Delayed gamma energy analysis in KALIMER-600 by MCNP

Min-Ho Baek*, Won S Park, Sang-Ji Kim, Jeawoon Yoo
Korea Atomic Energy Research Institute, Daedeok-Daero 989-111, Yuseong, Daejeon 305-353
**Corresponding author: baekmh@kaeri.re.kr*

1. Introduction

Delayed gamma may not be a concern during the operation of reactor in terms of heat removal. However, delayed gamma becomes a key safety factor after shut-down of the reactor because most of the decay heat comes from delayed gamma. The strength and energy spectrum of the delayed gamma were derived in this report. In addition, delayed gamma energy flux and heat in the sodium cooled fast reactor core fueled with 20% enriched uranium were evaluated using MCNP.

2. Methods and Results

First of all, basic characteristics of delayed gamma were investigated and analyzed from the JAEA experimental data. Two types of methods were evaluated to handle external source problem in MCNP code for delayed gamma calculation. And delayed gamma was investigated about KALIMER-600 by using MCNP.

2.1 Mechanism

Two types of gamma were emitted when the fission event occurred. Prompt gamma was emitted before 50ns after fission event. After then delayed gamma was emitted after 50ns. Gamma ray emission mechanism is shown in Fig. 1.

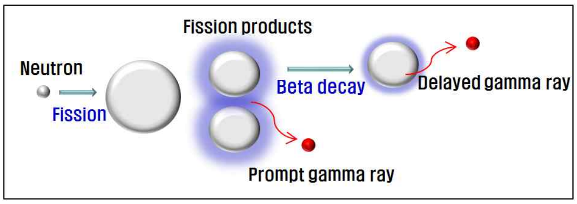

Fig. 1.gamma-ray emission mechanism

2.2 Review of basic characteristics

Delayed gamma energy spectra of main nuclides were fitted from JAEA experimental data as shown in Fig. 2.[2] It was showed similar trend at the low energy range and a little different at the high energy range. It can be explained that delayed gamma energy of U-238 has higher than another nuclides from the evidence that U-238 was highest among the nuclides at the high energy range.

Fig. 3. shows energy spectra of prompt gamma and delayed gamma. Prompt gamma energy spectrum was harder than delayed gamma spectrum although some references said that prompt gamma can be used instead delayed gamma.[1] Therefore if it is used prompt gamma instead delayed gamma for calculation, the result is over estimated.

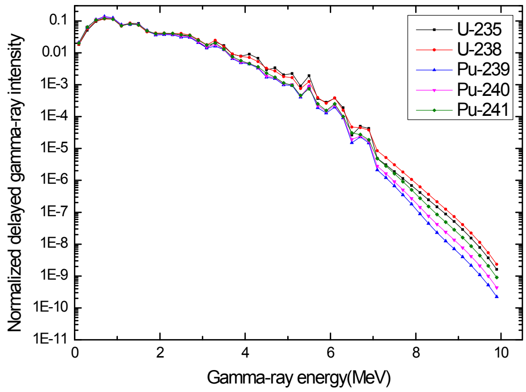

Fig. 2. Delayed gamma energy spectra of main nuclides

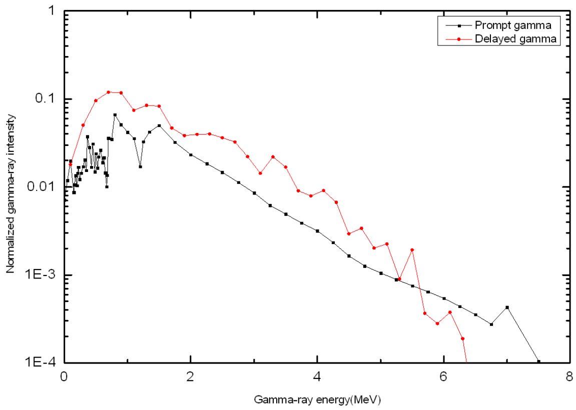

Fig. 3.Prompt gamma and delayed gamma energy spectra

2.3 Calculation model and method

A unit fuel assembly of KALIMER-600 core as calculation model was analyzed.[3] The calculation of delayed gamma was performed by using MCNP code. It was used ENDF/B-VI.6 as cross section library. Firstly, it was performed the KCODE calculation to know the space distribution of fission. After then, it was calculated the external source problem for delayed gamma calculation with writing the external source information in MCNP input directly.

