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On the Two Formulations of Continuous-Energy Monte Carlo Local Problem Embedded in OLG Iteration Methodology

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1. Introduction

The direct whole-core transport calculation without homogenization (in either multigroup deterministic or continuous-energy Monte Carlo method) is not yet tractable for routine use with current computing power. As an alternative to the direct approach, an overlapping local/global (OLG) iteration scheme [1, 2] was introduced, in which the local problem based on a multigroup deterministic method or a continuous-energy Monte Carlo method is embedded in the partial current-based coarse-mesh finite difference (p-CMFD) global problem. The p-CMFD method is based on the $\hat{D}^{\pm}_{G,i\pm1/2} \leftrightarrow J^{\pm}_{G,i\pm1/2}$ "correspondence device"; for details, see the review paper [3] and references therein.

In the case of continuous-energy Monte Carlo local problem, Refs. [1] and [2] describe an eigenvalue problem (EVP) formulation with albedo boundary condition $\alpha = J^{-}/J^{+}$ given, but k^{local} is unknown. As another formulation, Ref. [4] presents a fixed-source problem or fixed-k problem (FKP) formulation and compares EVP and FKP formulations. This paper assesses the two formulations and tentatively concludes that EVP is more robust and is a method of choice.

2. Two Formulations of Continuous-Energy Monte Carlo Local Problem

2.1 Eigenvalue Problem (EVP) with Albedo Boundary Condition [1, 2]

When a Monte Carlo particle is about to cross a boundary surface, it is reflected with a new weight corrected by albedo α. This is enabled by the "albedo-to-weight" conversion device developed in a Monte Carlo depletion study [5], and it is almost trivial to implement the method in an existing Monte Carlo code.

2.2 Fixed-k Problem (FKP) with Incoming Partial Current Boundary Condition

In this problem formulation, incoming partial current $J^{BC} = J^{-}$ (in angular bins) and $k^{local} = k^{global}$ are given from the previous local/global iteration. In each generation *j*, we consider *N* histories such that

$$N = N_j^s + N_j^f,\ j = 1, 2, \cdots, \tag{1}$$

where N is user input, N_j^s is the number of histories sampled from the incoming boundary source and N_j^f is the number of histories taken from the fission source banked in generation *j*-1 and obtained as

$$N_j^f = \sum_{i=1}^{N_{j-1}^s + N_{j-1}^f} \left(\sum_{col} \left(floor\left(\frac{\nu\sigma_f / \sigma_t}{k^{global}} wgt_{i,col} + \xi \right) \right) \right), \tag{2}$$

$$N_j^s = N - N_j^f. \tag{3}$$

In initial generation, $N_1^s / N_1^f = r$ from the previous global calculation. Note that $\nu\sigma_f$ is divided by k^{global} in Eq. (2).

After several generations are discarded, the subnode p-CMFD parameters [1, 2] are tallied based on collision estimators for next global calculation.

3. Numerical Results

The two formulations of continuous-energy Monte Carlo local problem in the OLG methodology are tested and their performances are compared in two test problems of multi-slab thermal and fast reactor cores. The Monte Carlo calculations are performed by the in-house research code McSLAB [6], which considers at the present time three major interactions (elastic scattering, capture, fission) with resolved resonances and isotropic scattering in the center-of-mass system taken into account. For cross section data, ENDF/B-VII.0 continuous-energy libarary is used

3.1 1-D Thermal Reactor Problem [1]

Table I shows Monte Carlo calculation conditions. The boundary conditions for local problems are modulated in 45 energy groups and four angular bin partial currents.

Table I. Monte Carlo calculation conditions

	FKP	EVP	Reference Whole-core Calculation
No. of Histories per Generation	5×10^4	6.5×10^4	2.5×10^5
Inactive/Active Generations	50/500		200/3000

Table II shows various computing times depending on local problems for FKP, and similar computing times among local problems for EVP when the constant number of histories per generation is used for local problems. Figs. 1 and 2 show global k's and rRMSEs of subnode averaged power distributions in the two formulations as the OLG iteration proceeds.

