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Calculation of the Skyshine Radiation Measurement Experiment in Kansas by PHITS/PHITS によるカンザスでのスカイシャイン線測定試験の線量評価

Kansas State University measured exposure dose from skyshine radiation using ^{60}Co sources at Kansas in 1977 [1]. Mitsubishi Nuclear Fuel (MNF) performed calculation of this experiment with a three-dimensional Monte Carlo code PHITS v3.24 (Particle and Heavy Ion Transport code System), which is developed by JAEA [2].

For nuclear facilities, it is necessary to calculate the exposure dose objective to public which is calculated direct and skyshine radiation. Direct radiation is gamma rays emitted from the ^{60}Co source that penetrate the shielding wall and reach the detector location directly. Skyshine radiation is gamma rays emitted from the ^{60}Co source that penetrate the relatively thin ceiling, are reflected in the sky, and reach the detector location. The analysis method for the skyshine radiation is adopted the single-scattering calculation method which is used by G33 code. For the skyshine calculation of the MNF facilities, G33 code or Pre-GAM/S code, which has equivalent performance, is used.
However, the single-scattering calculation method has the disadvantage that it cannot correctly calculate the effect of attenuation of gamma rays for a concrete ceiling condition. In addition, due to the characteristics of the calculation method, it cannot accurately simulate the geometry of the analysis system. Furthermore, gamma rays that are scattered multiple times in the sky cannot calculated.

A solution of this situation is to use a Monte Carlo code in three dimensions that can handle a wide variety of geometries, and PHITS code can treat accurate model geometries. The radiation behavior can be correctly analyzed by applying a relatively accurate geometry model.
However, PHITS code makes the analysis more complicated. In particular, the shielding analysis, in which the number of particles decreases due to transmission through concrete and other materials, has a large uncertainty. And large number of histories is necessary to obtain sufficiently reliable analysis results. Recent advances in computers have made it possible to achieve this.

In this study, MNF performed a calculation of the skyshine measurement experiment and found that PHITS code can predict results in ±10% error between experiment and calculation.
In contrast, the conventional code, G33 overestimated the results of the experiment by about five times.
This result confirms that PHITS code can simulate the skyshine measurement experiment more accurately than G33 code.
In the future, MNF expects to improve the accuracy of shielding calculation changing the analysis code to PHITS. As a result, more rational shielding design will be expected.

References

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