Effects of Sample Thickness on the Micro Gamma Scanning for the PWR Spent Fuels

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1. Introduction

Fission production (FP) distribution is of an importance for the fuel performance of PWR. Several analysis methods have been applied to study FP behavior [1]. Recently, one of the most common techniques, the wavelength dispersive spectrometer (WDS) has been installed in the shielded SEM at Post Irradiation Examination Facility (PIEF) of Korea Atomic Energy Research Institute (KAERI). The shielded SEM is possible to deal with the high radioactive material under 0.5 Curies.

The study of WDS and micro gamma scanning for spent fuels is in progress to complement each other. However, thickness of the spent fuel sample for SEM is limited under 0.5 mm to minimize harmful effects of irradiation exposure on the system. While on the other, the sample for the micro gamma scanning is usually about 3 mm thick to detect sufficient counts of gamma-ray emitted from samples. This paper aims to analyze effects of sample thickness on the micro gamma scanning and discuss if a 0.5 mm thick fuel section can be applied for the micro gamma scanning. The target sample with 60 GWd/tU burnup and 1.5 year cooling time has been analyzed.

2. Methods and Results

2.1 Micro Gamma Scanning

Micro gamma scanning was carried out on a commercial PWR rod, using a high purity Ge detector (HPGe) with a slit of 0.5 mm × 0.5 mm. Operation of the scanning mechanism and data acquisition and analysis are done by an on-line computer.

The commercial PWR rod for the experiment has a rod average burnup, 58.1 GWd/tU. The sample with 60 GWd/tU local bunrup and 0.5 mm thick was taken at 3094 mm from the fuel rod bottom. The active length of fuel rod is 3,810 mm and the pellet outer diameter is 8.192 mm.

The spectra were obtained at the center of the sample in live time; 600, 2000, 4000 sec. As shown in Table 1, as live time increases, uncertainty in the net peak count rate decreases. The uncertainty at 4000 sec live time is similar with that of 3 mm thick sample measured for 1000 sec live time at the same condition of burnup and cooling time. The spectrum at 4000 sec live time is shown in fig 1.

Table I. Micro gamma scanning on 0.5 mm thick sample

Net peak count rate		Live time, sec	600	2000	4000
Nuclide	Energy, keV				
Ru-106	512	cps	1.81	1.95	1.97
		error, %	12.3	7.4	5.4
Cs-134	605	cps	7.16	7.21	7.28
		error, %	4.1	2.3	1.6
	796	cps	6.07	5.69	6.02
		error, %	5.2	4.8	4.3
Cs-137	662	cps	6.40	6.82	6.65
		error, %	4.0	2,2	1.6

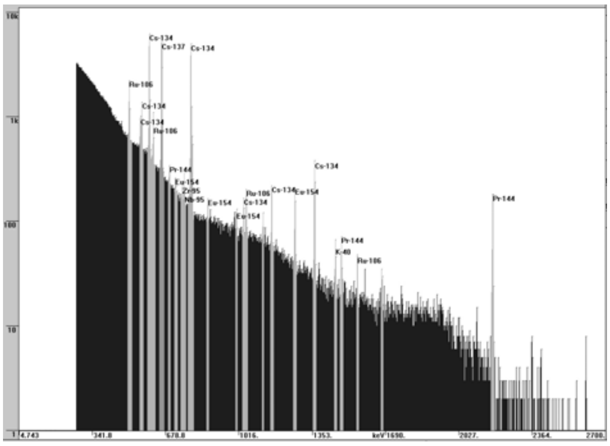

Fig 1. Gamma ray spectrum at 4000 sec live time

2.2 MCNP analysis

MCNP [2] analyses were performed to estimate the effect of gamma ray self-absorption in the source material. Mono-directional source and same intensity of each gamma ray lines were assumed to calculate the relative efficiency of two gamma rays; 605 keV for Cs-134 and 662 keV for Cs-137. The ratio of the efficiencies for two distinct gamma ray lines become simplified due to same intensity condition as follow,

$$\frac{\varepsilon_i}{\varepsilon_j} = \left(\frac{E_i}{E_j}\right)^p = \frac{C_i}{C_j}\frac{F_i}{F_j}$$

Where p is an empirical constant, C is the net peak counts, ε is the full energy peak efficiency for a gamma ray of energy E, and F is the cumulative correction factor [3]. In this study, the self-absorption effect was only considered as a correction factor.

Table 2. Estimated value of p and F

Thickness (mm)	0.0	0.5	1.0	3.0
p	-0.504	-0.509	-0.450	-0.261
F		1.000	0.995	0.978

Table 2 shows results of the MCNP analysis. 0.0 thick means no effect of self-absorption in this table. As the result, the self-absorption correction factor to the net peak area ratio was nearly about 1.0 in the 0.5 mm disk-shaped source. On the other side, F of 3 mm thick source which is used as an ordinary gamma scanning sample was 0.978 less than that of 0.5 mm thick source.

3. Conclusions

- The uncertainty of net peak count rate at 4000 sec live time is similar with that of 3 mm thick sample measured for 1000 sec live time at the same condition with 60 GWd/tU burnup and 1.5 year cooling time.
- As the result of MCNP analysis, the self-absorption correction factor to the net peak area ratio was nearly about 1.0 in the 0.5 mm disk-shaped source. This means the self-absorption effect is seen as negligible in this case.

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