Annals of Nuclear Energy 90 (2016) 205–211

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Real variance analysis of Monte Carlo eigenvalue calculation by McCARD for BEAVRS benchmark

Ho Jin Park [a], Hyun Chul Lee [a,*], Hyung Jin Shim [b], Jin Young Cho [a]

[a] Korea Atomic Energy Research Institute, 111, Daedeok-daero 989-beon-gil, Yuseong-gu, Daejeon 305-600, Republic of Korea
[b] Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-744, Republic of Korea

ARTICLE INFO

Article history:
Received 3 July 2015
Received in revised form 13 October 2015
Accepted 14 December 2015
Available online 28 December 2015

Keywords:
McCARD
Real variance
Apparent variance
BEAVRS
History-based batch method

ABSTRACT

The real variances of local tallies, such as the pin-wise and assembly-wise fission powers, were estimated for the Benchmark for Evaluation and Validation of Reactor Simulations (BEAVRS) fresh core problem using real variance estimation methods implemented in the Seoul National University Monte Carlo (MC) code, McCARD. This code employs Gelbard's batch method, Ueki's method, the fission-source distribution inter-cycle correlation method, and the history-based batch method. Results show that the estimated apparent variances of the local tallies tend to be smaller than the real one, whereas the apparent variance of a global MC tally such as the effective multiplication factor is similar to the real one. Moreover, it was observed that the real-to-apparent standard deviation (SD) ratio of the assembly-wise fission power is larger than that of the pin-wise fission power. The large real-to-apparent SD ratio of the former is explained by considering the correlation coefficients between the local tallies.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The Monte Carlo (MC) particle transport analysis method is widely used in neutronic analyses, because it can easily model the detailed structure of a complex-geometry reactor core and handle continuous-energy nuclear data libraries directly. Moreover, in response to enhancement of the computing performance of related hardware and software, the MC particle transport analysis method has been applied to the whole-core analyses of commercial nuclear power reactors and research reactors. However, in MC eigenvalue calculations for large-scale whole core problems, certain significant difficulties are encountered. This is because of the higher dominance ratios (DRs) of these problems, which are not observed in scenarios involving smaller DRs, such as fuel assembly (FA) or small-sized critical facility problems.

Previously, Ueki theoretically analyzed the underestimation of local tallies and noted that large bias in the sample variance estimator may occur for the local reaction rates of high DR systems and showed the fluctuation of track length tallies for local fission rate using the autoregressive moving average process (ARMA). (Ueki et al., 2003; Ueki and Brown, 2010) Further, Yamamoto showed that the estimated statistical errors for pin-by-pin fission rate distributions obtained via an MC calculation are somewhat underestimated in the case of a large geometry. (Yamamoto and Nakamura, 2009) There are two approaches to estimating the variance bias. One utilizes batch-based methods such as the Gelbard's batch method (Gelbard and Prael, 1990) and the history-based batch (HB) method (Shim et al., 2009, 2014), while the other involves inter-cycle correlation methods such as the Ueki's method (Ueki et al., 1997) and the fission-source distribution inter-cycle correlation method (Shim and Kim, 2009). In the Seoul National University MC code, McCARD (Shim et al., 2012), the four approaches mentioned above are implemented for real variance estimation.

Recently, a new whole-core benchmark, the Benchmark for Evaluation and Validation of Reactor Simulations (BEAVRS) (Horelik et al., 2013), has been proposed by the Massachusetts Institute of Technology (MIT) computational reactor physics group. This benchmark provides detailed descriptions of the FAs, burnable absorbers, in-core fission detectors, core loading patterns, and numerous in-vessel components on a three-dimensional (3-D) scale. It is known that the BEAVRS problem has quite a high DR. Fig. 1 shows the core loading pattern for BEAVRS cycle 1.

In this study, the real variances of the MC tallies for the core physical parameters of a reactor, such as the effective multiplication factor (k_{eff}) and the pin-wise (P^P) and FA-wise fission powers (P^A), are estimated for the BEAVRS fresh-core problem using the

* Corresponding author.
E-mail address: lhc@kaeri.re.kr (H.C. Lee).

http://dx.doi.org/10.1016/j.anucene.2015.12.009
0306-4549/© 2015 Elsevier Ltd. All rights reserved.

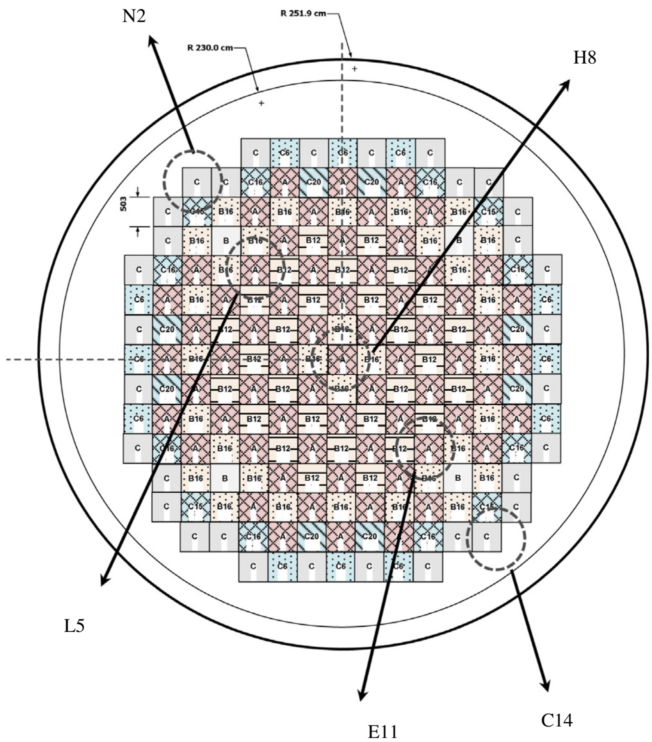

Fig. 1. Core loading pattern for BEAVRS cycle 1.

