Analysis of Radiation Field Distribution in Yonggwang Unit 3 with MCNP Code

Cheol Woo LEE,[a] Wi-Ho HA,[a] Chang-ho SHIN,[a] Soon Young KIM,[b] Jong Kyung KIM,[a]
a Dept. of Nuclear Engr, Hanyang Univ., 17 Haengdang, Seongdong, Seoul,133-791, Korea,
peng@nural.hanyang.ac.kr
b Innovative Technology Center for Radiation Safety, Hanyang Univ.,17 Haengdang, Seongdong, Seoul 133-791, Korea

1. Introduction

Radiation field analysis is performed at the inside of the containment building of nuclear power plant(NPP) using the well-known MCNP code. The target NPP in this study is Yonggwang Unit 3 Cycle 8. In this work, whole transport calculations were done using MCNPX 2.4.0 due to the functional benefits, such as Mesh Tally, that the code provides. The neutron spectra released from the operating reactor core were firstly evaluated as a radiation source term, and then dose distributions in the work areas of the NPP were calculated.

2. Modeling and Calculation

2.1 Evaluation of the Neutron Source Term

In order to estimate the source term, Yonggwang Unit 3 Cycle 8 core was explicitly modeled including baffle, barrel, thermal shield, and pressurizer vessel. The core was modeled at beginning of cycle, hot full power, and all rods out conditions. Criticality calculation was performed with the KCODE option in MCNPX code to obtain k_{eff} value of the system and relative power distributions. As a result of the KCODE calculation, it is found that k_{eff} converged to 1.00937 ± 0.0002 and the RMS error of power distribution in each assembly against Nuclear Design Report was 0.0251. With this model, the neutron spectra distributed in outer surface of pressure vessel were evaluated.[1] The neutron spectra were used as a radiation source in the next transport calculation.

2.2 Modeling of Containment Building

Modeling of the containment building should be performed as close to the real structure as possible based on FSAR and ISO drawing, because the structure of the building is very complex and large. Main targets of the modeling are the work areas in the height level of 86~100, 100~122, 122~142, and 142~150 ft from the bottom of containment building. The primary and secondary shield concrete structures were modeled as described in FSAR. Since there are various structures in the containment building, steam generator, pressurizer, and reactor coolant pump(RCP) were preferentially modeled, which are the very important structures to radiation dose calculation. Since each of the components has the complicated design and material compositions, the compositions inside of those components were homogenized based on FSAR and ASME code. Figure 1 shows the MCNP modeling for the containment building of Yonggwang Unit 3 in this study.

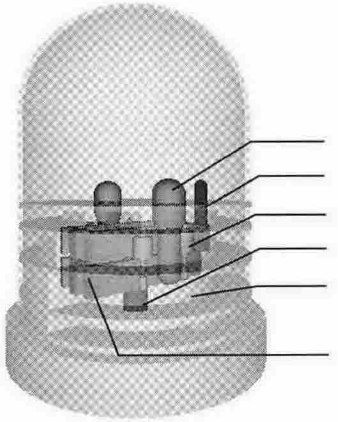
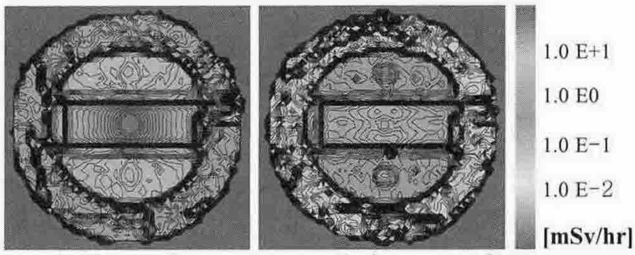


Figure 1. MCNP Model of the Containment Building of Yonggwang Unit 3

2.3 Calculation of Dose Distributions

The dose distributions from neutron and neutron induced gamma-ray were calculated in the containment building to analyze the radiation field distribution.[2] The space in the containment building was divided by 1×1 m mesh along X-Y coordinates in each height level of z-coordinate, 86~100, 100~122, 122~142, and 142~150 ft. The dose calculation was carried out for each mesh using the track average tally option and ICRP-74 ambient dose equivalent supported by MCNPX 2.4.0. The dose distributions were mapped using the results and the maps are shown in Figures 2 ~ 4.

