An Assessment of Uncertainty for a Head End Process in the Pyroprocessing

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1. Introduction

- Korea has been developing the pyroprocessing that changes spent fuels of a LWR to fresh fuels of a SFR.
- In the pyroprocessing, a non-destructive analysis, like a (Pu/^{244}Cm) mass ratio method showed in Eq. (1), is usually used because nuclear material accountancy is controlled by weight unit.
- Heterogeneous (Pu/^{244}Cm) mass ratio of spent fuel rods appears by height when a fuel assembly are burned.
- In this study, we analyzed the heterogeneous the (Pu/^{244}Cm) mass ratio by height of spent fuels according to burnup and cooling periods based on computer simulations, and calculated a uncertainty of the (Pu/^{244}Cm) mass ratio in a head process of the pyroprocessing by random samplings.

$$\textbf{Pu mass} = \left(\frac{\textbf{Pu mass}}{{}^{244}\textbf{Cm mass}}\right) \times {}^{244}\textbf{Cm mass} \qquad \textbf{(1)}$$

2. Methods and Results

2.1 Reference Reactor

- OPR1000 was selected as a type of reference reactor.
- By analyzing the nuclear design report of OPR1000, we found core design characteristics and selected typical 3 fuel assemblies which are shown in table 1.

Table 1. Information of typical fuel assemblies

Fuel assembly type	Enrichment [w% ^{235}U]	Burnup [MWd/kgU]	Number of fuel rods
A0	1.42	11.6~14.2	236
B0	2.92/2.42	37.1~39.7	184/52
C0	3.43/2.93	33.8~44.1	184/52

2.2 Computer codes

- MCNP based on Monte Carlo method is a particle transport analysis code that generates random numbers to describe behavior of particles and estimate a solution of the Boltzmann transport equation.
- CINDER`90 performs a reactor irradiation calculation and solves the Bateman equation to track nuclide change in materials.
- A link system was used to simulate the fuel assembly burnup calculations between MCNP and CINDER`90 showed in figure 1.
- In the link system, Predictor-Corrector method was used which calculates a ratio of nuclide at the midpoint of each time step to mitigate a oscillation of neutron flux by ^{135}Xe.

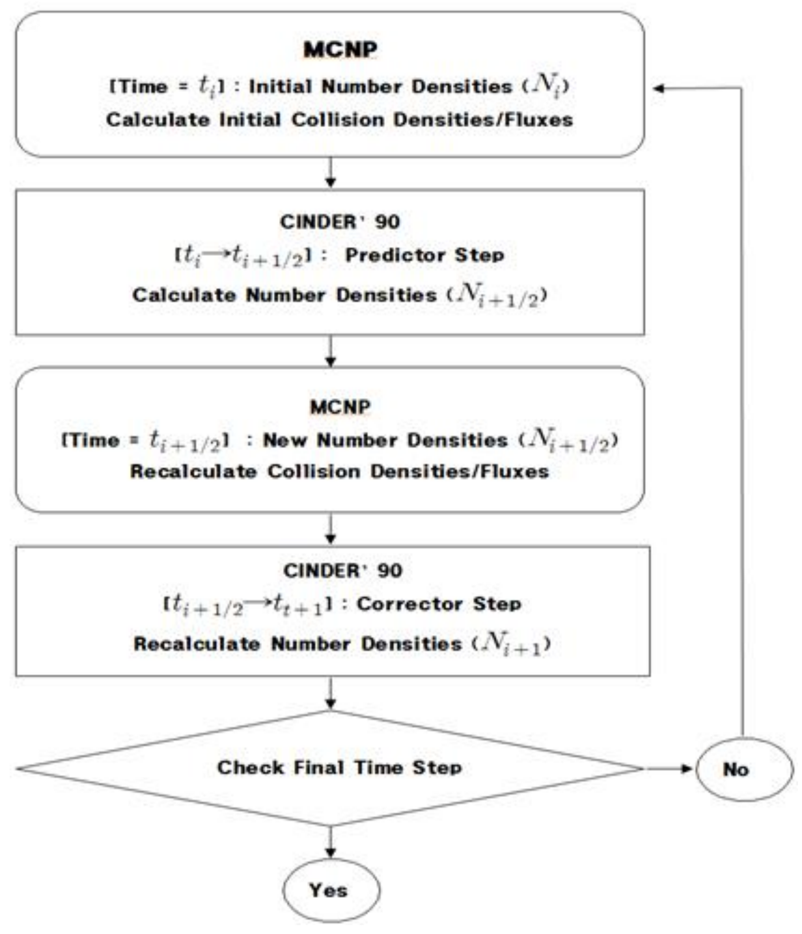

Figure 1. Link system between MCNP and CINDER`90

2.3 Input file for the computer codes

- To find out the heterogeneous (Pu/^{244}Cm) mass ratio by height of the fuel assembly, middle burnup region was divided into long meshes, and end burnup regions were divided into short meshes.
- The burnup periods were set to 400, 500, 600, 700, and 800 days, and the cooling periods were set to 0, 10, 20, 30, and 40 years.

