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Comparison of 10B4C Neutron Monitors of Various Type for Nuclear Material Inspection in Cargo Container Using Monte Carlo Simulation

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1. Introduction

Generally, the He-3 is mainly used as a reactant of a neutron monitor for detecting nuclear material inside a cargo container truck. However, the supply of He-3 has decreased since several years due to various reasons. Therefore, studies are being conducted to develop various alternative neutron detectors by many researching groups. Among the various neutron reactants, B-10 is suitable for use as an alternative neutron detection material due to its many advantages [1]. However, in the case of the neutron detection method using B-10, it is necessary to make the B-10 thin because the path length of secondary radiations for signal detection is short in dense material. Therefore, to increase the neutron detection capacity, the neutron detector must be constructed in a multi-layer B-10 structure and is designed to optimal structure [2]. In order to design an optimal structure, neutron detection capacity for various type neutron monitor should be calculated. The aim of this study is to calculate the neutron detection capacity of neutron monitor of various geometrical type for nuclear monitoring in cargo container using Monte Carlo simulation code.

2. Methods and Results

2.1 Monte Carlo Simulation Model

In order to calculate the neutron detection capacity, Monte Carlo simulation was performed using Monte Carlo N-Particle Transport Code (MCNP, version 6,

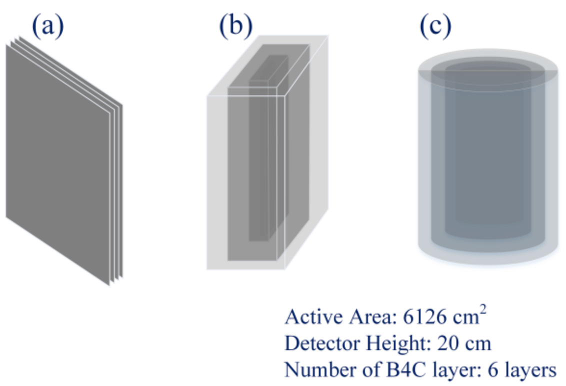

Fig. 1. Neutron monitor models of three type; (a) planar type, (b) rectangular type, and (c) cylindrical type

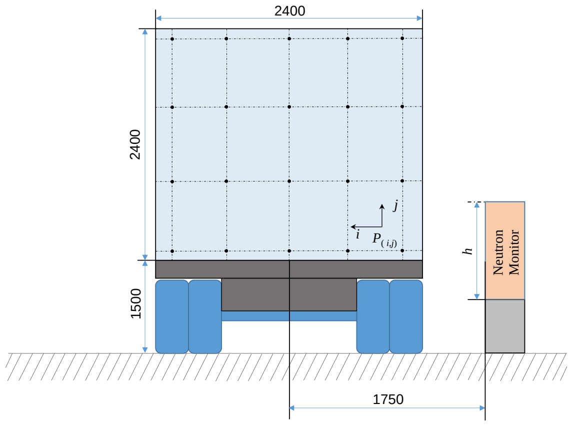

Fig. 2. Neutron source generation point and monitor install position in simulation model; the distance between center source point in *i* direction and detection surface is 1.750 m. The neutron monitor of 2 m height (h) is located at 1 m above the ground.

LANL, USA). In this simulation model, the thickness of thin film and the number of film layer were designed 2 um thickness and 6 layers. In order to collect secondary particles, argon based mixed gas was used. And the thin film in the neutron monitor simulation model was consist of 10B4C containing B-10. As shown in Fig. 1, the neutron detection capacity of three different models was calculated using simulation tool. Fig. 1 (a) describes the planar type monitor. Second and third are monitors of rectangular and cylindrical type as presented in Fig. 1 (b), (c). Size of the active area of monitors is the same and they consist of 6 layer 10B4C thin film. In order to conduct simulation of the neutron

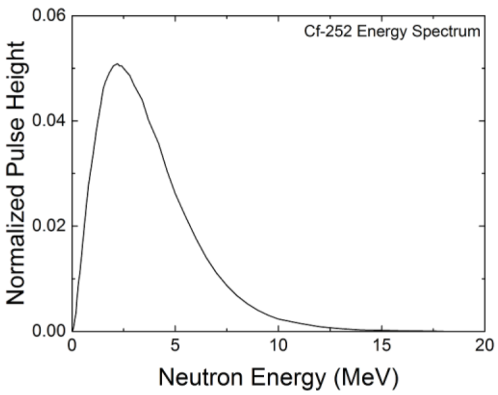

Fig. 3. Cf-252 neutron energy spectrum model

transfer process inside the neutron monitor models, Cf-252(1 ng) was used as a neutron source. Fig. 3 presents the energy spectrum of Cf-252 source model that has used at the simulation. Also, in order to increase the neutron detection capacity of monitors, a 1-inch-thick HDPE (High Density Polyethylene) was used for neutron moderating in the simulation.

In the simulation, the positions of the neutron sources are 16 points, and their coordinates were set at 50 cm intervals in the horizontal and vertical directions as shown in Fig. 2. The neutron detection capacity of monitors was calculated as the average of simulation results for each sources, as shown in the following equation

$$\overline{R}(P_d) = \frac{\sum_{i=1}^{i=n}\sum_{j=1}^{j=m} R_{ij}}{n \times m} \quad (1)$$

Here *i* and *j* present the source position coordinates of horizontal and vertical direction. *P* indicates the location of the source from 0 to 500 cm in the direction of cargo container truck movement. The simulation history was 10^7 and neutron detection capacity was calculated using F8 pulse height tally in MCNP6.

2.2 Result

Fig. 4 is the result graph of simulation. As a result of the simulation, it was confirmed that the planar type monitor has higher neutron detection capacity than the cylindrical and rectangular type monitors, and the cylindrical type detector was two time higher than rectangular type detector. The difference between the neutron detection capability of the planar type monitor and the cylindrical type monitor decreased as the distance increased and there was small difference when the source position was more than 4.5m as shown in Fig. 4.

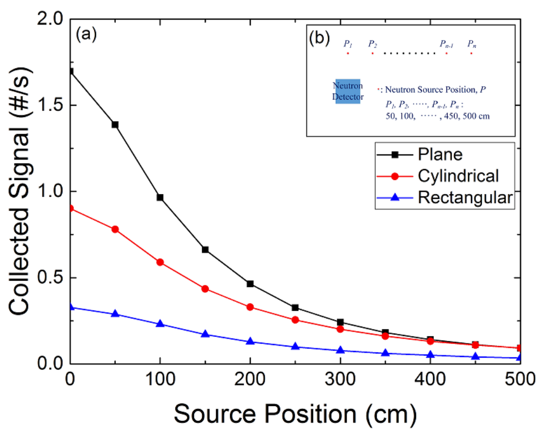

Fig. 4. Change curve of collected neutron signal according to change of source position.

3. Conclusions

In this study, we have been calculated the detection capacity of 3 type neutron monitor for cargo container nuclear inspection using Monte Carlo simulation code. According to result, planar type neutron detector, which has the multi-layer B4C thin film, was useful for optimizing the cargo container neutron detecting system. As shown in result, we could confirm that the neutron detection capacity of monitor depends on the solid angle of incident neutron as well as reaction area of detector through this study.

REFERENCES

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