COO--2458-32
CONF-820609--49

MASTER

CONF-820609--49

DE82 016966

Hexagonal-Geometry Fast-Reactor Nodal Modeling*

by

E. Caro and M. Becker

Department of Nuclear Engineering
Renssealer Polytechnic Institute
Troy, New York 12181

Summary of a Paper Prepared for the 1982 Annual Meeting of the American Nuclear Society

*Sponsored by U.S. Department of Energy

Several nodal methods have been developed for simulating power distributions in thermal reactors, and have been tested for applicability to fast reactor problems[1]. The testing was performed in rectangular geometry. Since fast reactor configurations typically use hexagonal assemblies, the most promising of the techniques tested was extended to hexagonal geometry and applied to a range of test cases.

The approach selected was the generalized coarse mesh procedure (GCMDT) using different interpolation parameters in different zones. In the hexagonal geometry extension, the average flux $\bar{\phi}_i$ is expressed in terms of the note flux ϕ_i and the interface fluxes ϕ_{ij} according to

$$\bar{\phi}_i = a_i \phi_i + \frac{2}{3} \frac{1-a_i}{6} \sum_{j=1}^{6} \phi_{ij} + \frac{1-a_i}{6} \sum_{j=7}^{8} \phi_{ij} \qquad (1)$$

The factor of $\frac{2}{3}$ in Eq. 1 is to assure that dimensions are weighted on an equal basis, in particular that planar and axial dimensions are weighted equally. The a_i parameter used in hexagonal geometry is based on the a_i that would be obtained for a square assembly of equal area.

Although others have utilized polynomial or basis-function interpolation in hexagonal geometry[2-5], we elected not to do so. Formulation of orthogonal polynomial expansions in hexagonal geometry is substantially more complicated than formulation in rectangular geometry. However, in rectangular geometry, generalized coarse mesh, which is simpler to formulate, gave consistently better results[2] than polynomial interpolation. Others have found it desirable to apply auxiliary correction to polynomial interpolation.

The general response matrix procedure[6] that permits use of alternate nodal models as special cases was used here. This procedure was extended to hexagonal geometry with the leakage flux in group g and node i L_{gi} given by

$$L_{gi}\left[\frac{1-t_i^{g\to g}}{t_i^{g\to g}}+\sum_{j=1}^{8}\frac{r_{ij}^{g}(1-\rho_{ji}^{g})}{1-\rho_{ij}^{g}\rho_{ji}^{g}}\right]=\sum_{j=1}^{8}\frac{r_{ji}^{g}(1-\rho_{ij}^{g})L_{gj}}{1-\rho_{ij}^{g}\rho_{ji}^{g}}$$

$$+\sum_{g'\neq g}C_i^{g'\to g}\sum_{j=1}^{8}\frac{(1-\rho_{ij}^{g})\,r_{ij}\,L_{g'i}}{1-\rho_{ij}^{g}\rho_{ji}^{g}}+\sum_{g'\neq g}\frac{r_{ji}(1-\rho_{ji}^{g})\,C_j^{g'\to g}L_{g'j}}{1-\rho_{ij}^{g}\rho_{ji}^{g}}$$

A test code in hexagonal geometry was written with the eigenvalue introduced as a parameter to divide into $t_i^{g\to g}$. During the iteration process this eigenvalue was parametrically iterated to unity yielding a value for k_{ff}.

A set of test problems was devised to include the types of zones of concern in fast reactors - fuel, blanket, control and control follower. Results of these test problems are summarized in Table 1. The GCMDT gives consistently better results for eigenvalue than a_i values in a range typically used. Assembly data for particular cases are shown in Fig. 1. Here too, good results are obtained using GCMDT, particularly in low-power blanket regions. It also has been found that the GCMDT results gave better spectral agreement than the other coarse mesh options.

In summary, nodal procedures have been adapted for fast reactor application in hexagonal geometry. Results indicate that nodal analysis of a form similar to that used successfully in light water reactors is capable of providing good results for fast reactors.

