Depletion Calculation of the Irradiated Dry Process Fuel Using ORIGEN-ARP

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1. Introduction

The Dry Process Fuel (DPF), which is fabricated with the OREOX (Oxidation and Reduction of Oxide Fuel) process using the spent PWR fuel,[1] has been irradiated five times in the HANARO research reactor. For the latest fifth irradiation test, a central temperature instrumented irradiation has performed from February 2004 to April 2004.[2] To find out the isotope behavior of the irradiated fuel, ORIGEN-ARP (automatic rapid processing) was used.[3] ORIGEN-ARP is being supported by ORNL (Oak Ridge National Laboratory) and an updated version of ORIGEN-2 which is not supported now by ORNL.[4] The isotope contents and activities of several actinides and fission products are compared with those of ORIGEN-2.

2. Methods and Results

The ORIGEN code is widely used for depletion calculation supporting isotopic mass change, decay heat, radiation intensity, and gamma and neutron spectrum. Since 1970s, ORNL began developing the ORIGEN code to perform the source term calculation solving isotope decay equations. ORIGEN-S was published in 1983, providing enhanced additional options and user friendly environment. Recently, ORIGEN-ARP was issued as a module of the SCALE code package. In ORIGEN-ARP, the new ENDF-VI library is implemented and 1119 fission products are dealt with. The cross section library for ORIGEN-ARP can be made by SAS2 module of the SCALE code to evaluate a certain type of reactors.

To perform decay calculation with ORIGEN, the power rates of the fifth irradiated DPF was approximated as shown in Fig. 1. Table I shows the mass changes of several actinides and fission products at the end of each cycle. The calculation results, which are from ORIGEN-2 with the PWR library and ORIGEN-ARP with the PWR library and with the HANARO library, are compared. ORIGEN-ARP provides slightly larger inventories for U-235 and U-238 than ORIGEN-2. For Np-237 and Pu-239, ORIGEN-ARP gives less inventories than ORIGEN-ARP. After 72 days at HANARO, the differences of isotopic contents between two codes are estimated to be -3.2%, -0.2%, 14.4% and 1.7% for U-235, U-238, Np-237 and Pu-239, respectively. These differences result from not only the deficiency of decay chains of ORIGEN-2 but also the difference of actinide and fission products libraries. A slight difference of the ORIGEN-ARP cross section library was also found from the results. After the 72 days, the differences of isotopic contents calculated with different cross section libraries are estimated to be 2.8%, 0.0%, 2.4% and -1.5% for U-235, U-238, Np-237 and Pu-239, respectively.

For the fission products, there also exist differences between ORIGEN-2 and ORIGEN-ARP. Especially, for the isotope content of Cs-137, ORIGEN-2 and ORIGEN-ARP predict to be 121 g and 72 g, respectively, at the end of the third irradiation cycle. For Ce-144, ORIGEN-2 over-estimates about two times compared to ORIGEN-ARP. This affects the radioactivity of irradiated fuel and source term analysis. It is found that the isotopic contents of Ru-106, Ru-103, Ce-141, Zr-95 and Y-91 show significant discrepancies when comparing the ORIGEN-2 with the ORIGEN-ARP. However, the isotopic contents of Xe-133 and I-131, which is related with fission gas, show a similar behavior between ORIGEN-2 and ORIGEN-ARP. Table II shows radioactivity changes of DPF during cooling days. It is noted that the relative differences of activities of ORIGEN-2 and ORIGEN-ARP slightly increase with cooling time, but the absolute values of both results are enough low compared to the discharge stage. Fig. 2 shows the radioactivity changes of the irradiated DPF using the ORIGEN-ARP graphic tool. The total activity decreases rapidly as cooling time increases.

3. Conclusion

The isotopic performance of the irradiated dry process fuel was evaluated using the ORIGEN-ARP code. The inventory changes and activities of major actinides and fission products are compared with those of the ORIGEN-2 code. It was found that there are significant differences between ORIGEN-2 and ORIGEN-ARP for some kinds of isotopes such as Np-237, Ru-106 and so forth. There also exists slight difference in the results from different cross section libraries of ORIGEN-ARP. It is recommended that ORIGEN-ARP is useful enough to evaluate the source term analysis. In addition, the reactor-dependent cross section library should be generated correctly to estimate the reliable isotopic content and radioactivity.

Acknowledgements

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REFERENCES

[1] H.S. Park et al., "The DUPIC Fuel Cycle Alternatives: Status & Prospective," *Proceeding of the 10th PBNC*, 1996, Kobe, Japan.

[2] C.J. Park et al., "Fuel Performance Analysis for the Fifth Irradiation Test of the Dry Process Fuel," *Korea Nuclear Society Autumn Meeting*, October 2005, Yong-pyeong, Korea, 2005.

[3] I.C. Gauld, et al., *ORIGEN-ARP: Automatic Rapid Processing for Spent Fuel Depletion, Decay, and Source Term Analysis*, ORNL/NUREG/CSD-2/V1/R7, 2004.

[4] A.G. Corff., *A User's Manual for the ORIGEN2 Computer Code*, ORNL/TM-7175, 1980.

