Shielding Design of Multi-View 9MeV X-Ray Imaging Facility for Cargo Container Inspection using Monte Carlo Method

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1. Introduction

The container inspection system is a device that inspects the interior of a container without opening the container using an X-ray. It has been mainly used for the smuggling of container cargo but recently it has been widely used to monitor terrorist material in order to prevent terrorism in the world. In general, the container inspection system for smuggling inspection may not accurately distinguish the object type depending on the shape of the object inside the container and the loading direction. Therefore, two X-ray imaging systems are currently used to acquire images for two views (direct and orthogonal) directions. However, the container scanner using this method has a higher cost than the scanner using one X-ray imaging system. As an alternative to this, a multi-view X-ray image acquiring device for container search for acquiring two images using one X-ray generating device is being developed in Korea research institute of ships & ocean engineering. In such inspection system, X-ray generated in a specific angular range is used instead of a fan beam type X-ray generally used. Therefore, it is required to design a shielding facility suitable for a multi-view X-ray image acquisition device. In this research the approximate shielding thicknesses of the primary and secondary barriers were set by referring to NCRP 49 and NCRP 151. The optimal thicknesses of the primary and secondary barriers for the maximum 9 MeV X-ray were calculated using MCNP6.

2. Methods

2-1. X-ray and radiation shielding facility model

In this research, to calculate the external leakage dose according to the wall thickness of the X-ray facility were analyzed by Monte Carlo N-Particle transport code (MCNP version 6, RSICC, Oak Ridge, TN). As shown in Figure 1, the shielding structure of the container inspection system is divided into an X-ray generator room, a detector room, and a container moving room. As shown in the figure, the distance between the X-ray generation position and the inner wall of the detector chamber is 16.4m, the inner height of the detector chamber is 10.52m, and the width is 7m. The material of the shielding facility is composed of a density of 2.35 g / cm^3. The generation of X-rays was generated by colliding electrons with a 3mm-thick tungsten target as shown in Figure 2. As shown in Figure 3, the distribution of X-rays was generated by using a 4 cm-thick tungsten collimator at 0 to 4 degrees right and left, – 8.5 to 15 degrees up and down. And the generated X-rays pass through the primary and secondary guide walls and are irradiated to the detector.

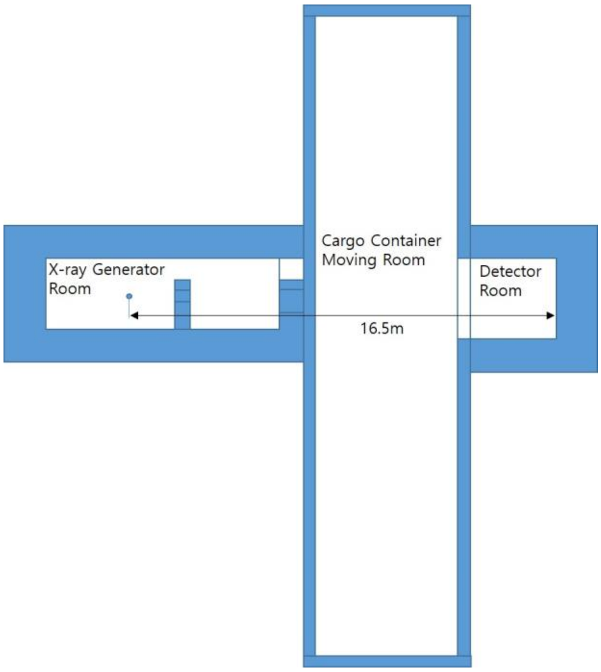

Figure 1. Internal design of container inspection system

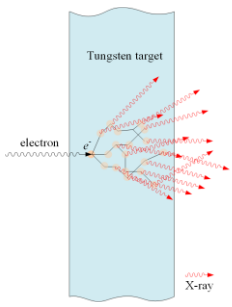

Figure 2. X-ray generation process using tungsten target

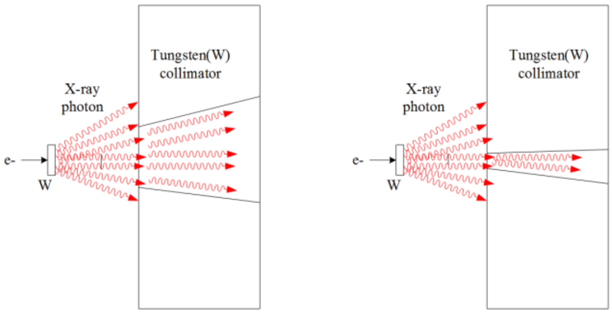

Figure 3. Tungsten collimator model at left and right 0 ~ 4 degrees and up and down -8.5 ~ 15 degree angle for limited angle X-ray beam generation

2-2 Calculation of external leakage dose using MCNP

The shielding calculation was performed on the first and second barrier of various thicknesses as shown in Figure 4. The thicknesses of primary and secondary barriers were set to 150 ~ 250mm and 50 ~ 150mm respectively. As shown in the figure, the survey position of the leakage dose of the primary barrier was measured at the same position as the center point of the X-ray source. And the leakage dose of the secondary barrier was measured at the outer wall of the detector chamber. Leakage dose calculation using MCNP was performed using F5 tally, and ICRP-20 provided by MCNP was used for gamma conversion factor. And 0.1 mA of the tube current of the actual generator.

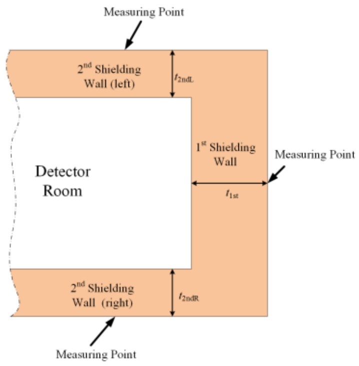

Figure 4. Detector room model for calculating leakage dose using MCNP

3. Results

Figure 5. shows the variation of the leakage dose according to the detector chamber first and second wall thicknesses. As shown in Figure 5. (a) and (b), the thicknesses of primary and secondary barriers should be more than 200cm and 100cm, respectively, to satisfy the allowable dose of radiation workers (10 μSv / h).

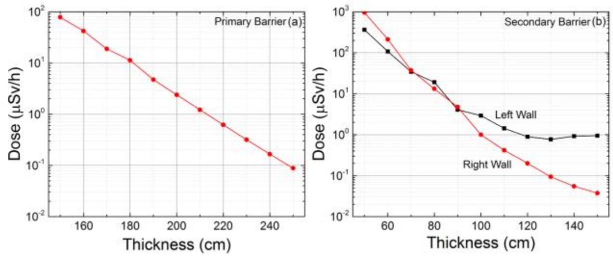

Figure 5. Primary (a) and Secondary (b) Leakage dose surveys according to wall thickness variation

3. Conclusion

This research was conducted to determine the thickness of the most critical part of the 9 MeV X-ray to meet the design criteria.
When the calculation results of this study are satisfied, the annual maximum exposure dose of the worker is much smaller than the recommended value and satisfies the design criteria.
The safe and efficient thickness shall be determined taking into account the maximum operating time of the X-ray system.

REFERENCES

[1] MCNP6 User's Manual, Version 1.0, LA-CP-13-00634, Los Alamos National Laboratory, May 2013
[2] NCRP REPORT No. 49 Structural Shielding Design and Evaluation for Medical use of X Rays and Gamma Rays of Energies up to 10 MeV, September 15, 1976
[3] NCRP REPORT No. 151 Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities, December 31, 2005