Determination of the Relative Detection Efficiency of a Section and Axial Gamma Scanning on a PWR Fuel by using the MCNP code

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1. Introduction

The gamma-ray spectroscopy of a nuclear fuel has been employed for determination of the axial burnup of the fuel rods in PIEF, KAERI. The relative detection efficiency of the gamma-ray spectrometer is an important factor for a calculation of a burnup of a fuel rod. In the case of the axial gamma scanning, γ-rays emitted from the decay of Cs-134 have been used for determination of a relative detection efficiency. But, the variation of the measurement on Cs-134 γ-rays for the section gamma scanning is relatively higher due to a lower emission of the γ-rays than that of the axial gamma scanning. MCNP code has been used for determining the relative detection efficiency of a section gamma scanning. It is a general-purpose, coupled neutron/photon/electron Monte Carlo transport code [1].

In this study, the radial and axial γ-rays distributions of Cs-137 and Cs-134 were measured by the gamma spectrometry. Also, burnup determinations between axial and section gamma scanning have been compared after the relative detection efficiency was determined by the MCNP code. An additional comparison with the Nd-148 chemical method was conducted.

2. Methods and Results

2.1 Experimental techniques

Axial and radial micro gamma scanning was carried out on a commercial PWR rod, using a high purity Ge detector (HPGe) with each slit of 25.0 mm × 0.5 mm and 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 experiments has a rod average burnup, 53.8 GWd/tU. The thickness of specimens of this rod for the section gamma scanning is 3.0 mm and the pellet outer radius is 8.22 mm. The gamma-ray emitted from the isotopes Cs-137, Cs-134 was measured.

2.2 Section gamma scanning

Figure 1 shows the distribution of Cs-134 and Cs-137 across a pellet cross section of a fuel rod segment sampled at 2048 mm from the rod bottom. 605 keV γ-ray was measured for Cs-134, and 662 keV γ-ray for Cs-137. Each γ-ray has a high branching ratio, 97.6% and 85.1% and also higher emission rate among γ-rays emitted spent PWR fuel nuclides. With the growing trend in the fuel rod burnup, cesium tends to be released in the center of fuel pellet as shown in figure 1. It is likely to induce a greater error in determining a burnup.

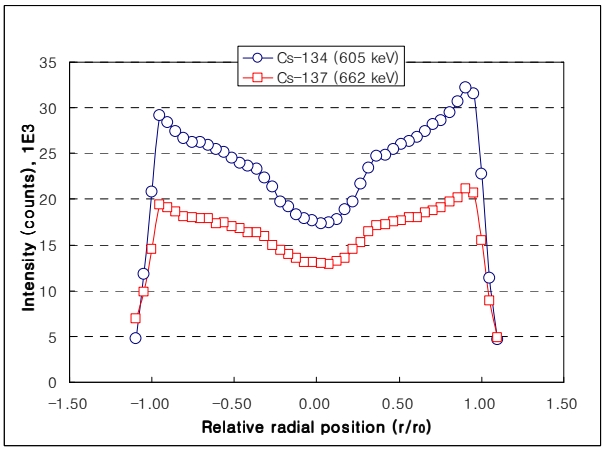

Figure 1. Cs-134 and Cs-137 profiles across a fuel pellet

2.3 Nd-148 chemical method

Fission product Nd was chemically separated from the spent fuel specimen sampled at the nearby section gamma scanning specimen and determined by the isotopic dilution mass spectrometry. Nd-148 is an ideal burnup indicator because of its non-volatile and non-radioactive nuclide, low destruction cross section and good emission characteristics for a mass analysis and nearly same fission yield from U-235 and Pu-239 etc [2].

The burnup of the specimen was 59.0 GWd/tU.

2.4 MCNP analysis

The determination of the relative detection efficiencies was performed with the MCNP code. To define a source term of the MCNP for the axial gamma scanning, the cylindrical source was divided into 20 area nodes in accordance with the results of the section gamma scanning. A mono-direction biasing for the source was used to release the burden of a long-time calculation.

If the relative detection efficiency of Cs-137 662 keV γ-ray is unit, the efficiency calculated by MCNP is 0.9622 for Cs-134 605 keV γ-ray. Figure 2 shows the relative detection efficiency as a function of the photon energy measured by the axial gamma scanning. According to the measurement, the efficiency is 0.9893.

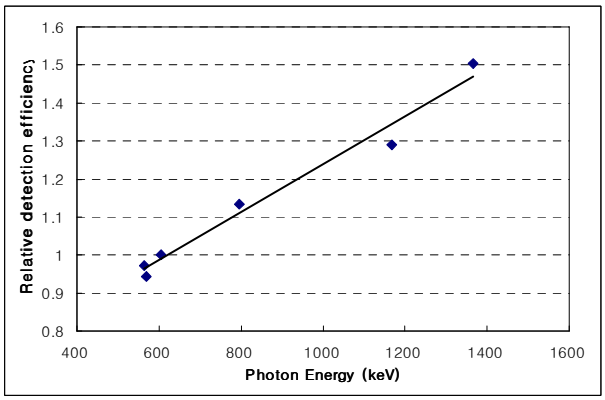

Figure 2. Relative detection efficiency measured by the axial gamma scanning

With the result of the MCNP, the burnup of the specimen is 59.8 GWd/tU and with the measurement, it is 60.0 GWd/tU. Both show similar results.

With the same assumption, the relative detection efficiency of Cs-134 605 keV γ-ray for the section gamma scanning is 1.0131, which was calculated by the MCNP. Using this value and section gamma scanning result of the specimen, the burnup was estimated to be 60.8 GWd/tU.

3. Conclusion

MCNP code has been applied to determine the relative detection efficiency of a gamma ray detector. MCNP results agree with the measurements by the Nd-148 method and the gamma spectrometry.

REFERENCES

[1] Judith F. Briesmeister, MCNP – A General Monte Carlo N-Particle Transport Code Version 4C, LA-13709-M, 2000
[2] Standard Test Method for Atom Percent Fission in Uranium and Plutonium Fuel, ASTM E321-96