Table II. Computing times (min, Intel Xeon X5670 single processor running at 2.93 GHz) of local problems at the 6-th OLG iteration

Local Problem	1	2	3	4	5	6
FKP	78.63	62.56	68.00	63.32	69.75	48.92
EVP	70.89	73.90	73.92	74.45	77.77	73.28

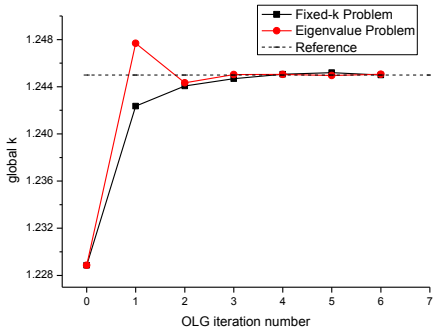

Fig.1. Comparison of global k's in two formulations in a thermal reactor problem

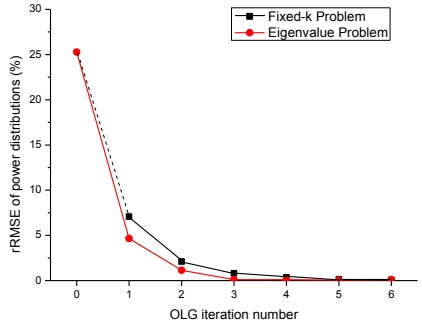

Fig.2. Comparison of rRMSEs of subnode averaged power distributions in two formulations in a thermal reactor problem

3.2 1-D Fast Reactor Problem [2]

Tables III and IV show Monte Carlo calculation conditions. The boundary conditions for local problems are modulated in *i*) 37 and *ii*) 68 energy groups, and four angular bin partial currents. Figs. 3 and 4 show global k's and rRMSEs of subnode averaged one group flux distributions as the OLG iteration proceeds.

Table III. Monte Carlo calculation conditions

	FKP	EVP	Reference Whole-core Calculation
No. of Histories per Generation	See Table IV	2.0×10^4	2.0×10^5
Inactive/Active Generations	20/400		200/1200

Table IV. Number of histories per generation in each local problem for FKP

Local Problem	1	2	3	4
No. of Histories per Generation	4.0×10^4	1.2×10^4	7.0×10^4	8.0×10^4

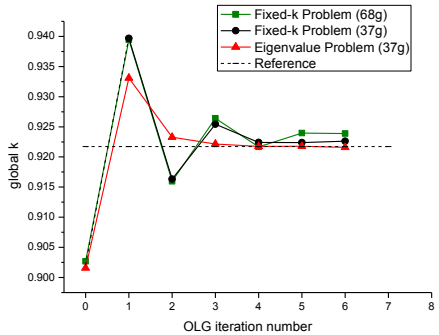

Fig.3. Comparisons of global k's in two formulations in a fast reactor problem

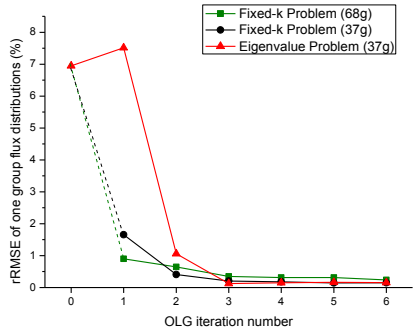

Fig.4. Comparison of rRMSEs of subnode averaged one group flux distributions in two formulations in a fast reactor problem

4. Discussion and Conclusions

This paper presents the overlapping local/global (OLG) iteration methodology using *i*) eigenvalue problem (EVP) formulation and *ii*) fixed-k problem (FKP) formulation for local Monte Carlo calculations and applies the two problem formulations to two test problems.

In the case of a thermal reactor problem, the two formulations perform well, with EVP showing slightly better convergence in k_{eff} and power (flux) distributions.

In the case of a fast reactor problem, EVP performs well again but FKP appears to exhibit some bias or converges very slowly at best. This may be due to the fact that EVP reflects a neutron with continuous energy at the boundary (in contrast to FKP), while fast reactor core exhibits complicated energy spectrum due to many resonances. Therefore, we conclude at this time that EVP is more robust and is a method of choice.

References

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