Verification of Results with MCNP for TRITON Usability to Speed up Magnox Plutonium Quality Evaluation

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1. Introduction

DPRK has been producing and upgrading nuclear weapons from the past to the present, and it is observed that the Yongbyon 5MWe reactor for reprocessing is still active recently. Accordingly, not only nonproliferation experts but also ROK continue to study analysis and scenarios to predict DPRK's fissile material production. KINAC conducted a study to analyze the 5MWe reactor in Yongbyon based on MCNP and studied the several reactor operation scenarios. As the MCNP calculation is evaluated as accurate, However, there is a disadvantage in that it takes a lot of time to calculate the reactor. In this study, the analysis results using the 2-D depletion calculation code SCALE TRITON were compared and verified with MCNP to quickly respond to pending issues and estimate DPRK's fissile material production within a reasonable time.

2. Code Calculation

MCNP was calculated in one cycle for the quadrant core, with an initial heavy metal charge of 50 tons and natural uranium used. DPRK's Yongbyon 5MWe reactor program is estimated to be operated unstably, but it is known that the reactor is operated based on 600 to 800 GWd/MTU. In this study, the results of depletion calculation up to 1000 GWd/MTU were compared to the U/Pu index used to estimate burnup and Pu quality (Pu-239/Pu, Pu239+Pu241/Pu).

SCALE TRITON, which was used as the 2-D depletion calculation code (cross-section processing, transport, and depletion), was calculated for a single cell for reflective condition using the ENDF/B-VII.1 252 energy group library provided in SCALE 6.2. The depletion was conducted with the burnup steps 20, 40, 60, 80, 100, 200, 400, 600, 800, and 1000 GWd/MTU. The detailed specifications used in the SCALE TRITON calculation performed in this study were the same as the MCNP input value. Although there is a library of TRITON calculations for MAGNOX in SCALE 6.2 ORIGEN, the library model is CALDER HALL in the UK, so there is a difference in detailed specifications from DPRK's MAGNOX reactor.

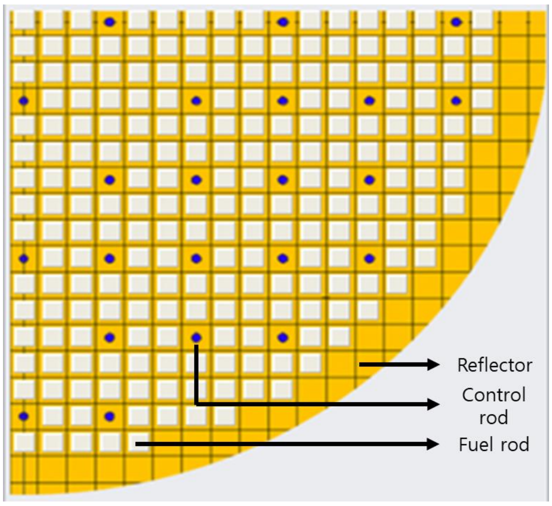

Fig. 1. MATMAN (Modeling and Analysis Tool for Magnox using MCNP) Modeling for the 5 MWe Magnox

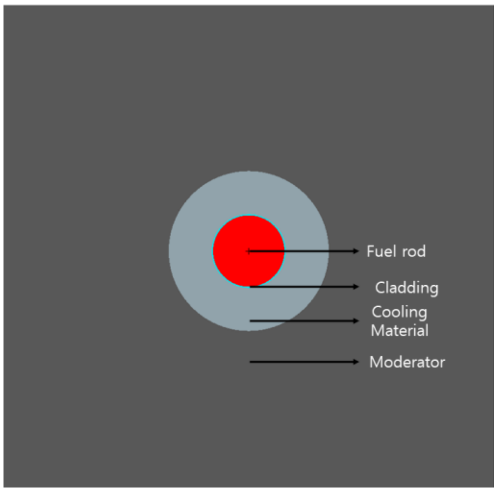

Fig. 2. SCALE TRITON Modeling for the 5MWe Magnox

3. Results

The Pu quality evaluation was performed by comparing the mass ratio of Pu-239 and Pu-241 to the total Pu isotope and Pu-239 to the total Pu isotope. As shown in Figures 1 and 2, as it is known that the production of plutonium is proportional and the quality is inversely proportional as the burnup increases, the quality of plutonium tends to decrease almost linearly as the burnup increases. Also, Pu-239 and Pu-241 quality evaluation error rate between the two codes fits very well at less than 1% in the evaluated ten burnup steps. In addition, Also, it can be confirmed that the error in the result of the U/Pu value, which can be used as an index of burnup estimation, was reliable within about 5-7%.

