Generation of Transport Correction Factor through the Comparison of Reactivity Coefficients Calculated by Transport and Diffusion Theory

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1. Introduction

The purpose of this research is to generate the transport correction factor to come close to the accuracy of the transport theory by using the result of diffusion theory calculation which mainly used in the core design of liquid metal reactor, KALIMER.

2. Methods and Results

The reactivity feedback coefficients that calculated for transport correction factor are as follows; fuel Doppler coefficient, steel Doppler coefficient, sodium density coefficient, steel density coefficient, fuel density coefficient, absorber worth, axial expansion coefficient, and radial expansion coefficient. And the objective cores of this research are the BN-600 reactor core proposed as IAEA CRP benchmark problem, the BFS-73-1 critical experiment in Russia IPPE, KALIMER-150 and KALIMER-600 breakeven cores.

2.1 Calculation method

The reactivity feedback coefficients were calculated by using the K-CORE code system based on transport and diffusion theory, on and after they were compared with each other.

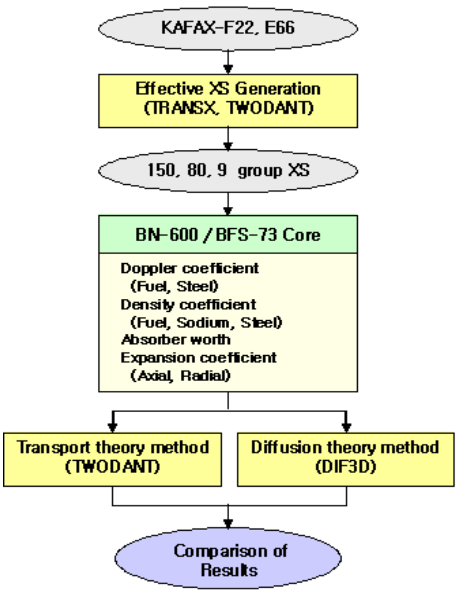

Fig. 1 K-CORE system

K-CORE is a core design and analysis computer code system constructed for KALIMER. Fig. 1 shows the calculation flow and the connection of codes in the K-CORE system.

2.2 BN-600 reactor

The calculation results of BN-600 reactor are presented in Table 1. The k-eff and the fuel Doppler coefficients of KAERI show a little bit higher than the other's values.

Table 1 BN-600 reactor calculation result

Reactivity Coefficients	Participants	KAERI Korea		ANL USA	CEA/SA France	CIAE China	IGCAR India	IPPE Russia	JNC Japan	OKBM Russia
	XS Data	JEF-2.2	ENDF/B-VI	ENDF/B-V2	JEF-2.2	UEH V-M	CV2M	ABBN-93	JENDL-3.2	ABBN-93
	Energy Groups	80/9	150/9	2082/230	1968/33	46/12	26/26	26/18	70/18	26/26
K-EFF	Transport	1.0235	1.0210	1.0079	1.0230	1.0150		1.0058	1.0095	
	Diffusion	1.0145	1.0182	0.9968	1.0168	0.9981	1.0036	1.0014	1.0042	0.9980
Fuel Doppler	Transport	-0.0081	-0.0074		-0.0067			-0.0063	-0.0062	
	Diffusion	-0.0079	-0.0076	-0.0065	-0.0068	-0.0050	-0.0046	-0.0062	-0.0064	-0.0066
Steel Doppler	Transport	-0.0013	-0.0012		-0.0015			-0.0012	-0.0011	
	Diffusion	-0.0013	-0.0012	-0.0011	-0.0013	-0.0005		-0.0012	-0.0012	-0.0010
Sodium Density	Transport	0.0050	0.0089		0.0034			0.0021	0.0040	
	Diffusion	0.0078	0.0106	0.0175	0.0052	0.0021	0.0045	0.0090	0.0077	0.0107
Steel Density	Transport	-0.0118	-0.0149		-0.0147			-0.0088	-0.0149	
	Diffusion	-0.0098	-0.0080	-0.0884	-0.0112	-0.0055	-0.0021	-0.0053	-0.0126	-0.0114
Fuel Density	Transport	0.3547	0.3642		0.3382			0.3466	0.3491	
	Diffusion	0.3488	0.3643	0.3343	0.3423	0.3492	0.3410	0.3505	0.3491	0.3528
Absorber Worth	Transport	-0.0278	-0.0277		-0.0263			-0.0260	-0.0270	
	Diffusion	-0.0273	-0.0252	-0.0266	-0.0273	-0.0391	-0.0269	-0.0274	-0.0265	-0.0267
Axial Expansion	Transport	-0.1419	-0.1466		-0.1374	-0.1341		-0.1267	-0.1361	
	Diffusion	-0.1378	-0.1430	-0.1327	-0.1378	-0.1432	-0.1395	-0.1297	-0.1393	-0.1415
Radial Expansion	Transport	-0.4852	-0.4940		-0.4573	-0.4803		-0.4787	-0.4647	
	Diffusion	-0.4801	-0.4948	-0.4360	-0.4650	-0.4232	-0.4840	-0.4868	-0.4812	-0.4827

2.3 BFS-73-1 Critical Experiment

Table 2 shows the calculation result of BFS-73-1 critical experiment. As shown in Table 2, the result of transport calculation agrees well with the diffusion calculation.

