Comparison of Activation Analysis Codes between CINDER'90 and ORIGEN-S

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1. Introduction

A Slowing Down Time Spectrometer (SDTS) system is the most feasible technology among the non-destructive techniques to directly analyze the content of isotopic fissile material [1,2]. SDTS is necessary to a source neutron for inducing isotopic fissile fission. The source neutron is produced between the electron beam and a metal target by an (e,γ)(γ,n) reaction in the target. The target is required to have a high intensity neutron source through a proper target design. The status of activation on the designed target is analyzed through the activation code. Also, an activation evaluation of the material of the shielding facilities for SDTS system is required. The radioactivity intensity and kind of nuclides are measured through an activation analysis.

ORIGEN-S and CINDER'90 codes are an activation code and are used in combination with the MCNPX code. ORIGEN-S code interprets a problem as one point about target. It cannot describe the geometry. CINDER'90 code can describe a 3D-geometry, and the result of CINDER'90 has high reliability when using a multi-group library.

In this research, CINDER'90 was introduced as an activation analysis code and compared with the ORIGEN-S code. An activation analysis was conducted on the materials of the designed target. The ORIGEN-S and CINDER'90 code simulation results are provided for a selection of the activation analysis code.

2. Experimental Procedure

2.1 ORIGEN-S

ORIGEN-S is an updated version of the Origen code with flexible dimensioning and free-form input processing. One of the primary objectives in developing ORIGEN-S was that the calculations are able to utilize a multi-energy-group neutron flux and cross sections in any group structure. ORIGEN-S performs point depletion and decay analyses to obtain the isotopic concentrations, decay heat source terms, and radioactivity source spectra and strengths for use in subsequent system analyses [3].

2.2 CINDER'90

The cinder code began its evolution in 1960 by T. England at Bettis Atomic Power Laboratory (BAPL).

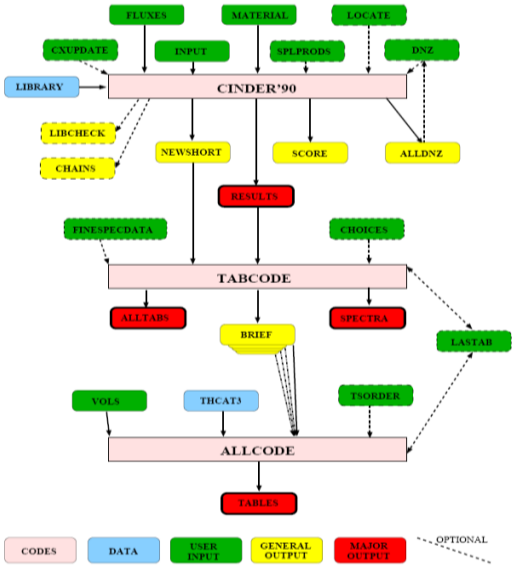


Fig. 1. Execution process of CINDER'90

Cinder'90 uses Markovian chains to determine the temporal densities of nuclides in a neutron environment. CINDER'90 was written in Fortran 90. It calculates the atom density, activity density, delayed -neutron production rate and cumulative SF, absorption, decay and (n, f) events for each nuclide in each time step. Cinder'90 tracks the time-dependent reaction of 3400 isotopes using an intrinsic cross section and decay data inherent in the cinder'90 code when the information is not specified from MCNPX. Cinder'90 library is made up of 3400 isotopes ($1 \leq Z \geq 103$), 1325 Fission products, and yield sets for over 30 actinides. Fig. 1 shows the progress of the CINDER'90 code [4].

2.3 Activation analysis simulation

The activation of neutrons irradiated at the target in the code was predicted. The material composition, average neutron flux of the total area, irradiation time, and source energy are required. The neutron flux in the target structure is calculated using the MCNPX code [5].

