Self Shielding in Nuclear Fissile Assay Using LSDS

YongDeok Lee*, Chang-Je Park, Geun-il Park, Kee Chan Song
Korea Atomic Energy Research Institute, P.O. Box 105, Yusung, Daejon, Korea 305-600
**Corresponding author: ydlee@kaeri.re.kr*

1. Introduction

The new technology for isotopic fissile material contents assay is under development at KAERI using lead slowing down spectrometer(LSDS). LSDS is very sensitive to distinguish fission signals from each fissile isotope in spent and recycled fuel. The accumulation of spent fuel is current big issue. The amount of spent fuels will reach the maximum storage capacity of the pools soon. Therefore, an interim storage must be searched and it should be optimized in design by applying accurate fissile content. When the storage has taken effect, all the nuclear materials must be also specified and verified for safety, economics and management.

Generally, the spent fuel from PWR has unburned ~1 % U235, produced ~0.5 % plutonium from decay chain, ~3 % fission products, ~ 0.1 % minor actinides (MA) and uranium remainder. About 1.5 % fissile materials still exist in the spent fuel. Therefore, for re-utilization of fissile materials in spent fuel at SFR, resource material is produced through pyro process. Fissile material contents in resource material must be analyzed before fabricating SFR fuel for reactor safety and economics.

In assay of fissile content of spent fuel and recycled fuel, intense radiation background gives limitation on the direct analysis of fissile materials. However, LSDS is not influenced by such a radiation background in fissile assay. Based on the decided geometry setup[1], self shielding parameter was calculated at the fuel assay zone by introducing spent fuel or pyro produced nuclear material. When nuclear material is inserted into the assay area, the spent fuel assembly or pyro recycled fuel material perturbs the spatial distribution of the slowing down neutrons in lead and the prompt fast fission neutrons produced by fissile materials are also perturbed. The self shielding factor is interpreted as that how much of absorption is created inside the fuel area when it is in the lead. Self shielding effect provides a non-linear property in the isotopic fissile assay. When self shielding is severe, assay system becomes more complex and needs special parameter to treat this non linear effect.

Additionally, assay of isotopic fissile content will contribute to accuracy improvement of burnup code and increase transparence and credibility for spent fuel storage and usage, as internationally increasing demand.

2. Self Shielding

The spent fuel assembly, SinUljin site, was referenced. It is 16x16 fuel type and 4.5 initial enrichment and 55,000MWD/MTU were cited[2]. The assembly has 236 rods with 9.5mm rod diameter and 12.85mm pitch size. In the simulation[3], equivalent volume was used. The source neutron, having ~0.5MeV mean energy, slows down in the lead medium and induces fissile fission with respect to the slowing down energy. Lead medium has a continuous neutron energy spectrum and low neutron capture loss. A broad range of interrogation neutron energies is available in the lead spectrometer. In the slowing down neutron energy, the fission characteristics of each fissile is showed below several tens keV energy. Therefore, the energy between 30 keV to 0.1 eV was determined which was very sensitive to the fissile material fission. However, a good energy resolution in the fission signatures must be also considered simultaneously to distinguish these isotopes from each other. Because of spent fuel length(4m), scanning mechanism is considered in neutron detection.

For analysis of self shielding of pyro product material, fuel composition at steady state of SFR was referenced. Mainly 11wt% of Pu239, 1.69wt% of Pu241, 64.6wt% of U238 and 10wt% of zirconium were used in the assay area for calculation.

Table I shows the self shielding results for PWR spent fuel and pyro produced material. Table II is the dominant neutron absorption energy for U235, U238, Pu239, Pu240. U238 is used as a base material for fabricating SFR fuel and is also used as a threshold detector material to measure the prompt fast fission neutron from fissile. Therefore, the energy range in Table I covers the dominant absorption energy. From the results, the effect is relatively larger in low neutron energy for pyro process material. At 0.3eV and 1eV, Pu239 and U235 have dominant fission characteristics. However, the energy range becomes broader, the self shielding is shown lesser effect. For the spent fuel assembly, the effect shows 20~30% range in the various slowing energy range.

Table I: Self shielding effect with respect to neutron slowing down energy: PWR spent fuel and pyro process material

Energy	Self shielding	
	PWR Spent Fuel (16x16) assembly	Pyro process material for SFR

0.1eV-1eV	1.25	1.31
0.1eV-3eV	1.27	1.19
0.6eV-8eV	1.26	1.17
5eV-30eV	1.20	1.07
40eV-100eV	1.22	1.05
3eV-300eV	1.25	1.06
20eV-600eV	1.27	1.05
3eV-1keV	1.27	1.05
0.1eV-1keV	1.27	1.05
0.1eV-10keV	1.30	1.04
0.1eV-30keV	1.29	1.04

Table II: Dominant neutron absorption energy for different nuclear materials

Isotope	Resonance energy
Pu239	0.3eV, 10eV, 70eV
Pu240	1eV
U235	1eV
U238	1keV, 20eV, 700eV

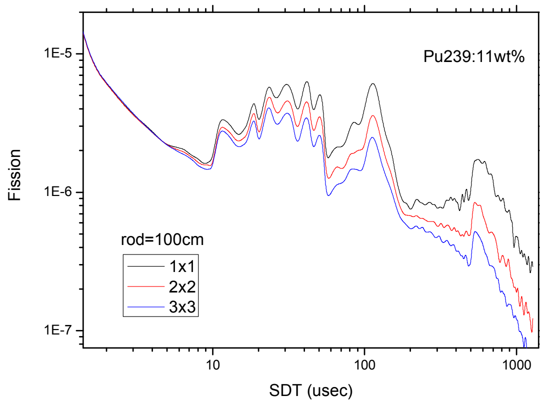

Fig. 1. Fission signature of Pu239 with respect to slowing down neutron energy by volume change.

Fig. 1 shows the fission spectrum of 11wt% Pu239 by changing the Pu239 volume. The figure shows that the absorption increases after 200 μsec slowing down time with volume increase. Therefore, in the LSDS system, the self shielding is more of concern when bulky or highly enriched fissile materials are analyzed because this effect provides a non-linear effect in the isotopic fissile assay. The result of self shielding by different slowing down energy range will be used for final fissile content assay with energy resolution, neutron gain and spectrum analysis.

3. Results and Conclusion

The LSDS system is the most feasible choice to analyze the isotopic fissile contents directly in spent and recycled fuel. The LSDS has the power to resolve the fission characteristics from each nuclear material. In the designed device, self shielding parameter was searched when the spent fuel assembly or pyro process production material was inserted into the LSDS. The self shielding is not severe for those materials by insertion into the lead. However, when bulky or highly enriched fissile materials are introduced, this parameter must be considered and evaluated. The self shielding is very important parameter for LSDS system working.

Additionally, an accurate fissile material analysis will contribute to the fuel stability, reactor operation economy and safety. Furthermore, it will increase the international transparency on the nuclear fuel cycle.

Acknowledgement

This work is performed under the auspices of Korea Ministry of Science and Technology as a R&D project.

REFERENCES

[1] YongDeok Lee et. al., "Status of Lead Slowing Down Spectrofmeter Development for Nuclear fissile Assay," INMM, Baltimore, July 11, 2010.
[2] A. G. Croff, ORIGEN2 Isotope generation and depletion code matrix exponential method, Oak Ridge National Laboratory, 1985.
[3] J. F. Briesmeister, MCNP: A General Monte Carlo Code for Neutron and Photon Transport, LA-7396-M, Los Alamos National Laboratory, Los Alamos, 1986.