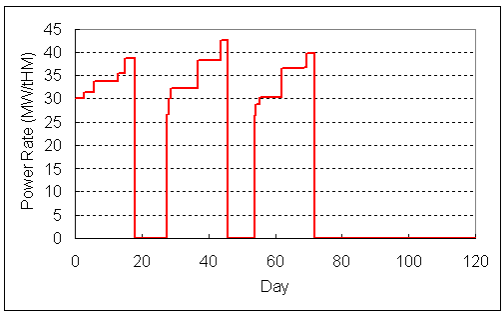

Figure 1. Simplified linear power rate of the fifth irradiation test of the dry process fuel in the HANRO.

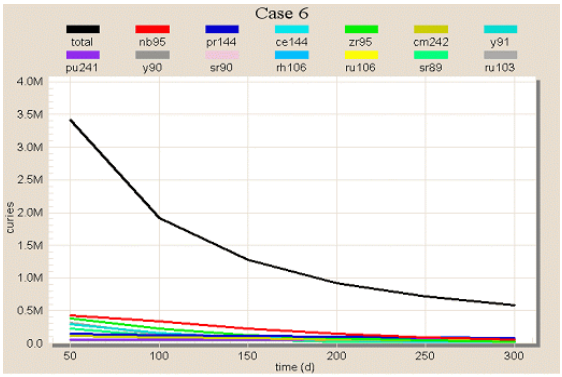

Figure 2. Radioactivites for the fifth irradiated dry process fuel using the ORIGEN-ARP.

TABLE I. Inventory Changes of the Fifth Irradiated Dry Process Fuel at the End of Each Cycle (g/tHM)

Isotopes	First cycle (18 days)	Second cycle (46 days)	Third cycle (72 days)
U-235	1.01E+04[a]	9.41E+03	9.14E+03(-3.18% [d])
	1.03E+04[b]	9.99E+03	9.70E+03(2.75% [e])
	1.02E+03[c]	9.82E+03	9.44E+03
U-238	9.76E+05	9.75E+05	9.74E+05(-0.20%)
	9.76E+05	9.76E+05	9.76E+05(0.0%)
	9.76E+05	9.76E+05	9.76E+05
Np-237	3.88E+02	4.17E+02	4.30E+02(14.4%)
	3.79E+02	3.85E+01	3.85E+02(2.40%)
	3.76E+02	3.76E+02	3.76E+02
Pu-239	4.92E+03	4.84E+03	4.82E+03(1.69%)
	4.88E+03	4.75E+03	4.67E+03(-1.48%)
	4.92E+03	4.82E+03	4.74E+03
Y-91	1.34E+01	2.48E+01	2.63E+01(23.5%)
	8.46E+00	1.49E+01	1.95E+01(-8.45%)
	9.22E+00	1.63E+01	2.13E+01
Zr-95	2.04E+01	3.86E+01	4.15E+01(34.7%)
	1.27E+01	2.25E+01	2.95E+01(-4.22%)
	1.33E+01	2.35E+01	3.08E+01
Ru-103	1.96E+01	3.32E+01	3.38E+01(41.4%)
	1.24E+01	2.02E+01	2.52E+01(5.44%)
	1.17E+01	1.92E+01	2.39E+01
Ru-106	1.32E+01	3.22E+01	3.91E+01(104.7%)
	7.42E+00	1.49E+01	2.18E+01(14.1%)
	6.50E+00	1.31E+01	1.91E+01
I-131	7.31E+00	7.90E+00	7.02E+00(2.63%)
	5.99E+00	6.80E+00	6.79E+00(-0.73%)
	5.99E+00	6.82E+00	6.84E+00
Xe-133	1.01E+01	1.07E+01	9.73E+00(-1.62%)
	9.18E+00	9.95E+00	9.70E+00(-1.92%)
	9.33E+00	1.01E+01	9.89E+00
Cs-137	3.97E+01	9.94E+01	1.21E+02(68.8%)
	2.37E+01	4.87E+01	7.20E+01(0.42%)
	2.36E+01	4.85E+01	7.17E+01
Ce-141	2.62E+01	4.15E+01	4.09E+01(22.5%)
	1.69E+01	2.67E+01	3.23E+01(-3.29%)
	1.74E+01	2.75E+01	3.34E+01

[a]ORIGEN-2 with PWR library (Ma),
[b]ORIGEN-ARP with PWR library (Mb),
[c]ORIGEN-ARP with HANARO library (Mc),
[d]Relative Error of ORIGEN-2, (Ma-Mc)/Mc X 100,
[e]Relative Error of ORIGEN-ARP, (Mb-Mc)/Mc X 100.

TABLE II. Comparison of Radioactivity for the Fifth Irradiated Dry Process Fuel (Ci/tHM)

Case	Discharge	100 days cooling	200 days cooling	300 days cooling
A	2.21E+08	2.74E+06	1.38E+06	9.03E+05
B	2.10E+08	1.93E+06	9.44E+05	6.14E+05
C	2.04E+08	1.92E+06	9.20E+05	5.87E+05

A: ORIGEN-2 with PWR library,
B: ORIGEN-ARP with PWR library,
C: ORIGEN-ARP with HANARO library.