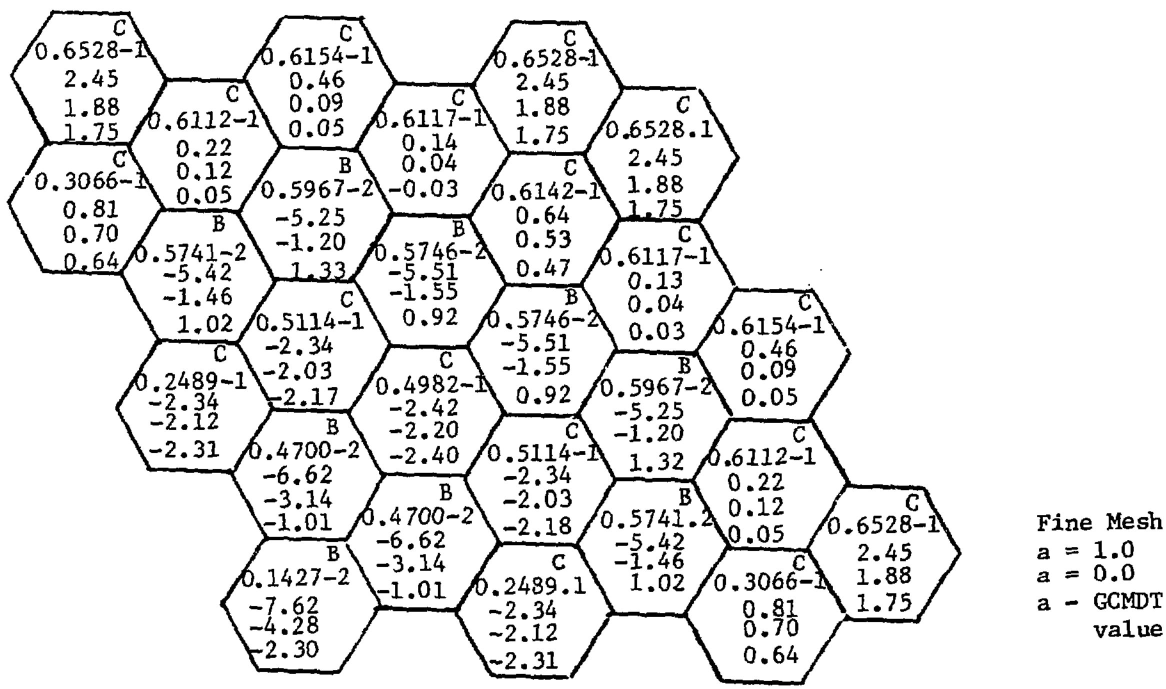
References

1. J. Anaf, M. Becker, "Application of Nodal Options to Fast Reactor Situations", Trans. Am. Nucl. Soc. 39, 890 (1981).
2. R.D. Lawrence, "A Nodal Interface Current Method for Multigroup Diffusion Calculations in Hexagonal Geometry", Trans. Am. Nucl. Soc. 39, 461 (1981).
3. J.J. Arkuszewski, M. Makai, "Analytical Coarse Mesh Approximations for Solving Diffusion Equations in Hexagonal and Square Geometries", Proc. Int. Topl. Mtg. Advances in Mathematical Methods for the Solution of Nuclear Engineering Problems", ANS/ENS, 1981.
4. E. Kaloinen, P. Siltanen, R. Terasvirta, "Two Group Nodal Calculations in Hexagonal Fuel Assembly Geometry", Proc. Specialists Meeting on The Calculation of 3-Dimensional Rating Distributions in Operating Reactors, OECD, 1980.
5. H. Lukas, U. Wehmann, "A Fast Two and Three Dimensional One Group Coarse Mesh Diffusion Program in Hexagonal Geometry", Proc. Int. Topl. Mtg. Advances in Mathematical Methods for the Solution of Nuclear Engineering Problems", ANS/ENS, 1981.
6. A. Ancona, M. Becker, M. Beg, D.R. Harris, A. DaC. Menezes, D.M. VerPlanck, E. Pilat, "Nodal Coupling by Response Matrix Principles", Nucl. Soc. Eng. 64, 405 (1977).

TABLE 1: Multiplication Factors for a Set of Test Problems

Problem Number	Reference K_{eff}	Interpolation factor (a)*	K_{eff}	error(o/o)
1	0.9331	1.00 0.00 GCMDT	.9721 .9538 .9414	4.18 2.22 0.89
2	1.3109	1.00 0.00 GCMDT	1.3233 1.3146 1.3084	0.95 0.28 0.19
3	1.4280	1.00 0.00 GCMDT	1.4431 1.4225 1.4262	1.06 0.39 0.13
4	1.6836	1.00 0.00 GCMDT	1.6834 1.6827 1.6835	0.01 0.05 0.01
5	1.1848	1.00 0.00 GCMDT	1.1989 1.1885 1.1856	1.19 0.31 0.07
6	1.3759	1.00 0.00 GCMDT	1.3839 1.3807 1.3733	0.58 0.35 0.19

*Note that a = 1.00 is coarse mesh diffusion and that a = .3 would correspond to modified (PRESTO-type) coarse mesh diffusion.



C CORE MATERIAL

B BLANKET MATERIAL

FIGURE 1

Power Distribution Accuracy (%) for Test Problem 2