A Method of Generating Directional Diffusion Coefficients
Using the TWODANT code

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1. Introduction

Various studies have been made to generate the broad group cell averaged directional diffusion coefficients. Benoist[1] and Gelbard[2] showed the typical methods of generating them. Benoist used directional first-flight collision probability to get the directional diffusion coefficients of fuel assemblies and Gelbard used homogenized neutron paths calculated with Monte Carlo method.

In this study we produced directional diffusion coefficients by adjusting the diffusion coefficients so that the diffusion leakage terms are same as the calculated ones from the transport theory code TWODANT[3] to avoid cell calculations which were used in the previous methods.

The purpose of this paper is to present a method of generating directional diffusion coefficients using the TWODANT code and to show the effects of directional diffusion coefficients in the DIF3D code. The result showed that the effective multiplication factors of the DIF3D code using directional diffusion coefficients are more accurate than those of using conventional diffusion coefficients.

2. Methods and Results

2.1 A method of Generating Directional Diffusion Coefficients Using the TWODANT Code

Transport theory code like TWODANT deals with angular scattering of neutrons and directional leakage can be obtained without diffusion coefficients. The neutron leakage term of any coarse mesh in R-Z geometry can be written as following equation;

$$\int \vec{J}\cdot\vec{n}dA = \int \vec{J}_r\cdot\vec{n}_r dA + \int \vec{J}_z\cdot\vec{n}_z dA \qquad (1)$$

And the Fick's law is expressed as following equations;

$$J_r = -D_r\frac{\partial\phi}{\partial r},\ J_z = -D_z\frac{\partial\phi}{\partial z} \qquad (2)$$

In eq. (2), ϕ are the fluxes of fine meshes adjacent to the boundary of a coarse mesh, and the directional diffusion coefficients can be obtained when fluxes and currents are known.

The MCC2 code[4] was used to generate 80 and 9 groups of P1 cross sections which do not contain directional diffusion. To obtain the directional diffusion coefficients in eq. (2), we used the directional coarse mesh currents and averaged fine mesh fluxes adjacent to the boundaries of coarse meshes calculated from the R-Z full core model of the TWODANT code. Then the leakage weighted zone-wise directional diffusion coefficients are generated from the coarse mesh-wise coefficients.

2.2 The Application of Directional Diffusion Coefficients Using the DIF3D Code

The diffusion theory code DIF3D[5] was used to show the effect of directional diffusion. The inputs for directional diffusion coefficients in the DIF3D code are A and B of eq. (3), and the zone-wise directional diffusion coefficients calculated from the TWODANT code were used.

$$D_{directional,i} = A_i \times D + B_i \qquad (3)$$

Where, A is the multiplier and B is the additive term of diffusion coefficient to convert to the directional diffusion coefficient. The R-Z full core model used for the DIF3D calculations is same as that of TWODANT code. The subscript i of eq. (3) denotes the direction, namely R and Z in this geometry model.

2.3 Results

We made comparison calculations for KALIMER-150 and KALIMER-600, which produce 150 and 600 electric powers of the conceptual sodium cooled fast reactors. Four cases of comparison were made for hot full power condition and the effective multiplication factors calculated from the TWODANT code were assumed to be the references of all cases.

1) KALIMER-150, 18 zones, 12x4 R-Z coarse meshes
2) KALIMER-600, 19 zones, 11x6 R-Z coarse meshes
3) KALIMER-600, 19 zones, 18x19 R-Z coarse meshes
4) Same as case 3 but all control rods in condition

Table 1 shows the results for KALIMER-150. The results of the DIF3D using directional diffusion are more accurate than those of not using it. Whereas, results for KALIMER-600 as seen in table 2 have no merits of directional diffusion. The radius of KALIMER-600 is about 1.5 times larger than that of KALIMER-150. And the zone-wise directional diffusion coefficients for KALIMER-600 from the TWODANT code were somewhat erroneous because the numbers of coarse meshes are too small to get zone-wise averaged.

Table 3 and 4 show the results for KALIMER-600 with 18x19 coarse meshes, and the results of these cases imply that increasing the numbers of coarse meshes is needed to get the correct zone-wise directional diffusion coefficients.

Table 4 shows the results for all control rods inserted condition for KALIMER-600. It shows that directional diffusion coefficients are still valid for control rods inserted case.

Table 1 Comparison between the effective multiplication factors of KALIMER-150

	80 Group ($\Delta k^{\dagger}$)	9 Group ($\Delta k^{\dagger}$)
DIF3D (Diffusion)	1866	2195
DIF3D (Directional Diffusion)	-690	90

[†] Δk =TWODANT-DIF3D (pcm)

Table 2 Comparison between the effective multiplication factors of KALIMER-600

	80 Group ($\Delta k^{\dagger}$)	9 Group ($\Delta k^{\dagger}$)
DIF3D (Diffusion)	853	1196
DIF3D (Directional Diffusion)	-884	-883

[†] Δk =TWODANT-DIF3D (pcm)

Table 3 Comparison between the effective multiplication factors of KALIMER-600 with increased numbers of coarse meshes

	80 Group ($\Delta k^{\dagger}$)	9 Group ($\Delta k^{\dagger}$)
DIF3D (Diffusion)	853	1196
DIF3D (Directional Diffusion)	-374	-367

[†] Δk =TWODANT-DIF3D (pcm)

Table 4 Comparison between the effective multiplication factors of KALIMER-600 ARI condition with increased numbers of coarse meshes

	80 Group ($\Delta k^{\dagger}$)	9 Group ($\Delta k^{\dagger}$)
DIF3D (Diffusion)	715	1005
DIF3D (Directional Diffusion)	-300	-279

[†] Δk =TWODANT-DIF3D (pcm)

3. Conclusion

The directional diffusion coefficients calculated from transport theory code by this method are effective in correcting the directional leakage rates due to the transport effect in the diffusion theory code. Therefore the directional diffusion coefficients can be applied for the diffusion theory code to increase the calculation accuracy of core parameters and control rods worth.

Proper numbers of coarse meshes should be given to obtain the zone-wise directional diffusion coefficients, because the proposed method calculates coarse mesh-wise directional diffusion coefficients and generates leakage weighted zone-wise directional diffusion coefficients.

The directional diffusion coefficients of the proposed method depend on the core wide neutron spectrum. Further studies will be performed to get the directional diffusion coefficients of control assemblies which do not depend on the core wide spectrum.

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