Calculation of Radiation Shielding Performance for a Beam stopper of the Thermal-TAS at HANARO using MCNP6

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1. Introduction

The thermal neutron Triple-Axis Spectrometer (thermal-TAS) consists of various components. Roughly, it can be classified as a virtual source, neutron optics components, Monochromator Shielding Unit (MSU), Sample table and Analyzer & Detector bank.

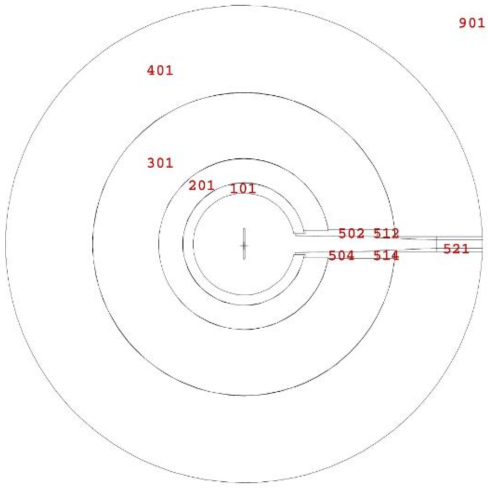
At a monochromator, specific wavelength of neutron beam is selected by the Bragg scattering theory. Because the neutron beam comes from reactor source has high intensity, massive shielding units are placed around monochromator. After monochromator, selected neutron beam goes toward sample table. At the sample table, the neutron beam is incident on a sample and diffracted. The diffracted neutron beam goes to Analyzer & Detector bank and the beam is analyzed and detected. This is a brief account of the Thermal-TAS experiment.

Previously, a conceptual design on a beam stopper was conducted.[3] The design was concentrated on neutron shielding performance only, and biological shielding was not considered because shielding walls consisting of heavy concreate had already been installed around the Thermal TAS. Nevertheless, another perspective of the beam stopper have been appeared by instrument scientists. It means that the beam stopper should be designed with perspective of neutron shielding and biological shielding. In this paper, calculation of radiation shielding, not only neutron but also gamma, on a beam stopper is conducted to determine the design specification as one of works on conceptual design of a new beam stopper.

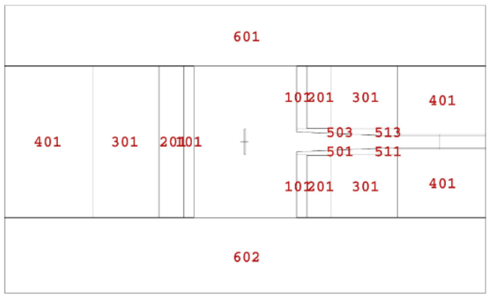
2. MCNP coding

2.1 Geometry modeling

Radiation shielding calculation has been conducted using MCNP6[1]. For the shielding calculation, simplified modeling has been conducted. Geometry modeling of MSU is absolutely same with previous research.[3] As presented in Fig. 2, the MSU consists of a borated epoxy shield(101), a cylindrical shield(201), a rotating disk(301), outer cover walls(400, 60x) and beam path segments(5xx). A cylindrical shield, a rotating disk and outer cover walls are made with heavy concrete and beam path segments are made with borate polyethylene. Fig. 3 shows a structure of the beam stopper. It is consisting of a lead block(701) and a boron carbide plate(702).

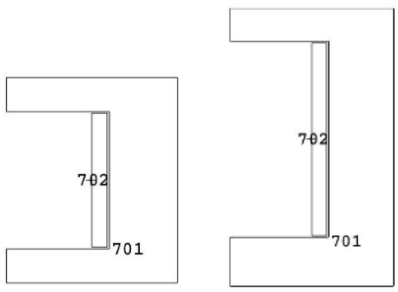


(a)



(b)

Fig. 1. MSU modeling in MCNP6. (a) is a horizontal and (b) is a vertical cross sectional view.



(a) (b)

Fig. 2. Beam stopper modeling in MCNP6. (a) is a horizontal and (b) is a vertical cross sectional view.

Table I: Composition of materials

Material	Composition. (Density)
Borated Epoxy	H: 25.81 %, B: 39.15 %, C: 23.75 %, N: 6.45 %, O: 4.84 %. (1.46 g/cm^3)
Heavy Concrete	H: 0.4476 %, B: 3.132 %, C: 0.868 %, O: 18.55 %, Si: 15:49 %, Ca: 3.5 %, Pb: 58 %. (5.7 g/cm^3)
Borated Poly - ethylene	H: 13.57 %, B: 5 %, C: 81.43 %. (1.6 g/cm^3)
Lead	Pb: 100 %. (11.34 g/cm^3)
Boron Carbide	B: 80 %, C: 20 %. (2.52 g/cm^3)

2.2 Source definition

Identical source information in previous research[3] is utilized for this shielding calculation. Generally, simulation results using MCNP6 can be utilized for simulations using McSTAS[2] as source data. However, results of McSTAS are not utilized in MCNP6 calculations as source data because McSTAS does not support radiation production simulations. Nevertheless, McSTAS simulation data is utilized to define source data for MCNP6 calculation because of bellowing 2 reasons.

The first reason is that gamma ray calculation result will not be considered. The thermal-TAS already has enough shielding walls to protect user and workers from gamma-rays. Also, gamma-ray does not affected on experimental results. The second is that there's no measured neutron flux data at the monochromator position. An energy distribution of radiation is necessary to define source in the MCNP6 but there's no measurement. Therefore, source data has been defined with a result of McSTAS simulation as 25-52 meV Maxwell distribution. (Peak at 32meV).

