Calculation of Radiation Field for KOMAC with 20 MeV Acceleration Beam Line

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1. Introduction

The PEFP (Proton Engineering Frontier Project) is building the Korea Multipurpose Accelerator Complex (KOMAC). The KOMAC consists of a 100 MeV proton linear accelerator and various particle beam lines. Presently, 20 MeV proton acceleration equipments are being assembled. In this study, radiation distribution in the accelerator tunnel building are evaluated, and required shielding thickness are calculated for this 20 MeV beam line of the KOMAC using MCNPX code.

2. KOMAC Modeling

Inside of accelerator tunnel building was modeled with the MCNPX 2.5e. The beam acceleration part consists of injector, RFQ, DTL tank assembly and dump.

Injector produces 50 keV proton beam of 20 mA current. These protons are accelerated from 50 keV to 3 MeV in the RFQ. And 3 MeV protons are accelerated in the the DTL tank assembly. The DTL tank assembly consists of repeated tank units. In the current design, four units are repeated for acceleration of 20 MeV. The MCNPX model for the accelerator tunnel building of KOMAC with 20 MeV acceleration equipments are shown in Fig. 1..

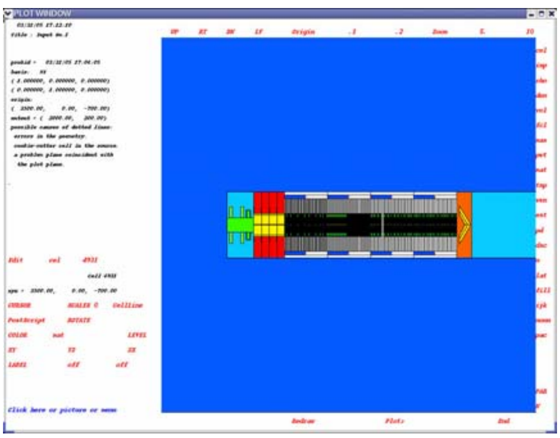

Figure 1. MCNPX Model for Accelerator Tunnel Building of KOMAC with 20 MeV Acceleration Equipments.

3. Simulation and Results

Radiation transport in the accelerator tunnel building is simulated with the model and proton beam source term using MCNPX code. The proton beam source terms is divided into two parts. First source term is mono-energy proton beam with 20 MeV. This proton beam directly impinges against 20 MeV beam dump from the end of the DTL Tank assembly. Second source term is the protons from loss in the acceleration. These escape from acceleration equipments. In the simulation, the cylindrical surface is modeled around acceleration line, and the source particle, proton, starts at this cylindrical surface with 1 W/m of proton beam loss. The proton has a direction of cosine distribution for normal vector of cylindrical surface. The energy of proton is in proportion to the distance of acceleration. Therefore, the energy of proton are in the range of 0~50 keV in the region of injector, and 50 keV ~ 3 MeV in the region of RFQ, and 3 MeV ~ 20 MeV in the region of DTL tank assembly.

3.1 Radiation Field Distribution Map

From the operating proton accelerator, radiation field are distributed around the accelerator equipments. These radiations are protons from beam loss, prompt radiation from reaction between proton beam and material of equipments, and delayed radiation from the activation. Therefore, the four kinds of radiations, such as neutron, photon, proton, and electron are considered in the simulation. The space in the accelerator tunnel building is divided to $5\times1\times1(X\times Y\times Z)$ m meshes. The average ambient dose for each mesh is calculated using the mesh tally cards of MCNPX code. In this simulation, the ambient doses equivalent from neutron, photon, proton and electron are calculated based on the ICRP-74.

The calculation showed that only neutrons and photons contribute to the dose distribution outside the acceleration equipments while protons and electrons were kept inside. The dose distribution map from this simulation is shown in Figure 2.

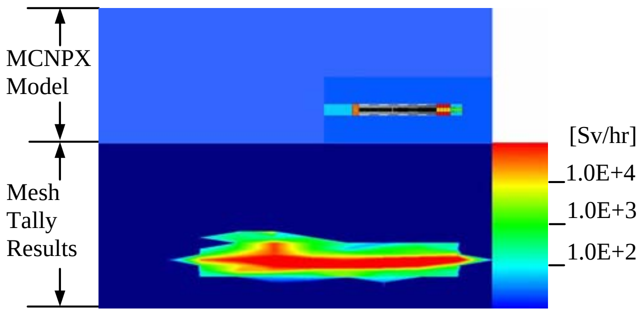

Figure 2. Ambient Dose Equivalent Distribution in the Accelerator Tunnel Building

The doses at the outer surface of the accelerator equipments ranges from 9.60×10^3 to 4.26×10^4 Sv/hr. The maximum dose rate is calculated near the 20 MeV dump. And the dose rate is 1.22×10^2 Sv/hr at the point 2m far from the 20 MeV dump.

3.2. Neutron Spectrum and Concrete shield thickness

The shielding against exposure is required for designing particle accelerator. The neutron spectra outside of the acceleration equipments are calculated to evaluate required concrete shield thickness. The neutron flux and spectrum are different for each calculation position. However, the spectrum at the point of maximum dose is needed in order to evaluate the required shield thickness.

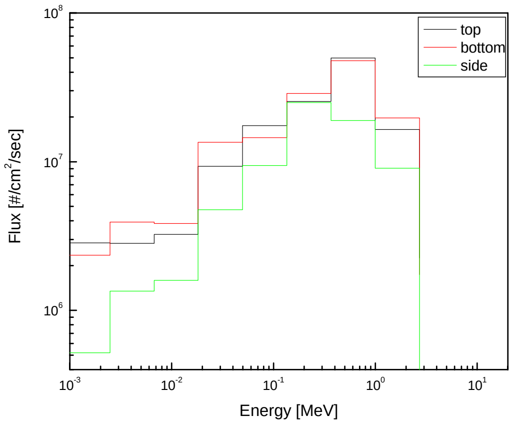

Figure 3. Neutron Spectrum from the 20 MeV Dump

The neutron spectrum in Figure 3. is from 20 MeV beam dump. The dose rate near the bean dump is higher than any other places. The maximum flux is 3.84×10^{12} cm2/sec at the ceiling over the dump. The exposure limit for the controlled area considering 1/2 design margin is 12.5 μSv/hr. Concrete shield of 158 cm thick is calculated to satisfy the exposure limit with evaluated neutron spectrum.

4. Conclusion

For the shielding of 20 MeV beam line of the KOMAC, radiation distribution in the accelerator tunnel building are evaluated and required shield thickness are calculated. This study will be extended to 100 MeV shielding design with additional modeling of the DTL tank assembly, as well as the shielding of 20 MeV beam utility.

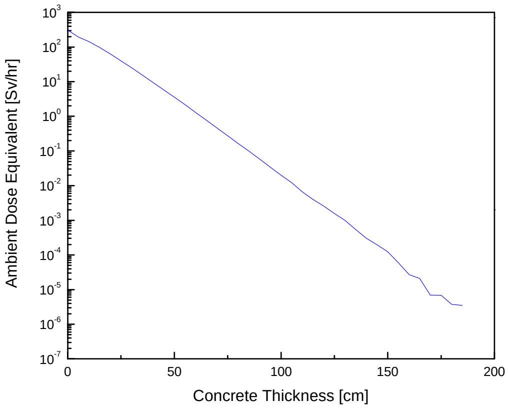

Figure 4. Dose Rate behind Concrete Shield Using Neutron Spectrum from the 20 MeV Dump

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