4/ -66.44	-51.99/ -66.49	-52.18/ -66.53	-52.51/ -66.77	-52.76/ -67.02	-52.81/ -67.15
Avg. discharge BU (MWD/kg)	M-M	53.76	50.84	45.91	40.21	39.36	38.18	36.90	36.70	36.58	36.40
	D-M	55.21	52.03	47.18	41.39	40.29	38.99	37.53	37.50	37.51	37.52

*M-M: McCARD-MASTER code procedure, *D-M: DeCART2D-MASTER code procedure

The analysis of TRU mass flow in the core was conducted to evaluate the TRU consumption performance of the SMR core. Table IV shows the summary of the TRU mass flow for each cycle calculated by McCARD/MASTER and DeCART2D/MASTER two-step procedures. For consistent comparison, four cores corresponding to 5th, 8th, 11th, and 14th cycles are considered. The 5th cycle core is comprised of the fresh, once-burnt, and twice-burnt fuel assemblies that contains only not recycled TRUs and the 8th cycle core is comprised of the fresh, once-burnt, and twice-burnt fuel assemblies containing only once recycled TRUs in MOX rods. Similarly, the 11th and 14th cycle cores are loaded with fresh, once-burnt, and twice-burnt assemblies of twice and thrice recycled TRUs in MOX rods, respectively. As shown in Table IV, total TRU consumption rate calculated by the McCARD/MASTER code system was evaluated to be similar to those of the DeCART2D/MASTER code system. Also, at 14th cycle, the fact that the production of Pu by radiative capture of ^{238}U starts to be larger than the consumption of Pu was same for both McCARD/MASTER and DeCART2D/MASTER code systems. For the 5th cycle core, the FCM rods have a high TRU consumption rate of 26.3 % but the MOX rods have a low TRU consumption rate of 8.1 %, which leads to a net TRU consumption rate of 14.3 %. Total consumption rate was reduced by ~41 % from 14.33 % in 5th cycle to 8.46 % in 14th cycle. The consumption rate of the FCM rods was slightly decreased by ~25 % from 26.27 % to 19.73 % while that of the MOX rods was significantly reduced by ~81 % from 8.13 % in 5th cycle to 1.52 % in 14th cycle. The slight decrease of TRU consumption rate in FCM rods is due to the fact that only external TRU feed (i.e., not recycled TRU) is used in FCM rods. In MOX rods, it is noted that a negative plutonium consumption rate of -0.4 % in 14th cycle meaning a slight production of plutonium occurs, which is due to the degradation of TRU quality as recycling. On the other hand, MA (Minor Actinide) consumption rates are all significantly positive in both MOX and FCM rods for all the cycles.

Table IV. Summary of TRU mass flow analysis for 5th, 8th, 11th, and 14th cycle calculated by McCARD/MASTER and DeCART2D/MASTER two-step procedures

Cycle		Plutonium			Minor actinides			TRU (Pu+MA)		
		MOX	FCM	Total	MOX	FCM	Total	MOX	FCM	Total
5 (*M-M)	Charged (kg)	244.44	127.06	371.50	46.03	23.93	69.96	290.47	150.99	441.46
	Discharged (kg)	227.07	92.05	319.12	39.79	19.27	59.06	266.86	111.32	378.18
	Consumption rate (%)	7.10	27.55	14.10	13.56	19.48	15.59	8.13	26.27	14.33
5 (*D-M)	Charged (kg)	244.42	127.07	371.49	46.02	23.92	69.94	290.44	150.99	441.43
	Discharged (kg)	227.30	91.68	318.99	39.10	18.62	57.72	266.41	110.30	376.71
	Consumption rate (%)	7.00	27.85	14.13	15.02	22.16	17.46	8.27	26.95	14.66
8 (*M-M)	Charged (kg)	219.71	127.06	346.77	47.02	23.93	70.95	266.73	150.99	417.72
	Discharged (kg)	214.64	99.04	313.68	40.88	20.28	61.16	255.51	119.32	374.84
	Consumption rate (%)	2.31	22.05	9.54	13.06	15.24	13.80	4.21	20.97	10.27
8 (*D-M)	Charged (kg)	220.09	127.07	347.17	45.66	23.92	69.59	265.76	150.99	416.75
	Discharged (kg)	215.71	98.66	314.37	39.75	19.71	59.46	255.46	118.37	373.83
	Consumption rate (%)	1.99	22.36	9.45	12.96	17.60	14.55	3.88	21.61	10.30
11 (*M-M)	Charged (kg)	207.95	127.06	335.01	46.12	23.93	70.05	254.07	150.99	405.06
	Discharged (kg)	206.90	100.65	307.55	40.86	20.52	61.39	247.76	121.18	368.94
	Consumption rate (%)	0.51	20.78	8.20	11.41	14.23	12.37	2.48	19.74	8.92
11 (*D-M)	Charged (kg)	209.12	127.07	336.19	44.48	23.92	68.40	253.60	150.99	404.59
	Discharged (kg)	208.64	100.60	309.24	39.60	20.03	59.63	248.25	120.63	368.87
	Consumption rate (%)	0.23	20.83	8.02	10.96	16.27	12.82	2.11	20.11	8.83
14 (*M-M)	Charged (kg)	200.29	127.06	327.35	44.92	23.93	68.84	245.21	150.99	396.20
	Discharged (kg)	201.10	100.69	301.78	40.39	20.52	60.90	241.48	121.21	362.69
	Consumption rate (%)	-0.40	20.76	7.81	10.09	14.25	11.53	1.52	19.73	8.46
14 (*D-M)	Charged (kg)	202.00	127.07	329.07	43.21	23.92	67.13	245.21	150.99	396.20
	Discharged (kg)	203.26	100.33	303.58	39.07	19.98	59.04	242.32	120.31	362.63
	Consumption rate (%)	-0.62	21.05	7.74	9.59	16.49	12.05	1.18	20.32	8.47

