Adjoint-weighted kinetics parameter calculation using multigroup version of Solomon solver

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Abstract: Adjoint-weighted kinetics parameters have been calculated using the multigroup version of a Monte Carlo solver Solomon. Three iterated fission probability (IFP) algorithms/methods have been implemented and compared for multigroup infinite geometry systems.

Keywords: Solomon solver, fuel debris, kinetic parameter, adjoint-weighting, iterated fission probability

1. Introduction

In response to the need of safe decommissioning of Fukushima Daiichi NPS, Japan Atomic Energy Agency is developing a new continuous-energy Monte Carlo solver Solomon (**Sol**ver **o**f **Mon**te Carlo) that can be applied to a system with random and continuous distribution of materials such as fuel debris. Currently, various capabilities are being implemented in the Solomon solver [1]. One important capability is to estimate adjoint-weighted kinetic parameters and k-eigenvalue sensitivity coefficients that are needed for kinetic and sensitivity/uncertainty analyses. The purpose of this study is to compare three different IFP algorithms, namely Non-Overlapping Blocks (NOB) [2], Multiple-Overlapping Blocks (MOB) [3], and Superhistory (SH) method [4], by implementing them in the multigroup version of Solomon solver.

2. Methodology

The three algorithms differ in their implementation rather than theoretical background as all three are based on the IFP method. In the NOB algorithm the active cycles are divided into non-overlapping blocks to accommodate the adjoint-weighted calculation. In the MOB algorithm, the active cycles are divided into over-lapping blocks and a new block for adjoint-weighted calculation starts essentially at each active cycle. On the other hand, the SH algorithm embeds a block in each active cycle based on the superhistory method [4].

The adjoint-weighted kinetic parameters have been calculated for three 2-group infinite geometry problems (i.e. Problem-1, Problem-2, and Problem-3), where analytic solutions are available for comparison [5], by each method. The three problems differ by a scattering cross section from group 1 to group 2 to make k_{inf}(Problem-1)=0.9, k_{inf}(Problem-2)=1.0, and k_{inf}(Problem-3)=1.1. All calculations were run with 2 inactive cycles, 100 active cycles, block size of 10, and 1 million neutron histories per cycle.

3. Results and discussion

Table I presents the calculated adjoint-weighted effective delayed neutron fraction β_{eff} and generation time Λ for Problem-2 as an example along with the analytic results. It can be seen from the table the three methods produced the values that are mostly within 1σ to the analytic solutions. The results for the other two problems showed also that most of the calculated kinetic parameters are within 1σ, all within 3σ, to the analytic solutions.

Table I. Comparison of calculated kinetic parameters of Problem-2

	NOB	MOB	SH	Analytic[5]
$\beta_{eff}\times10^3$ ($1\sigma\times10^3$)	5.4220 (0.0656)	5.4094 (0.0250)	5.4294 (0.0239)	5.4353
Λ, ms (1σ, ms)	4.0579 (0.0073)	4.0591 (0.0021)	4.0586 (0.0013)	4.0576

4. Conclusion

The adjoint-weighted kinetics parameter calculation capability has been implemented in the multigroup version of Solomon solver based on three different adjoint-weighting algorithms, namely Non-Overlapping Blocks (NOB), Multiple-Overlapping Blocks (MOB), and Superhistory (SH) method. The implemented capability has been tested for three 2-group infinite geometry problems. The calculation results showed good agreement with the analytic solutions and compared the NOB, MOB, and SH methods in the multigroup version of Solomon solver. In terms of accuracy, given the same number of active cycles for each algorithm, the SH algorithm generally gave better results for the considered problems in this study.

References

[1] Y. Nagaya, T. Ueki, and K. Tonoike. *11th International Conference on Nuclear Criticality Safety*, 2019.
[2] B. C. Kiedrowski, F. B. Brown, and P. P. H. Wilson. *Nucl. Sci. Eng.*, vol. 168, no. 3, pp. 226–241, Jul. 2011.
[3] Y. Qiu, Z. Wang, K. Li, Y. Yuan, K. Wang, and M. Fratoni. *Prog. Nucl. Energy*, vol. 101, pp. 424–434, Nov. 2017.
[4] R. N. Blomquist and E. M. Gelbard. *Nucl. Sci. Eng.*, vol. 141, no. 2, pp. 85–100, Jun. 2002.
[5] H. J. Shim and C. H. Kim. *PHYSOR 2010: Advances in Reactor Physics to Power the Nuclear Renaissance*, 2010.