Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2015

Comparative Criticality Analysis of Two Monte Carlo Codes on Centrifugal Atomizer: MCNP5 and SCALE

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1. Introduction

There are two well-known Monte Carlo codes for criticality analysis, MCNP5 and SCALE. MCNP5 is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron or coupled neutron / photon / electron transport, including the capability to calculate eigenvalues for critical system[1] as a main analysis code. SCALE provides a comprehensive, verified and validated, user-friendly tool set for criticality safety, reactor physics, radiation shielding, radioactive source term characterization, and sensitivity and uncertainty analysis[2]. SCALE was conceived and funded by US NRC to perform standardized computer analysis for licensing evaluation and is used widely in the world[2]. Therefore, we choose the SCALE as sub analysis code.

The centrifugal atomizer is one of fuel fabrication facilities for HANARO and other nuclear research reactors.

In this paper, we presented the results of the criticality analysis on centrifugal atomizer to confirm the safety of that process and to validate two codes.

2. Methods and Results

2.1 Validation of MCNP5

2.1.1 Statistical reliability[3]

In the criticality analysis, the number of source histories per cycle is used 10,000, which is 10 times greater than the number used generally in the Monte Carlo critical analysis. This value is determined to be uniformly distributed the sources sampled from one cycle of criticality analysis throughout the calculation area and to decrease the calculation variation.

The number of active cycle is 500 and the number of inactive cycle is 50. Five million sources, which are 10,000 times 500, give the statistically enough reliability on criticality analysis results.

2.1.2 Uncertainty

Table 1 shows the statistical uncertainty of MCNP5 validation analysis.

In this critical analysis, we choose the maximum design value reflecting the production tolerance without any consideration of uncertainty.

Table 1: Statistical uncertainty [3]

k_{eff}	Calculation bias	Bias uncertainty	Standard deviation
1.00395	0.003949	±0.01674	±0.00069

The sum of the calculation bias, uncertainty bias and standard deviation is 0.021379.

2.2 Subcritical conditions

The result of critical safety analysis must meet the following two requirements of the safety review guidelines [4,5,6].

◦ Optimum Neutron Moderation Conditions: The effective multiplication factor (k_{eff}) must be less than 0.98 at 95% confidence interval with 95% probability.
◦ Flooding conditions: The effective multiplication factor (k_{eff}) must be less than 0.95 at 95% confidence interval with 95% probability.

The final effective multiplication factor, added the uncertainty due to the production tolerance and uncertainty of the computer code itself to the effective multiplication factor calculated in the optimum reduction conditions, should meet the criteria.

2.3 Comparative analysis

We performed the comparative analysis for the results from critical analysis using MCNP5, SCALE4.4 CSAS26 module(KENO-VI) and SCALE version 6.1. Followings are considered the comparative analysis in this paper.

◦ Comparative analysis of SCALE 6.1 and SCALE 4.4, which is the code version used in the safety analysis report approved by regulatory agency for same centrifugal atomizer.
◦ Comparative analysis of MCNP5 and SCALE 6.1

The input parameter is assumed of same for the each analysis. The results of comparative analysis are summarized in Table 2. The criticality values analyzed using SCALE 6.1 are mostly lower than using SCALE 4.4 and the deviation between them is -2.65 to 1.39%.

The criticality values analyzed using MCNP5 are mostly higher than using SCALE 4.4 or SCALE 6.1 and the deviation between them is -0.72 to 10.27%.

Assuming double batch and triple batch, the k_{eff} is increased by 20% for in-melting condition and 26~34% for after-melting condition. However, k_{eff} values analyzed for all hypothetical conditions meet the requirements of the safety review guidelines.

Table 2: Criticality analysis results

Condition		$k_{eff}\pm2\sigma$		
		SCALE4.4 CSAS26	SCALE6.1 CSAS26	MCNP5
Normal	Before melting	0.35876	0.34925	0.3956
	In melting	0.39982	0.39645	0.41834
	After melting	0.38955	0.38295	0.39447
	Chamber/ Container	0.35577	0.35401	0.37657
Flooding	Before melting	0.68370	0.69318	0.7044
	Chamber/ Container	0.51037	0.49727	0.50667
Double batch	In melting	0.47755	0.47780	0.5052
	After melting	0.46289	0.46019	0.47511
Triple batch	In melting	0.53881	0.52990	0.56002
	After melting	0.50940	0.50826	0.53396

3. Conclusions

We performed a validation test of MCNP5 and a comparative analysis of Monte Carlo codes, MCNP5 and SCALE, in terms of the critical analysis of centrifugal atomizer.

In the criticality analysis using MCNP5 code, we obtained the statistically reliable results by using a large number of source histories per cycle and performing of uncertainty analysis.

MCNP5 code produces the more conservative result than SCAE codes, but k_{eff} values, which is analyzed for all hypothetical conditions of centrifugal atomizer, meet the requirements of the safety review guidelines

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