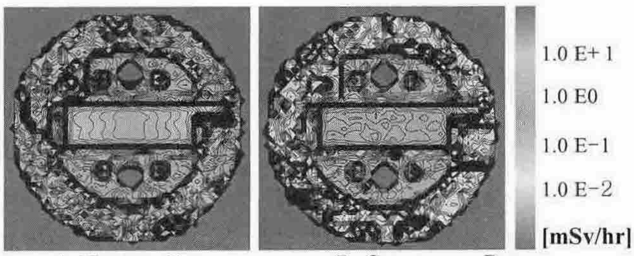
The Figures show the neutron and gamma-ray dose distribution in the work areas which were divided into three regions along the z-axis. Figure 2 shows the dose distribution at the work area in the height level of 100 ~ 122 ft. In this region, the reactor functions as a radiation source. At the center of dose map, high dose region with red color is the reactor. The rectangular bar around the reactor is the primary shield concrete structure. Because the black line is drawn to connect the locations in which the same dose level was formed, the black lines were drawn densely in the concrete shield. In this region, the dose is distributed from 19.01 to 82.9 mSv/hr for neutron and from 0.861 to 1.78 mSv/hr for gamma-ray. The round shape at the outside of the primary concrete shield is the secondary concrete shield. In the secondary shield region, the dose is distributed from 0.320 to 5.06 mSv/hr for neutron and from 0.023 to 0.0964 mSv/hr for gamma-ray. The outer round shape represents the containment building wall.



A. Neutron Dose B. Gamma-ray Dose

Figure 2. Dose Distribution in the Level of 100~122 ft in Containment Building

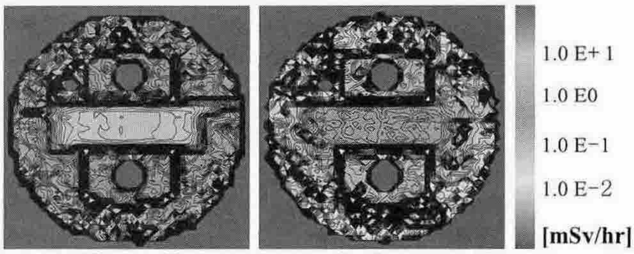
Figure 3 shows the dose distribution at the work area in the height level of 122 ~ 142 ft. this region contains steam generator, RCP, pressurizer, etc. In the primary shield, it is shown that the dose distribution was ranged from 14.2 to 36.8 mSv/hr for neutron and from 0.285 to 0.841 mSv/hr for gamma-ray. In the secondary shield, the dose distribution was so complicated because of the components in the containment building. The small round shapes in this region represent the components. In the around of the steam generator, the dose is distributed from 0.179 to 20.7 mSv/hr for neutron and from 0.101 to 0.142 mSv/hr for gamma-ray. The high dose region located at the right side of the map is the fuel transfer tube equipments which have not primary and secondary shield concrete. In this region, the dose is distributed from 6.59 to 17.7 mSv/hr for neutron and from 0.116 to 0.480 mSv/hr for gamma-ray.



A. Neutron Dose B. Gamma-ray Dose

Figure 3. Dose Distribution in the Level of 122~142 ft in Containment Building

Figure 4 shows the dose distribution at the work area in the height level of 142 ~ 150 ft. This region contains only the concrete shield around the steam generator. In this region dose level is lower than that in the previous regions, because this region is far from the reactor. In the steam generator room, the dose is distributed from 11.3 to 18.8 mSv/hr for neutron and from 0.146 to 0.496 mSv/hr for gamma-ray. In the region along the outer surface of steam generator room, the dose is distributed from 0.256 to 6.68 mSv/hr for neutron and from 0.00238 to 0.0169 mSv/hr for gamma-ray.



A. Neutron Dose B. Gamma-ray Dose

Figure 4. Dose Distribution in the Level of 142~150 ft in Containment Building

3. Conclusion

In this study, radiation distribution analysis is performed with the well-known MCNP Code. As the results, the information on the radiation distribution was obtained through the whole space in the containment building of Yonggwang Unit 3 Cycle 8. This study also shows the effects from the various components. It can be expected that the results from this work can support the radiation field analysis of NPP which has been relied upon solely measurements.

Hereafter, the comparison with measurements should be performed to analyze radiation field distribution more accurately.

Acknowledgement: This study was performed under the long-term nuclear research and development program sponsored by Ministry of Science and Technology of Korea, and supported by the Innovative Technology Center for Radiation Safety(iTRS).

REFERENCES

[1] KEPRI, "Neutron Spectrum Analysis inside a Reactor Building of Nuclear Power Plant," TR.96NS11.S1998.55, Korea Electric Power Research Institute (1998).

[2] Chol Woo LEE, "High-Level Radiation Field Analysis Using Monte Carlo Simulation in Kori Nuclear Power Plant Unit 1," Journal of Nuclear Science and Technology, **Supplement 4**, 90 (2004).