2-D Extension of the Global-Local Iteration Method with Homogenization by Monte Carlo Based on Non-Zero Leakage Spectra

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1. Introduction

In our previous study [1], we introduced a new two-level calculation procedure of global-local iteration framework, in which the global whole core calculation was based on a multigroup nodal method while the local lattice calculation was based on a continuous energy Monte Carlo method.

The Monte Carlo calculation provides homogenized nodal parameters according to the equivalence theory preserving the net currents between nodes. This was enabled by our recent work on Monte Carlo simulation under leakage-corrected (non-zero leakage) critical spectrum [2, 3], which was based on an extended albedo boundary condition treatment. The procedure was implemented in the MCNP5 code by adding scattering cross-section tally routine and albedo treatment routine.

In this paper, the implementation is refined and numerical results on a 2-D core structure are presented.

2. Global-Local Iteration Framework

A flow chart is shown in Fig. 1 for the global-local iteration framework. The global calculation is performed by a multigroup diffusion nodal method which provides, among others, node interface partial currents (i.e., albedos for each group and surface). The local calculation is performed by a continuous energy Monte Carlo method using the albedo boundary condition available from the global calculation.

In our calculation, the following discontinuity factor (DF) is used:

$$DF_{gs} = \frac{\phi_{gs}^{het}}{\phi_{gs}^{hom}}, \qquad (1)$$

where ϕ_s^{hom} is the surface-averaged flux obtained in the homogenized single node (characterized by the cross sections provided from Monte Carlo lattice calculation and diffusion coefficient chosen as $1/3\Sigma_{t,g}^{hom}$) calculation with the same nodal method to be used in the whole core calculation.

Any nodal diffusion method can be used for global calculation, as long as the discontinuity factors are consistently provided. In this paper, the Analytic Function Expansion Nodal (AFEN) method [4] is used.

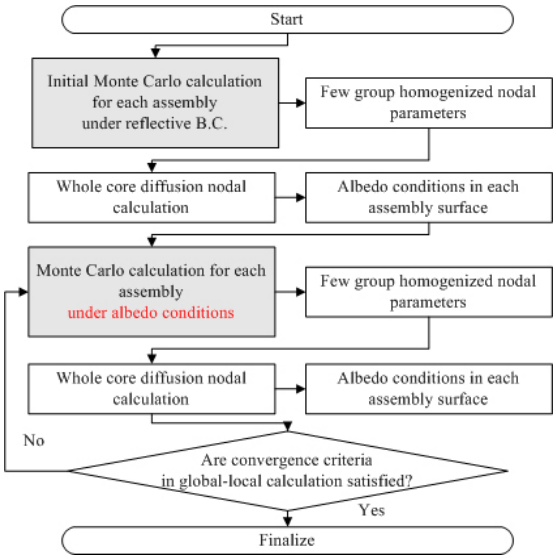

Fig. 1. Flow chart of global-local iteration

3. Numerical Results

A 2-D core structure composed of MOX and UO_2 fuel assemblies is considered to test our new two-level calculation algorithm. The configurations of fuel assemblies are benchmark problem 1A in Ref. [1, 5]. ENDF/B-6.6 continuous energy cross section library is used for assembly Monte Carlo calculations to generate two-group cross sections. For z-direction, 20cm height is used with reflective B.C.

The 2-D core structure is shown in Figs. 2 and 3. In which, reflective B.C. is used for every surface.

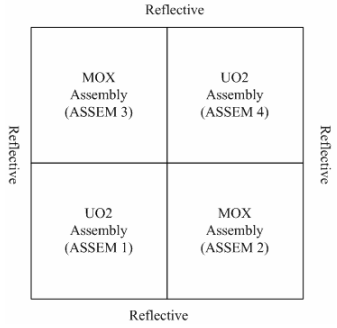

Fig. 2. Simplified Configuration of a 2-D core structure problem

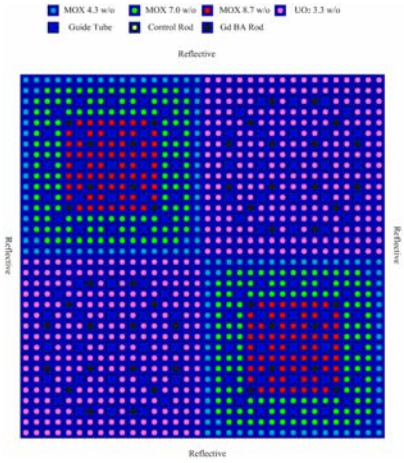

Fig. 3. Pin by pin configuration of a 2-D core structure problem

10^{-9} is used for AFEN whole core iteration criterion and 0.005 is used as iteration criterion of discontinuity factors in one assembly AFEN calculation. 20,000 histories per generation and 500 inactive/2,000 active generations are used for the reference whole core MCNP calculation, while 200 inactive/400 active generations with the same histories per generation are used for one assembly MCNP calculation.

The variations of eigenvalues in global-local iterations are shown in Fig. 4, and interface albedos of ASSEM1 and ASSEM4 are shown in Fig. 5.

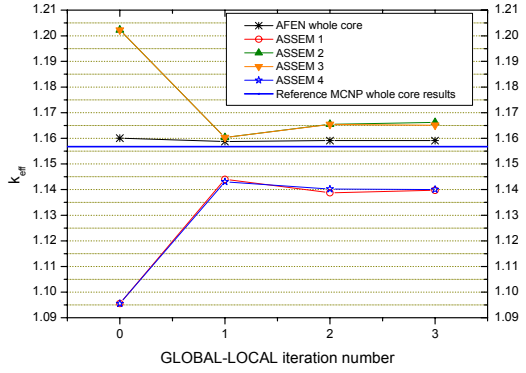

Fig. 4. Results of k_{eff} in global-local iteration

3. Conclusions

A new two-level calculation procedure consisting of global-local iteration framework based on Monte Carlo lattice calculation and multigroup nodal diffusion calculation was described and tested on a 2-D core structure problem.

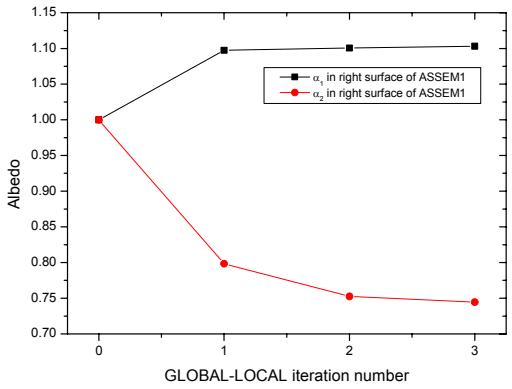

Fig. 5. Interface albedos of ASSEM1 in global-local iteration

The k_{eff} of 3rd global-local iteration shows 200 pcm discrepancy, while the k_{eff} of initial whole core calculation shows 284 pcm discrepancy from the reference solution. The k_{eff} of 0th global solution is already very close to the reference solution in this problem, because the boundary conditions of the problem are all reflective.

The results of global-local iterations seem to converge, but slowly or with an apparent "bias". The "bias" might have originated from the use of constant (surface-averaged) albedos. The results of this preliminary study are encouraging and warrant further tests. For example, use of location-dependent albedos and applications to vacuum boundary condition problems with reflectors, would be worthwhile to pursue.

REFERENCES

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