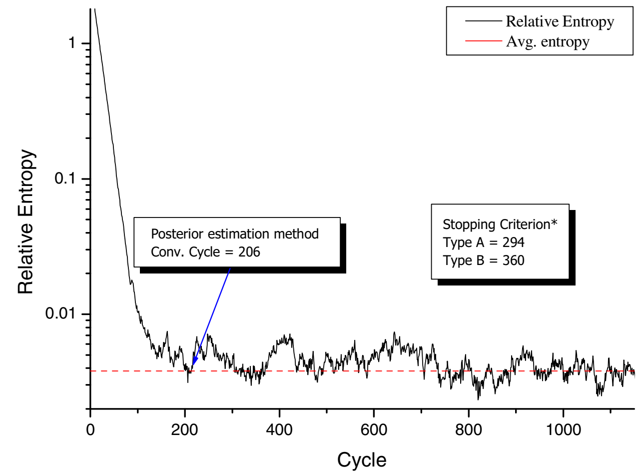

Fig. 2. Comparison of Ueki Shannon entropy method and Shim on-the-fly stopping criterion for BEAVRS cycle 1.

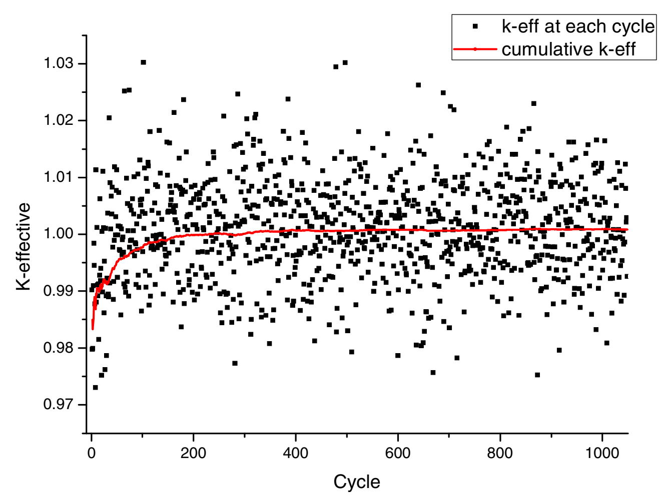

Fig. 3. k_{eff} at each cycle and cumulated k_{eff} for BEAVRS cycle 1.

real variance estimation methods implemented in the McCARD code. In addition, the real-to-apparent standard deviation (SD) ratios ($\sigma_{Ref}/\sigma_{App}$; where σ_{Ref} and σ_{App} are the SD values from the reference calculation and the apparent SD, respectively) for MC tallies of different sizes are calculated for comparison.

2. Real variance analysis of BEAVRS problem

2.1. Source convergence diagnosis for BEAVRS

In the MC eigenvalue calculation, inactive cycles are required in order to yield a converged fission source distribution. In McCARD, the Ueki's posterior method (Ueki and Brown, 2005), which is based on the Shannon entropy of the fission source distribution, and Shim's on-the-fly stopping criteria (Shim and Kim, 2007a) of type A and B are implemented in order to determine the number of inactive cycles necessary to ensure the fission source distribution convergence. Fig. 2 shows the relative entropy values and the inactive cycles for the BEAVRS problem. Here, "Avg. entropy" indicates the average value of the Shannon entropy of the fission source distributions for the last half of the active cycles. In the source convergence diagnosis, the McCARD calculations were performed on 1,000,000 neutron histories per cycle and the number of total cycles for the Ueki's posterior method was 1500. To calculate the relative entropy for the Ueki's method and the fission matrix for the Shim's on-the-fly stopping criteria, FA-wise regional discretization was used. The number of inactive cycles determined by the Ueki's posterior method was 206, while those yielded by the Shim on-the-fly stopping criteria of type A and B were 294 and 360, respectively. Through consideration of the results, the number of inactive cycles was conservatively set to 400 for all BEAVRS calculations. It was observed that the cumulative k_{eff} as a function of cycle number converged adequately at approximately the 400th cycle, as shown in Fig. 3. The DR of the BEAVRS fresh core calculated by McCARD from the fission matrix was approximately 0.99.

2.2. Real variance estimation for BEAVRS

As mentioned above, McCARD provides four methods to estimate the real variances of the tallied values. In this study, the number of batches for the HB method was set to 1000, while the batch size (the number of cycles in a batch) for the Gelbard's batch method and the maximum lag cycle distance for the Ueki's covariance estimation method were both taken to be 10. The MC eigenvalue calculation was performed on 100 active cycles with 1,000,000 neutron histories per cycle. The reference real SD was estimated from 100 replicas with different random number sequences.

Table 1 presents comparisons of the SD of the k_{eff} values estimated using the real variance estimation methods. As noted previously, σ_{App} is the apparent SD, which is defined as the expected value of the sample variance and evaluated with an assumption that each cycle is independent. Further, σ_{Bat} and σ_{Ueki} are the SDs

Table 1
Comparison of estimated real standard deviation of k_{eff} for various methods.

σ_{Ref}	σ_{App}	σ_{Bat}	σ_{Ueki}	σ_{HB}
0.00010	0.00010	0.00010	0.00010	0.00010

Download English Version:

https://daneshyari.com/en/article/1727924

Download Persian Version:

https://daneshyari.com/article/1727924

Daneshyari.com