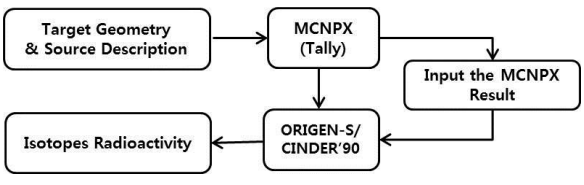
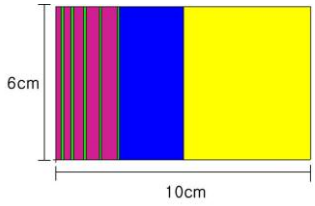


Fig. 2. Calculation procedure of CINDER'90 /ORIGEN-S

The results are applied to the ORIGEN-S and CINDER'90. Fig. 2 Shows the calculation procedure of the CINDER'90 and ORIGEN-S codes. Fig. 3 shows the target structure and material. It's a rectangular type. The target diameter is 6 cm and the height is 10 cm. The target is composed of tantalum, beryllium, and lead. Helium gas was used as a coolant. The irradiation time of the target is 10 hours. The cooling time is 30 mins, 1 hour, 1 day, 1 week, and 90 days. The incident electron energy is 30 MeV.



Target	Thickness(Cm)
1st(Ta)	0.2
2nd(Ta)	0.3
3rd(Ta)	0.4
4rd(Ta)	0.5
5rd(Ta)	0.6
6rd(Be)	2.5
7rd(Pb)	5
Coolants(He)	0.1

Fig. 3. Structure and material of the target

3. Simulation result

The results of radioactivity and created nuclides were compared in two different activation codes. Tables I and II show the activation results of the first layer tantalum. The activation results of CINDER'90 and ORIGEN-S codes difference the radioactivity intensity. However, the half-life of the nuclide was decreased proportionally. In the case of Ta-183, the radioactivity was similarly reduced during the cooling times. Tables III and IV show the activation results of lead. According to the two different activation codes, the radioactivity intensity of Pb-205 was different. However, nuclides Pb-209 and Bi-208 have a similar result of radioactivity intensity during the cooling times. The activation result s of the CINDER'90 code and ORIGEN-S code were similar or different according to the nuclides and consistent with the half-life of the nuclides.

Table I: Activation result of lead by CINDER'90

Unit : Ci

Nuclide	Cooling Time				Half-Life
	60min	1day	7day	90day	
Ta-180	3.01+09	4.26E+08	2.05E+03	5.65E-71	8.15 hours
Ta-182	1.42E-06	1.42E-06	1.37E-06	8.26E-07	114.4 days
Ta-183	1.17E-14	1.03E-14	4.54E-15	5.70E-20	5.1 days

Table II: Activation result of lead by ORIGEN-S

Unit : Ci

Nuclide	Cooling Time				Half-Life
	60min	1day	7day	90day	
Ta-180	1.64E+04	2.279E+03	1.07E-02	0.00E+00	8.15 hours
Ta-182	5.47E-03	5.44E-03	5.24E-03	3.17E-03	114.4 days
Ta-183	1.60E-10	1.41E-10	6.24E-11	7.87E-16	5.1 days

Table III: Activation result of lead by CINDER'90 code

Unit : Ci

Nuclide	Cooling Time				Half-Life
	60min	1day	7day	90day	
Pb-205	1.85E-28	1.85E-28	1.85E-28	1.85E-28	$1.53x10^7$year
Pb-209	8.30E-04	6.18E-06	2.92E-19	1.35E-203	3.253 hours
Bi-208	5.84E-24	5.84E-24	5.84E-24	5.84E-24	$3.68x10^5$year

Table IV: Activation result of lead by ORIGEN-S code

Unit : Ci

Nuclide	Cooling Time				Half-Life
	60min	1day	15day	30day	
Pb-205	1.54E-13	1.54E-13	1.54E-13	1.54E-13	$1.53x10^7$year
Pb-209	9.50E-04	7.07E-06	3.34E-19	0.00E+00	3.253 hours
Bi-208	1.21E-24	1.21E-24	1.21E-24	1.21E-24	$3.68x10^5$year

4. Conclusions

A Slowing Down Time Spectrometer (SDTS) system is a highly efficient technique in a nuclear material analysis. An activation analysis on the shielding and target material was required for the SDTS system. The activation results of CINDER'90 and ORIGEN-S codes were similar or different according to the nuclides because the cross section library of the codes is different. In utilizing the code, CINDER'90 code is more convenient than ORIGEN-S. It can describe the 3D-geometry, and therefore the activation information can be obtained by one simulation. The results of the activation code comparison are provided to select the activation analysis code.

5. ACKNOWLEDGMENTS

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