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Reflection-Based Interpolation in Nodal Reactor Simulation*

by

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In applying nodal procedures to fast reactor problems, it was found that a generalization of the modified coarse mesh diffusion method[1] led to particularly good results for a variety of cases. That modification involved use of different interpolation parameters in different types of nodes. Empirically, it was found that best results were obtained when these parameters were negative. This paper introduces a procedure which provides a consistent theoretical basis for the types of paramaters found empirically to give good results. The procedure is based on preservation of reflection by the node, and will be referred to as reflection-based coarse mesh theory (RBCMT).

Modified coarse mesh diffusion[2] expresses the average flux in a node as an *interpolation of nodal and interface fluxes.*

$$\bar{\phi}_i = a_i \phi_i + \frac{1-a_i}{6} \sum_j \phi_{ij} \tag{1}$$

The interpolation parameter can thus be expressed as

$$a_i = \frac{\bar{\phi}_i - \frac{1}{6} \sum_j \phi_{ij}}{\phi_i - \frac{1}{6} \sum_j \phi_{ij}} \tag{2}$$

The response matrix nodal formulation[3] *calls for obtaining nodal parameters from* responses for problems with the node considered in isolation, and sources placed separately on individual faces. RBCMT was formulated first by calling for evaluation of the right side of Eq. 2 by making use of an exact solution obtained by Fourier expansion and following three steps:

(1) Require total inward partial currents calculated by coarse mesh diffusion to match total imposed inward currents.

(2) Require $\bar{\phi}_i$ to equal that of exact solution.

(3) Require reflection from face through which current enters, when calculated by coarse mesh diffusion, to equal exact reflection.

These three conditions are sufficient to evaluate $\sum_j \phi_{ij}$, $\bar{\phi}_i$, ϕ_i.

The above procedure applied to a variety of fast reactor node types led to excellent agreement between predicted and actual powers in a variety of test cases. The a_i parameters were close to those empirically found to give good results. However, the Fourier analysis for the exact solution was found to be time-consuming.

As an alternative to the Fourier analysis, a second order orthogonal polynomial expansion was used. This expansion, based on the polynomial interpolation procedure for nodal analysis[4], led to values of a_i very close to those obtained via Fourier analysis at much lower cost. In addition, accurate analytical approximations are possible for the a_i which further simplify evaluation.

For non-cubical nodes, this procedure requires further generalization of Eq. 1 to

$$\bar{\phi}_i = \left(\frac{1}{3} \sum_{n=1}^{3} a_{in}\right) \phi_i + \frac{1}{3} \sum_{n=1}^{3} \frac{1-a_{in}}{2} \left(\phi^-_{i,n} + \phi^+_{i,n}\right) \qquad (3)$$

where a_{in} is different for dimensions of unequal size. This does not pose a serious problem for the response matrix procedure for evaluating the ρ,r and t nodal parameters.

In multigroup fast reactor problems the a_i differ in each group. This again poses no major problem. The availability of simple analytical approximations make evaluation inexpensive.

A variety of test problems, involving the various types of regions associated with fast reactors - fuel, blanket, control, control follower - were studied. Table 1 contains a comparison of eigenvalues. The RBCMT with group-dependent interpolation parameters is seen to give the best results for the range of problems considered. Results are seen to be better than those with direct application of polynomial expansion[4-6] options, an interesting result given the use of polynomial expansion in obtaining a_i. Similar relative mertis were observed for power distribution and absorption rates, particularly in the vicinity of control. (Note that the test problems were devised to emphasize types of interfaces rather than to simulate overall core configuration or obtain eigenvalue near one.

In summary, a procedure has been developed for evaluating interpolation parameters for nodal simulation. The procedure leads to better predictions than do several common nodal procedures for a variety of representative fast reactor configurations.

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TABLE 1

Selected Eigenvalue Comparisons for Nodal Options

Problem #	Fine Mesh	RBCMT	CMDT	MCMDT	2nd Order Polynomial	4th Order Polynomial
1	.8733	.8744	.8977	.8884	.8889	.8876
2	.8013	.7998	.8251	.8155	.8160	.8171
3	1.3795	1.3834	1.4068	1.3957	1.3963	1.3937
4	1.6797	1.6797	1.6797	1.6798	1.6799	1.6798
5	1.2491	1.2479	1.2594	1.2548	1.2550	1.2561
6	1.1015	1.1083	1.1341	1.1227	1.1233	1.1205
7	.5859	.5863	.6284	.6122	.6130	.6108