2.4 Heterogeneous results by height of the fuel assembly

- As a result of the fuel assembly burnup process, heterogeneous results by height appeared for 4 fuel assemblies showed in figure 2.
- The lower the enrichment, the smaller the average (Pu/^{244}Cm) mass ratio and the greater the (Pu/^{244}Cm) mass ratio difference.

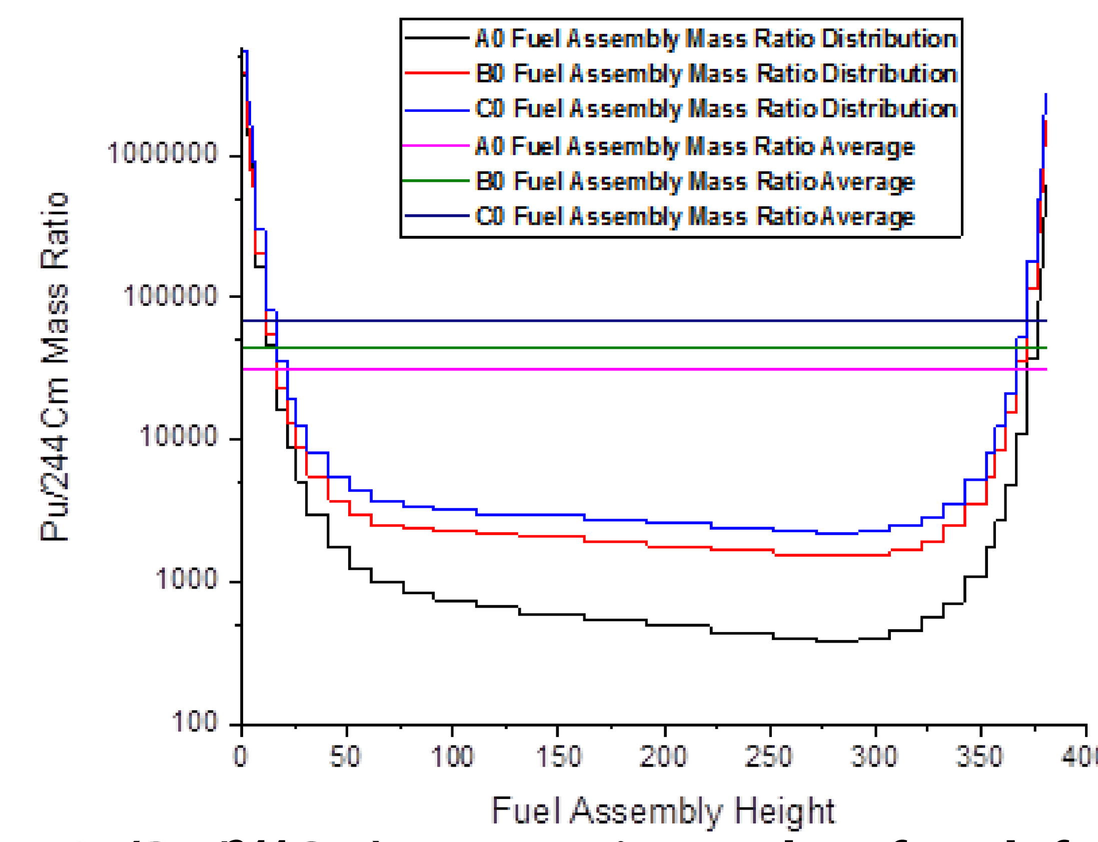

Figure 2. (Pu/^{244}Cm) mass ratio results of each fuel assembly

2.5 Uncertainty analysis using 1,000 random samplings

- We assumed that a fuel assembly is divided into 89,916 pellets in the chopping step, and 9,144 pellets are randomly selected to be oxidized corresponding to 50kgHM/batch.
- Random samplings of selecting 9,144 pellets out of 89,916 pellets were conducted 1,000 showed in figure 3.
- Uniform probability mass function was used for random samplings.
- Error propagation was used times to calculate uncertainty of the (Pu/^{244}Cm) mass ratio.

