On a New Acceleration Method for 3D Whole-Core Transport Calculations
Nam Zin Cho, Gil Soo Lee, and Chang Je Park
Korea Advanced Institute of Science and Technology

Abstract: Partial current-based CMFD (pCMFD) acceleration of the 3D whole-core transport calculation is described and its performance in the 2D/1D fusion method is compared with CMFD acceleration.

Key Words: 2D/1D fusion method, CMFD, pCMFD, MOC, acceleration

Introduction: The 2D/1D fusion method[1] recently proposed by the authors, in which the MOC for radial 2D calculation is combined with the 5x-like transport method for axial 1D calculation, reduces the computational burden drastically and thus it may constitute a practical method for the 3D whole-core transport calculations.

On the other hand, it is important to use good acceleration methods in transport calculations. Among the many acceleration methods, the coarse mesh finite difference (CMFD) acceleration method that is popular in the fast solution of nodal diffusion equations[2], has been employed for the acceleration of the transport calculations with remarkable results[3,4], although the transport calculations were limited to the 2D problems. In the CMFD method, a current correction coefficient is introduced to preserve the interface net current (obtained from the transport sweep) between two coarse meshes. It is known that the convergence of CMFD is very fast in optically thin problems but it becomes poor or divergent in optically thick problems[5]. This may be due to the weak physical basis of the way the correction coefficient is introduced.

This paper provides (1) a partial current-based coarse mesh finite difference (pCMFD) acceleration method, in which two correction coefficients are introduced at an interface between two coarse meshes such that partial currents are preserved, (2) its Fourier convergence analysis, and (3) its performance in the 2D/1D fusion method for a test problem in comparison with CMFD.

Description of the Method: Let us consider coarse mesh i and coarse mesh i+1. Outgoing and incoming partial current at the right interface $i+1/2$ of coarse mesh $i$ is corrected with a correction coefficient $C_{i+1/2}$ by

$$J_{i+1/2} = \frac{\hat{B}_{i+1/2}}{2} \hat{C}_{i+1/2} - \frac{\hat{D}_{i+1/2}}{2} \hat{C}_{i+1/2}$$

where $i$ is the iteration index and $\hat{C}_{i+1/2}$ is the usual coupling coefficient determined by the finite difference method. The two correction coefficients are defined to preserve the respective partial currents as

$$\hat{B}_{i+1/2} = \frac{2J_{i+1/2}^{i+1/2} - \hat{B}_{i+1/2} \hat{C}_{i+1/2} - \hat{C}_{i+1/2}^{i+1/2}}{2\hat{C}_{i+1/2}}$$

and corresponding variants to the other equations (1) and (2).

Then, the net current is obtained as

$$J_{i+1/2}^{i+1} = J_{i+1/2}^{i+1} - J_{i+1/2}^{i} = \hat{B}_{i+1/2} \hat{C}_{i+1/2} - \hat{C}_{i+1/2}^{i+1}$$

The computational procedures of the pCMFD method are similar to the original CMFD method and do not require any extra computation. In the new method, net currents are naturally preserved and, since outgoing or incoming partial current is corrected to be preserved by its own coarse mesh flux, it is more physically based. This indicates that pCMFD should perform better in problems with strong flux gradients.

Results: Fig. 1 shows the results of linearized Fourier analysis with the diamond difference (DD) and step characteristics (SC) schemes for various $P's$, the number of fine meshes per coarse mesh, indicating improved behavior of pCMFD over CMFD.
Although pCMFD is a general 3D acceleration method, its use in the 2D/1D fusion methodology was tested on a small two-group 3D problem that consists of a BWR assembly with 7x7 fuel cells and axial height 50cm with all reflective boundary conditions except the top side which has vacuum boundary condition. Table I shows the results for the case in which the full height consists of fuel. Note that pCMFD performs better than CMFD and succeeded in providing converged solutions where CMFD failed.

**Fig. 1.** Results of Fourier analyses of CMFD and pCMFD with DD (left) and SC (right), α=0.99, and $S_{th}$.

| Table I. Numerical Results of pCMFD and CMFD in a Problem with Full Height Fuel |
|---------------------------------|---|---|---|---|---|---|---|
| **Number of Axial Nodes**      | 8  | 10 | 16 | 16 | 20 | 16 | 16 |
| CMFD                           |    |    |    |    |    |    |    |
| pCMFD                          |    |    |    |    |    |    |    |
| CMFD                           |    |    |    |    |    |    |    |
| pCMFD                          |    |    |    |    |    |    |    |
| Converged                      |    |    | 118| 15 | 15 | 16 | 16 |
| Not Converged                  |    |    |    |    |    |    |    |
| Computation Time (sec)         |    | 208|    | 58 | 81 | 83 |    |

**Conclusions:** The partial current-based CMFD acceleration method using two correction coefficients instead of one at an interface that preserve outgoing and incoming partial currents respectively has been described and its performance was tested by Fourier analysis and a test problem. The improved performance of pCMFD over CMFD indicates that the pCMFD method warrants fuller investigation for its wide use in the whole-core transport calculations.

**Acknowledgement:** This work was supported in part by the Ministry of Science and Technology of Korea through the National Research Laboratory (NRL) Program.

**References**