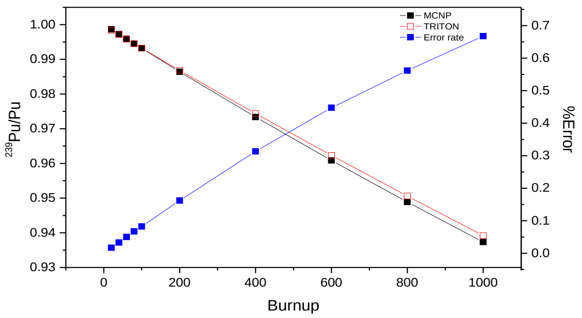

Fig. 3. Comparison of Pu-239 mass to total Pu isotope mass and error rate (MCNP6, SCALE 6.2 TRITON)

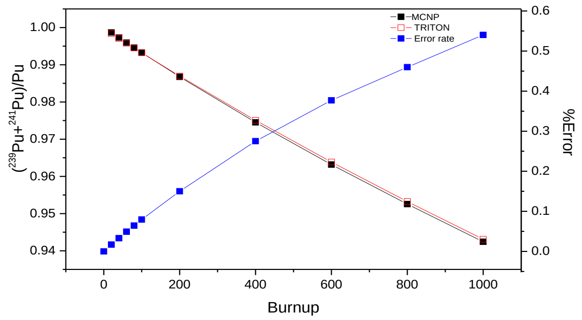

Fig. 4. Comparison of Pu-239 and Pu-241 mass to total Pu isotope mass and error rate (MCNP6, SCALE 6.2 TRITON)

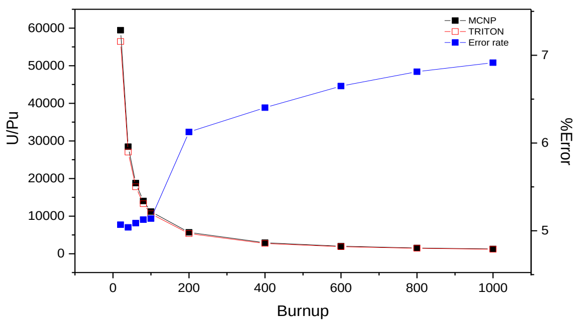

Fig. 5. Comparison of total U isotope mass to total Pu isotope mass and error rate (MCNP6, SCALE 6.2 TRITON)

4. Conclusion

The purpose of this study was to verify the performance with the SCLAE TRITON results on the MCNP code analysis results in order to respond quickly to pending issues. The results of the two codes were compared and verified for the Pu fissile mass ratio to the total Pu isotope mass determining Pu quality and the U isotope mass ratio to the Pu isotope used to estimate burnup. The results of the analysis comparison were evaluated to be sufficiently usable to respond to pending issues as an analysis code that could reduce time while satisfying a reasonable level of accuracy.

ACKNOWLEDGMENTS

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REFERENCES

[1] G. H. Park, S. G. Hong, An estimation of weapon-grade plutonium production from 5 MWe YongByon reactor through MCNP6 core depletion analysis, Progress in Nuclear Energy, Vol.130, 2020.
[2] Siegfried S.Hecker, Chaim Braun, Chris Lawrence, North Korea's Stockpiles of Fissile Material, Korea Observer, Vol.47, No.4, pp 721-749, Winter 2016.
[3] B. T. Rearden and M.A. Jessee, Eds., SCALE Code System, ORNL/TM-2005/39, Version 6.2.3, Oak Ridge National Laboratory, Oak Ridge, Tennessee (2018).