Table 2 BFS-73-1 critical experiment calculation result

	TRANSPORT	DIFFUSION					
Experimental value	TWODANT (R-Z/80g)	DIF3D (R-Z/80g)		DIF3D (Hex-Z/80g)		DIF3D (Hex-Z/9g)	
K-eff = 1,0008	Value	Value	Rel, Diff (%)	Value	Rel, Diff (%)	Value	Rel, Diff (%)
K-eff	1,00561	1,00065	0,49	0,99987	0,57	1,00324	0,24
Doppler	-0,00018	-0,00019	-5,83	-0,00020	-11,40	-0,00019	-5,83
Sodium Density	0,02097	0,02257	-7,63	0,02278	-8,63	0,02236	-6,63
Steel Density	0,02077	0,02283	-9,92	0,02272	-9,39	0,02240	-7,85
Fuel Density	0,36987	0,40246	-8,81	0,40178	-8,63	0,39822	-7,67
Axial Expansion	-0,44185	-0,45037	-1,93	-0,44978	-1,79	-0,44703	-1,17
Radial Expansion	-0,88487	-0,90244	-1,99	-0,90146	-1,87	-0,89631	-1,29

*Relative Difference=(Transport - Diffusion) / Transport x 100 (%)

2.4 KALIMER-150 Breakeven Core

The calculation results of KALIMER-150 breakeven core are presented in Table 3. As shown in Table 3, there were a lot of differences between the results of transport calculation and diffusion calculation.

Table 3 KALIMER-150 calculation result

	TRANSPORT	DIFFUSION			
	TWODANT (R-Z/80g)	DIF3D (R-Z/80g)		DIF3D (Hex-Z/80g)	
	Value	Value	Rel. Diff (%)	Value	Rel. Diff (%)
Fuel Doppler	-0.00236	-0.00265	-12.29	-0.00265	-12.29
Steel Doppler	-0.00058	-0.00059	-1.72	-0.00062	-6.90
Fuel Density	0.42380	0.41931	1.06	0.42671	-0.69
Sodium Density	-0.00520	0.00040	107.69	0.0001	101.92
Steel Density	-0.02211	-0.01390	37.13	-0.0141	36.23
Absorber Density	0.14408	-0.00170	101.18	-0.0014	100.97
Axial Expansion	-0.25640	-0.25570	0.27	-0.2612	-1.87
Radial Expansion	-0.56210	-0.57310	-1.96	-0.5672	-0.91

* Relative Difference = (Transport - Diffusion) / Transport x 100 (%)

2.5 KALIMER-600 Breakeven Core

Table 4 shows the calculation result of KALIMER-600 breakeven core. As shown in Table 4, we can see the good agreement between the result of transport calculation and diffusion calculation.

Table 4 KALIMER-600 calculation result

	TRANSPORT	DIFFUSION			
	TWODANT (R-Z/80g)	DIF3D (R-Z/80g)		DIF3D (Hex-Z/80g)	
	Value	Value	Rel. Diff (%)	Value	Rel. Diff (%)
Fuel Doppler	-0.00272	-0.00270	0.72	-0.00274	-0.63
Steel Doppler	-0.00112	-0.00108	3.90	-0.00111	1.15
Fuel Density	0.38338	0.38190	0.39	0.382508	0.23
Sodium Density	-0.03153	-0.03151	0.08	-0.02983	5.39
Steel Density	-0.07004	-0.07263	-3.69	-0.07018	-0.19
Absorber Density	-0.02839	-0.02830	0.31	-0.02733	3.73
Axial Expansion	-0.12199	-0.12000	1.63	-0.12553	-2.90
Radial Expansion	-0.48026	-0.48229	-0.42	-0.48212	-0.39

* Relative Difference = (Transport - Diffusion) / Transport x 100 (%)

2.5 Transport Correction Factors

According to the differences between the results of transport and diffusion calculation, the transport correction factors are produced based on those results. Table 5 shows the transport correction factors in the average sense.

Table 5 Transport correction factors

	JEF-2.2		ENDF/B-VI	
	보정인자	SD ±	보정인자	SD ±
Fuel Doppler	1.02792	0.00303	0.98024	0.00231
Steel Doppler	1.02400	0.00041	0.95082	0.00042
Sodium Density	0.63918	0.00560	0.37311	0.00588
Steel Density	1.20408	0.01297	1.86250	0.01371
Fuel Density	1.01692	0.01643	0.99973	0.03220
Absorber Worth	1.01832	0.00515	1.09921	0.00615
Axial Expansion	1.02975	0.01177	1.02517	0.01748
Radial Expansion	1.01062	0.03916	0.99838	0.05344

3. Conclusion

In this work, the transport correction factor to come close to the accuracy of the transport theory was studied. According to the differences between the transport and diffusion calculation results, the values of the K-CORE code system show higher trends than those of other country participants and the measurement results. Through the update of nuclear data libraries and the comparison analysis of more numbers of experiments meaningful in statistical analysis, more accurate verification and improvement will be carried out. The result of this study will be utilized as the basic data for the development of reactivity coefficients analysis system, and will improve the credit of reactivity coefficients calculation in conceptual core design.

But as we can see in Table3 and Table 4, the calculation results by the diffusion and transport theory are different by the core size, loading pattern and composition etc. Thus we conclude that it is better to generate the transport correction factor according to the each core in the detailed design stage.

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