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Overlapping Local/Global Iteration for Whole-Core Transport Problems

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1. Introduction

The conventional method of reactor analysis is whole-core diffusion nodal calculation in which nodal parameters are provided by isolated single-assembly transport calculation. This method does not incorporate the inter-assembly transport effect.

To overcome this limitation, the authors recently proposed the half-assembly overlapping local/global (OLG) iteration framework [1-3]. Local transport calculation and global diffusion-like calculation are "coupled" through interface boundary conditions in the OLG iteration. The global calculation can be performed via partial current-based Coarse-Mesh Finite Difference (p-CMFD) method, instead of nodal diffusion method, to obtain the whole-core transport solution [2, 3].

In this paper, the OLG iteration with p-CMFD global calculation is applied to 1-D heterogeneous slab geometry and 2-D rectangular geometry problems.

2. Description of OLG Iteration

The OLG iteration consists of two-level calculations: local calculation and global calculation.

A fine-group (or continuous Monte Carlo) transport method is used in the local problems whose domains are half-assembly overlapping subregions. The solution of assembly region is more accurate than that of the region near the boundaries, because the boundaries of the local problem with inaccurate boundary condition during OLG iteration are half-node away from the assembly region. Hence only assembly region is homogenized and condensed using this local solution. The p-CMFD acceleration methodology [4] is used in the global calculation. Similarly to the acceleration, it provides transport solution.

In the next iteration, each local problem needs new boundary condition which reflects more accurate inter-assembly transport effect. If angular fluxes at the center surface of a local problem are stored during local calculation, the coarse-group partial currents can be modulated or "resolved" to the fine-group angular fluxes. The equation for angular flux modulation can be expressed by

$$\psi_{\pm n,g}^{new}(\vec{r}) = \frac{\psi_{\pm n,g}^{local}(\vec{r})}{\bar{J}_G^{\pm,local}} \bar{J}_G^{\pm,global}, \qquad (1)$$

where

$\psi_{\pm n,g}^{local}(\vec{r})$ = angular flux at center surface of local problem,
$\bar{J}_G^{\pm,local}$ = partial current at center surface of local problem,
$\bar{J}_G^{\pm,global}$ = partial current at center surface of global problem,
$\pm n$ = discrete ordinate.

The modulated incoming angular fluxes or albedos (ratio of incoming to outgoing angular fluxes) then become boundary conditions for neighboring local problems in the next iteration (it is an advantage of half-assembly overlap). The procedures of these two-level calculations are performed iteratively.

3. Numerical Results

3.1 Test Problem 1

Test problem 1 shown in Fig. 1 is a 150-group heterogeneous multi-slab problem that characterizes a fast reactor core.

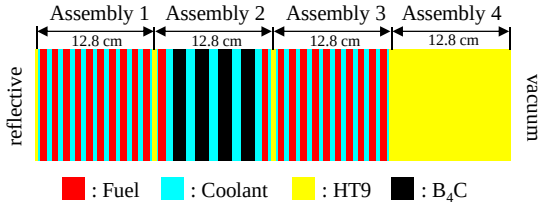


Fig. 1. Configuration of test problem 1.

This problem consists of two fuel assemblies, one control assembly (fuel rods on both sides), and one reflector assembly. 150-group to 1-group condensation and homogenization are performed to obtain homogenized parameters. Local transport calculation is done by S_8. Numerical results are shown in Table I. Table I shows that the OLG iteration converges well in early iterations.

Table I. k_{eff} values of the OLG iteration in test problem 1

Iteration number	k_{eff}	Relative error[a] (pcm)
0	0.946249	**-1472.39**
1	0.961820	**148.93**
2	0.960506	**12.11**
3	0.960296	**-9.76**
Conventional method[b]	0.981028	**2148.95**

[a] Reference k_{eff}= 0.96039 (whole-core 150-group S_8)
[b] AFEN with discontinuity factors

3.2 Test Problem 2

Test problem 2 is a modified C5G7 problem [5] with 2 by 2 fuel assemblies surrounded by baffle and reflector, which is shown in Fig. 2. 7-group to 2-group condensation and homogenization is performed to obtain homogenized parameters. Local transport calculation is done by S_8. Numerical results are shown in Fig. 3 and Table II. Similarly to test problem 1, the OLG iteration converges well and gives more accurate results than the conventional method.

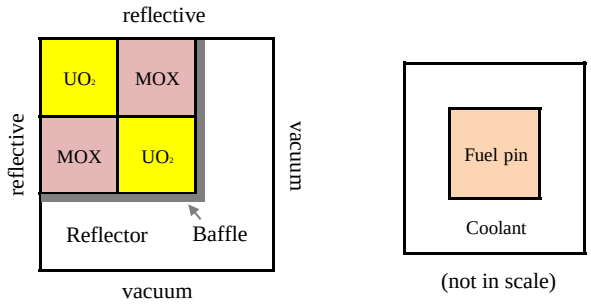
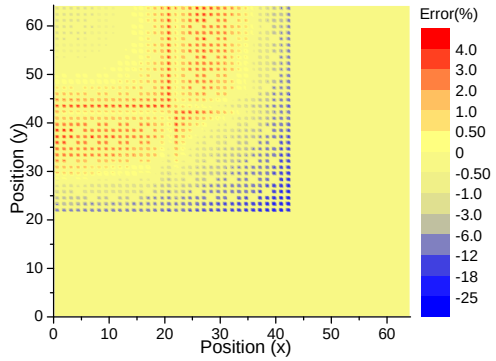
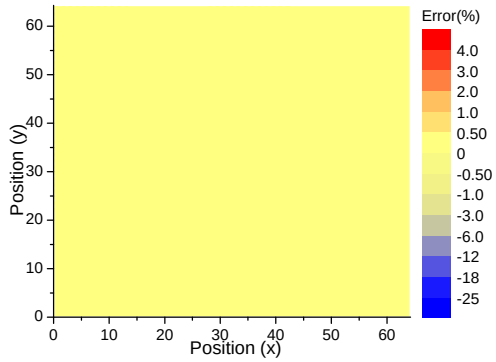


Fig. 2. Core and pin configurations of test problem 2.



(a) Relative error of power distribution by conventional method



(b) Relative error of power distribution by OLG (3rd iteration)

Fig. 3. Relative error of the power distribution for test problem 2.

Table II. k_{eff} values of the OLG iteration in test problem 2

Iteration number	k_{eff}	Relative error[a] (pcm)
0	1.153659	**-510.82**
1	1.158103	**-127.59**
2	1.159332	**-21.61**
3	1.159548	**-2.95**
Conventional method[b]	1.169991	**897.65**

[a] Reference k_{eff}= 1.159582 (whole-core seven-group S_8)
[b] FDM with discontinuity factors

4. Conclusions

The OLG iteration framework performs well in fine-group, heterogeneous whole-core problems. The OLG iteration provides whole-core transport solution, by removing the limitation of the conventional method. The numerical test results show that the multiplication factor and power distribution by OLG iteration are remarkably improved when compared to the conventional method. Therefore, the OLG iteration framework is expected to play a key role in providing whole-core transport solution to realistic problems.

An immediate future study is to apply this methodology to three-dimensional problems.

References

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