Table V summarizes the overall mass balance of U and TRU from 5th to 14th cycle. The amount of external uranium feed for MOX fuels loaded in all of cycle at BOC is 36,105 kg while the consumed amount of uranium is 1,336 kg and 34,768 kg uranium is sent to repository. The TRUs in MOX fuels are externally supplied by 290 kg only in 5th cycle at BOC and it is recycled through 5th to 14th cycle without external TRU feed. Finally, 241 kg TRU discharged from 14th cycle at EOC is disposed. In case of the TRU in FCM fuels, the amount of external TRU feed loaded at BOCs through 5th to 14th cycles is 1,510 kg and the TRU of 1,186 kg is discharged, at which the consumed mass is 323 kg. In the aspect of overall mass balance of TRU through 5th to 14th cycle, the amount of external TRU feed is 1,800 kg and 1,428 kg is discharged, which corresponds to the TRU consumption rate of 20.69 %.

Table V. Overall mass balance of U and TRU from 5th to 14th cycle calculated by McCARD/MASTER two-step procedure

Items	Values (in kg)
Uranium external feed through MOX fuels (A)	36,105
Uranium consumption through MOX fuels (B)	1,336
Discharged uranium from MOX fuels (C = A - B)	34,768
TRU external feed through MOX fuels (D)	290
TRU consumption through MOX fuels (E)	49
Discharged TRU from MOX fuels at EOC of 7th cycle (F = D - E)	241
TRU external feed through FCM fuels (G)	1,510
TRU consumption through FCM fuels (H)	323
Discharged TRU through FCM fuels (I = G - H)	1,186
Total TRU external feed (J= D + G)	1,800
Total TRU consumption (K = E + H)	372
Total TRU to be disposed after 14th cycle (L= J - K)	1,428
Total TRU consumption rate (%, M = K / J×100)	20.69 %

5. CONCLUSIONS

In this study, a small modular PWR core was designed and analyzed in detail for TRU multi-recycling with McCARD/MASTER two-step procedure in which the lattice calculation was performed by a Monte Carlo code called McCARD with a continuous energy library. We considered a new TRU recycling concept using a new fuel assembly design comprised of FCM and MOX fuel rods. In this concept, TRUs only in the MOX fuel rods are recycled while FCM fuel rods are used to achieve deep burning of TRU without recycling. The reload core analysis was performed initially without TRU recycling for facilitating the search of equilibrium cycle (5th cycle) and the subsequent reload core analysis was conducted with TRU recycling from 6th to 14th cycle core which is loaded with the fuel assemblies with thrice recycled TRUs in MOX fuel rods. From the analysis, it was found that 1) the analysis on the neutronic characteristics and TRU mass flow using the McCARD/MASTER code system shows good agreement with the previous ones obtained using the DeCART2D/MASTER code system, 2) the cycle lengths of the core considerably decrease as TRU recycling from 665 EFPD in 5th cycle to 443 EFPD in 14th cycle, 3) the net TRU consumption rate of the core was estimated to be 8.46~14.33 %, and the FCM rods have a high TRU consumption rate of 19.73~26.27 % during TRU recycling, and 4) overall TRU consumption rate through all of the cycles with TRU recycling was estimated to be 20.69 %. In conclusion, it is neutronically feasible to design PWR-based SMR core such that it has a significant net TRU consumption rate with TRU multi-recycling.

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