Evaluate of the Spent Nuclear Fuel Rod Model Using the Monte Carlo Simulation

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1. Introduction

The safeguards verification, material control and accountability requirements of a reprocessing facility are costly and very time consuming because they mainly rely on destructive analysis. With the growth occurring in the nuclear industry and the possibility of closing the fuel cycle by embracing fuel recycling, the number of reprocessing facilities is likely to grow. The IAEA will need supplemental systems that are less man-power intensive to provide verification assurance [1]. The CFOGRS is a next generation safeguarding detection system which is non-destructive, autonomous, and operates in near-real-time. The efficacy the gamma ray detection technique to the spent nuclear fuel rod has been evaluated. The goal of this work is to develop the spent nuclear fuel rod model and to evaluate the developed model to measure radiation of spent nuclear fuel using CFOGRS developed previously work. This model can be used as a radiation source to measure of the gamma ray emitted.

2. Modelling and Results

2.1 Modelling of the Spent Nuclear Fuel Rod

The Monte Carlo simulation package GEANT4 has been used to develop a model of the spent nuclear fuel rod. The decay of the fuel rod was constructed based on the Radioactive Decay libraries, which is provided with the GEANT4. And gamma ray emitted from the fuel rod were detected by Cerenkov-based FOGRS. This sensor was modeled based on the Optical libraries.

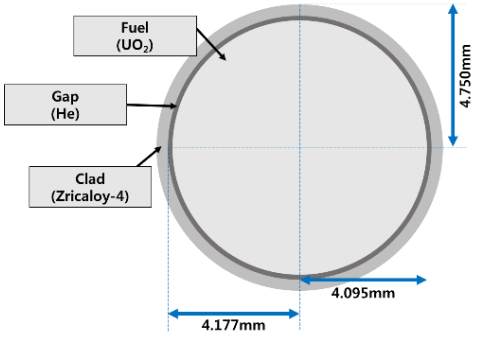

Fig.1. Plant view of a single fuel rod with the geometric properties.

A single spent fuel rod was designed to consist of a three-layer cylindrical tube which is consist of Fuel, Gap, and Cladding. Where a single fuel rod consists of enriched uranium, in the form of UO_2 pellets, contained in Zircaloy-4 tubing. And rods are pressurized internally with helium during fabrication to reduce clad creepdown during operation and thereby prevent clad flattening. A schematic layout of modeled fuel rod is presented in Fig. 1.

2.2 Source of the Spent Nuclear Fuel Rod

Complex source lists of modeled spent nuclear fuel rod samples were generated using irradiation and decay calculations performed using ORIGEN-ARP and a Matlab script to convert the output files to a format recognized by GEANT4. In ORIGEN, the Express Form was used to define fuel parameters, burnup, irradiation pattern, cooling time, and enrichment. The sample rod was in the reactor for a total of five cycles. The initial enrichment of the rod was 2.94%. The burnups have been cooling for approximately 28 years [2].

2.3 Simulation results

The entire structure is the square-shaped FOCRS, which consists of four CFOGRS. When four CFOGRS were irradiated by gamma rays, the four separate Cerenkov radiations generated in the optical fiber were guided to the MPPC. The output file was written wavelength, which was calculated by convert equations.

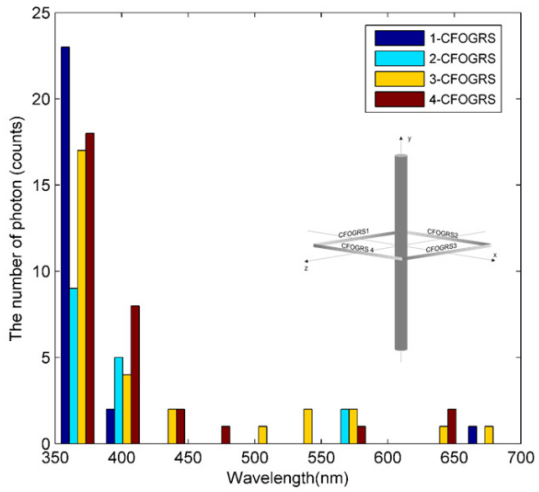

Fig.2. Wavelength spectra of detected Cerenkov photons.

3. Conclusion

In this work developed the spent nuclear fuel rod model and evaluated the developed model to measure radiation of spent nuclear fuel using CFOGRS. Spent nuclear fuel rod was modeled the general type of fuel rod. And the complex source of fuel rod was defined refer to the previous research. The gamma rays emitted from the modeled fuel rod was detected using CFOGRS. The simulation results showed that the CFOGRS can be detected gamma rays emitted from the source of the fuel rod. This model only can see the total gamma ray. Therefore, this work should be supplemented in the future. In order to be suitable for the purpose, it is considered that further improvement of this model.

REFERENCES

[1] C. R. Orton, C. G. Fraga, R. N. Christensen, and J. M. Schwantes, “Proof of concept simulations of the Multi-Isotope Process monitor: An online, nondestructive, near-real-time safeguards monitor for nuclear fuel reprocessing facilities,” Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 629(1), 209-219 (2011).

[2] Sarah E. Bender, “Application of Monte Carlo modelling of Compton suppression spectroscopy to spent fuel material accountancy”, M.S. thesis, Dept. Nuclear Eng., The Pennsylvania State Univ., 2011.