2.4 Results

It was investigated the effect of delayed gamma heating according to power shape as shown in Table I. Case 1 was supposed that all pin power is 1.0 in core and case 2 was supposed that center ring, second ring and third ring's power is 1.3, 1.2 and 1.0, respectively.

Table I: Effect of delayed gamma heating according to power shape

(Unit : Mev/Fission)

Cases	Parameter	Flow Tube	Bottom Plug	Top Plug
Case 1	Flux	4.04E-1 (0.0002)	4.98E-2 (0.0012)	1.26E-8 (1.000)
	Heat (Mev)	9.012E-2 (0.0003)	9.66E-3 (0.0015)	3.17E-9 (1.000)
Case 2	Flux	3.96E-1 (0.0002)	4.98E-2 (0.0012)	2.30E-8 (0.7104)
	Heat (Mev)	8.85E-2 (0.0003)	9.66E-3 (0.0015)	5.049E-9 (0.73)

Although the neutron flux change was about 20%, delayed gamma change was about 1~2% in flow tube. The other places, delayed gamma change was very slight.

It was investigated about energy spectrum and heating of delayed gamma according to the region. Fig. 4. shows the high energy range of delayed gamma is rapidly decreasing where the place is far from fuel region. Also average delayed gamma flux is rapidly decreasing according to far from the center as shown in Fig. 5.

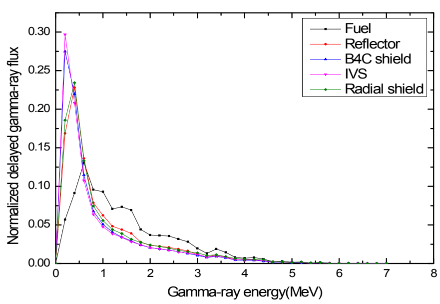

Fig. 4. Region-wise delayed gamma energy spectra

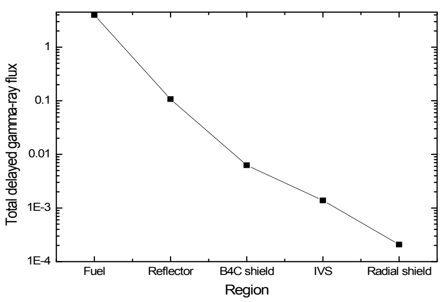

Fig. 5. Region-wise average delayed gamma flux

Table II. shows accumulated heating due to delayed gamma at a fission event according to region, respectively.

Table II: Region-wise total heating by delayed gamma

(Unit : Mev/Fission)

Region	Fuel	Reflector	B4C	IVS	R-Shield
Heat production at a fission event (MeV)	5.8655 (2.93%)	7.2868E-2 (0.0364%)	1.75211E-3 (0.0076%)	1.08474E-4 (0.00054%)	1.3753E-4 (0.00068%)

If it is supposed the fission energy of U-235 is about 200MeV, about 3% energy is deposited in the fuel region and the energy of non fuel region is very slightly deposited.

3. Conclusions

In this paper, delayed gamma was estimated about KALIMER-600 core by using MCNP. It was drawn following several conclusions from the calculation results. It is reasonable that the core power is same important, because that the effect of delayed gamma heating according to power shape did not show sensitive response. Region-wise delayed gamma spectrum at non fuel region is softer than fuel region and flux is rapidly decreasing far from the center. Also just 3% of total heating is deposited as delayed gamma at fuel region. The other region was shown that the effect is not sensitive from delayed gamma. From these conclusions, we can know the effect of delayed gamma is insignificant in KALIMER-600 core. But this study will be helped for accuracy calculation of shielding problem, estimation of decay heat and etc. Hence, for more detailed study, the calculation of shielding problem will be performed.

REFERENCES

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