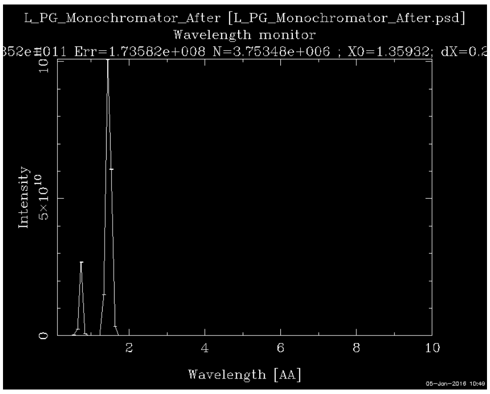


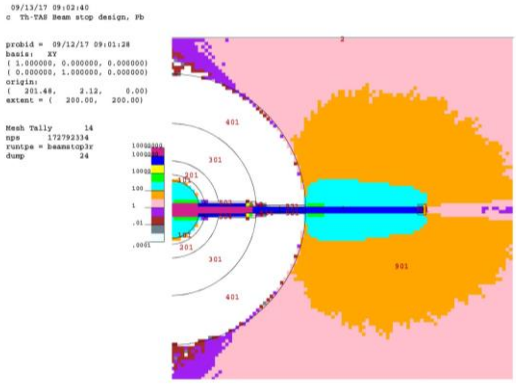
Fig. 3. A simulation result using the McTAS.

Above one is a result using McSTAS at the promptly after the PG monochromator when the take-off angle ($2\theta_M$) of that is 25 degree. In this case, the wavelength of neutron is approximately from 1.23 to 1.72Å.

3. Simulation result

A simulation was conducted to confirm the shielding performance. Mesh tally was utilized to confirm calculation result in visual data. Following figures show plot of the shielding calculation result in 2-D space using mcplot function of MCNP6. When neutron is passing arbitrary materials, neutrons can interact with the atomic nucleus of materials in specific probabilities. The probability is varied depends on the materials. As the result of interaction between neutron and nucleus of materials, the material has radioactivity. Because of that, secondary radiations are generated and emitted from the materials. Among the secondary radiations, neutrons and gamma rays were considered in this calculation.

Fig. 4 shows the calculation result for the neutron shielding performance. As shown in Fig. 4, the direct neutron beam is almost blocked by a beam stopper. After neutrons are passing the beam stopper, the count of neutrons are reduced by less than 100.



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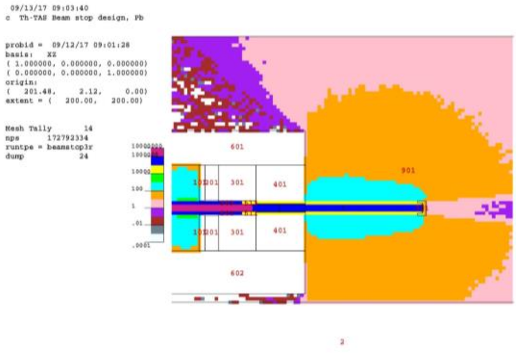
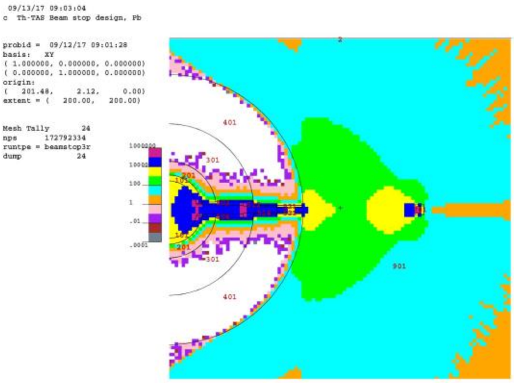


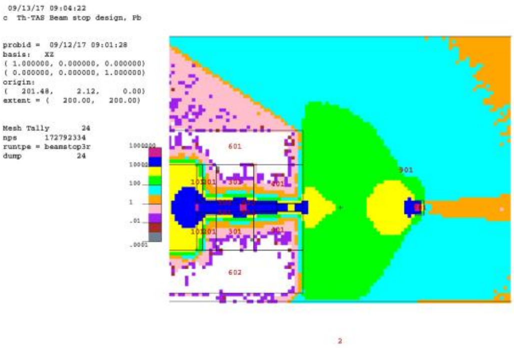
(b)

Fig. 4. Neutron beam shielding calculation using MCNP6. (a) is a horizontal and (b) is a vertical cross sectional view.

Fig. 5 shows the calculation result for gamma ray shielding performance. As shown Fig. 5, the gamma rays are almost blocked by a beam stopper similar to neutron result. After gamma rays are passing beam stopper, the counts are reduced by less than 100.



(a)



(b)

Fig. 5 Gamma ray shielding calculation using MCNP6. (a) is a horizontal and (b) is a vertical cross sectional view.

4. Conclusion

Calculation of radiation shielding performance on a new beam stopper for the Thermal TAS at HANARO was conducted. According to the instrument scientists, new beam stopper has shielding performance against neutrons and gamma rays. Using the calculation result, new beam stopper will be fabricated and installed on the thermal-TAS at HANARO.

REFERENCES

[1] MCNP6, A general monte carlo n-particle transport code, Los Alamos National Laboratory, http://mcnp.lanl.gov

[2] McSTAS, A neutron ray trace simulation package, DTU Physics, NBI KU, ESS, PSI and ILL, http://www.mcstas.org

[3] B. Jeon and J. Kim, Neutron Shielding Calculation of a Beam Stopper for the Thermal-TAS at HANARO using MCNP6, KNS Autumn meeting, 2016.