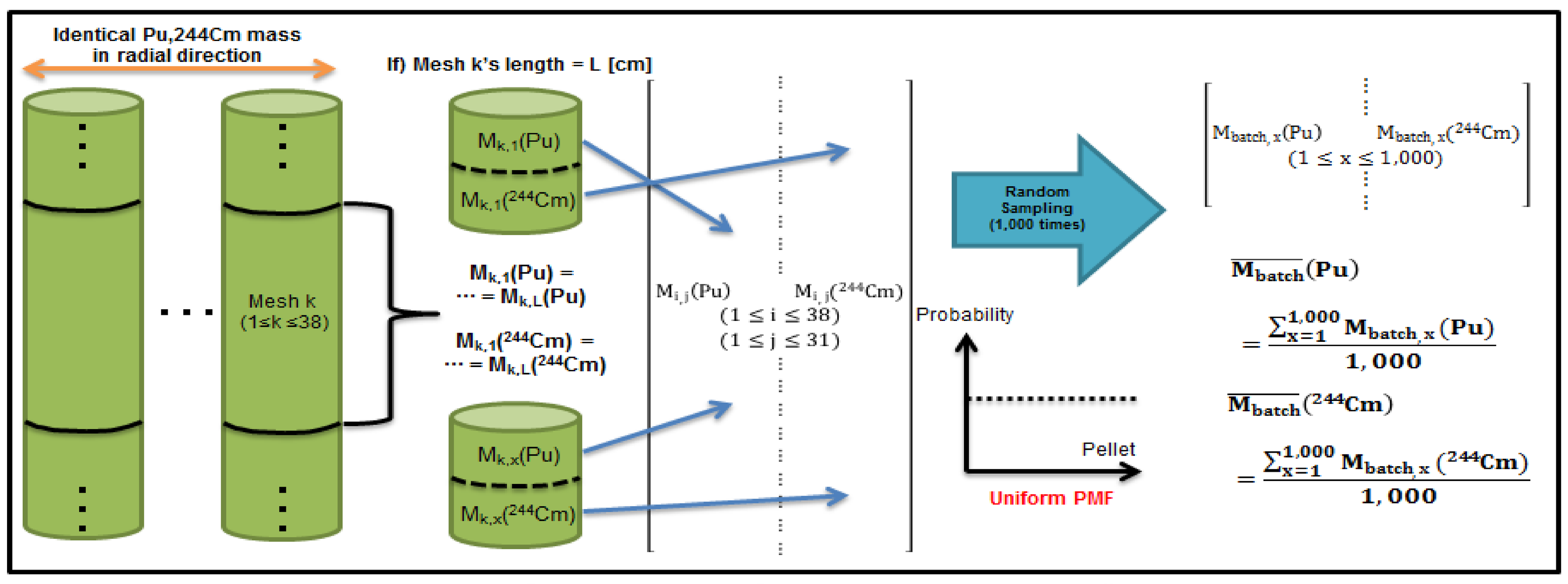

Figure 3. Random samplings using uniform PMF

Table 2. Uncertainty of the (Pu/244Cm) mass ratio by random samplings

Fuel assemb-ly	Cooling Period [yr]	Burnup period [days] 400 ratio	400 SD	500 ratio	500 SD	600 ratio	600 SD	700 ratio	700 SD	800 ratio	800 SD
A0	0	1212.8	7.8	560.8	3.4	310.4	1.7	190.2	1.0	128.5	0.6
	10	1723.3	11.4	793.3	4.6	438.0	2.4	267.9	1.4	180.8	0.9
	20	2454.8	17.1	1128.3	6.8	621.4	3.2	379.9	1.9	256.0	1.2
	30	3538.0	22.8	1621.4	9.9	890.9	4.9	544.8	2.8	367.2	1.9
	40	5126.4	31.9	2345.8	13.9	1288.8	7.0	787.0	4.1	530.3	2.7
B0	0	5922.0	33.2	2296.4	11.6	1092.6	5.2	599.2	2.7	363.5	1.5
	10	8467.1	47.1	3262.6	16.2	1544.8	7.4	844.3	3.6	510.4	2.2
	20	12137.3	66.0	4659.4	23.6	2199.1	10.5	1199.0	5.5	724.0	3.0
	30	17553.6	90.3	6718.7	33.7	3164.0	14.9	1722.4	7.7	1037.8	4.3
	40	25503.9	137.3	9747.9	48.7	4581.0	21.4	2491.4	11.5	1500.7	6.5
C0	0	8743.4	46.7	3351.2	16.6	1564.0	7.6	846.0	3.7	501.3	2.1
	10	12528.6	67.4	4772.6	23.4	2213.8	10.6	1193.9	5.4	705.0	3.1
	20	18009.0	96.2	6829.9	33.6	3156.8	15.0	1697.3	7.4	999.8	4.3
	30	26049.2	140.4	9852.1	49.1	4545.8	21.8	2439.2	10.8	1434.5	6.1
	40	37894.6	202.8	14297.8	73.9	6590.0	31.6	3530.3	15.7	2074.7	8.9

3. Conclusion

- It is confirmed that the heterogeneous (Pu/^{244}Cm) mass ratio appears in the spent fuel assemblies.
- Uncertainty of the (Pu/^{244}Cm) mass ratio was calculated by the 1,000 random samplings using uniform probability mass function.
- A methodology of this study could be used to enhance accuracy of the nuclear material accountancy.