Preliminary Assessment of Open Reactor Physics Database for Cross Section Adjustment

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1. Introduction

The uncertainty of nuclear data occupies a considerable portion in a fast reactor analysis compared with other uncertainty arising from analysis methodology, geometrical approximation. Korea Atomic Energy Research Institute (KAERI) is now developing a cross section adjustment method for enhancing a sodium cooled fast reactor (SFR) design. In order to get an appropriate accuracy from the cross section adjustment, many measured integral parameters are necessary. Unfortunately, the design feature in SFR that has been developed in KAERI is quite different from that had been validated so far. The main difference in design arises from the use of metallic fuel, which make harder neutron spectrum than that of oxide fueled core. The reactor physics database on metal fuel loaded core is very limited number and a new experiment is very costly.

In this context, KAERI considers the use of open reactor physics database in the cross section adjustment in addition to the own reactor physics experiment. Although the open reactor physics data are almost for the oxide core, it is considered to be partially used in the cross section adjustment. The main purpose of this study is to assess the open reactor physics database for inclusion of the cross section adjustment procedure.

2. Open Reactor Physics Database

There are several reactor physics database available for fast reactor application. One is CSEWG (Cross Section Evaluation Working Group) benchmark problem, which is often utilized for evaluating the accuracy of newly released evaluated nuclear data file. The other is IRPhE handbook which is the collection of reactor physics database of various reactor types.

Among the open reactor physics database, five problems, four problems from CSEWG and one problem from IRPhE, were selected through a preliminary screening procedure. Each measured spectral index (F28/F25) was compared with that of reference core and benchmark problems having similar index (within ±20%) are taken from the database. The selected reactor physics database are listed in Table I with brief descriptions. It should be noted that the reference core does not have any blanket while the open database has radial and axial blanket fuel surrounding the core region.

3. Method and Results

2.1 k-effective and spectral indices

Selected five benchmark problems were evaluated by using TWODANT code. The analyses were carried out with four different evaluated data (ENDF/B-VI.6, ENDF/B-VII.0, JENDL-3.3 and JEFF-3.1). The benchmark problems included in the CSWEG are homogeneous configurations. CSWEG also provides the heterogeneity correction factor for measured integral parameters. However, the ZEBRA problem in IRPhE is for heterogeneous configuration. In order to simplify the original configuration into homogeneous one, atomic number densities of each cell and sheath were homogenized for each assembly.

Table I: The description of benchmark-problems[1][2]

Model	Fuel	Enrichment (w/o)	Coolant	Core	F28/F25
Reference	TRU-U-Zr	TRU=21.2 ~26.4	Na	Cylinder	0.0289
ZPR-6-6A	UO2	^{235}U=18.2	Na	Cylinder	0.0240
ZPR-3-48	Pu/U/Mo alloy	Pu=19.3	Na, C	Cylinder	0.0320
ZPR-3-56B	MOX	Pu=20	Na	Cylinder	0.0310
ZPR-9	MOX	Pu=13.5	Na, C	Cylinder	0.0280
ZEBRA-LMFR-EXP-002	MOX		Na, C	Cylinder	0.0336

In this study, in TWODANT code with 150 groups of neutron energy processed from TRANSX are used to evaluate k-effective and spectral indices in the center of core. P3 scattering order and S8 angular quadrature set were used for TWODANT calculation. Furthermore, the results of MCNP are added to verify the homogeneous TWODANT modeling.

Table Ⅱ is shown the result of predicted k-effective using 4 nuclear data files. The calculated k-effective has reasonable accuracy within 330 pcm Δk compared with measured data. The heterogeneity correction was not made for the ZEBRA problem, which has large discrepancy with measured value. Difference between TWODANT and MCNP reflects difference in neutron spectrum that has been used as weighting function in making master library.

Table Ⅱ: k-effective values comparison using TWODANT code R-Z Modeling and nuclear data files

		*Lib.	(A) Experiment (Corrected)	(B) TWODANT	Diff. [B-A] (pcm)	(C) MCNP	Diff. [C-A] (pcm)
CSEWG	ZPR-3-48	VII.0	0.9817	0.98499	329	0.98407	237
		VI.6		0.99333	1,163	0.99050	880
		3.1		0.98668	498	0.98659	489
		3.3		0.98293	123	0.98230	60
	ZPR-3-56B	VII.0	0.9898	0.98651	-329	0.99086	106
		VI.6		0.99241	261	0.99132	152
		3.1		0.98759	-221	0.99084	104

		3.3		0.98647	-333	0.98964	-16
	ZPR-6-6A	VII.0	0.9933	0.99615	285	0.99528	198
		VI.6		0.99667	337	0.99536	206
		3.1		0.99874	544	0.99808	478
		3.3		0.98740	-590	0.98514	-816
	ZPR-9	VII.0	0.98724	0.98981	257	0.98806	82
		VI.6		1.00247	1,523	0.99671	947
		3.1		0.99310	586	0.99165	441
		3.3		0.98788	64	0.98607	-117
			Experiment				
IRPhEP	**ZEBRA-LMFR-EXP-002 MZA**	VII.0	1.0089	0.97645	-3,245	0.97487	-3,403
		VI.6		0.98321	-2,569	0.97951	-2,939
		3.1		0.97926	-2,964	0.98566	-2,324
		3.3		0.97483	-3,407	0.97343	-3,547
	ZEBRA-LMFR-EXP-002 MZB	VII.0	1.0038	0.99590	-790	0.99490	-890
		VI.6		0.99645	-735	0.99503	-877
		3.1		0.99466	-914	0.99790	-590
		3.3		1.04781	4,401	0.99180	-1,200

* Libraries : VII.0 : ENDF/B-VII.0, VI.6 : ENDF/B-VI.6, 3.1 : JEFF-3.1, 3.3 : JENDL-3.3

Table Ⅲ: Neutron spectral index in the center of core comparison using TWODANT code R-Z Modeling and nuclear data files

	Experiment(measured)			TWODANT(C/E)(corrected)			
Contents	Experiment (Uncertainty %)	Reference	Calculated Heterogeneity Correction Factor	VII.0	VI.6	3.1	3.3
ZPR-3-56B							
F49/F25	1.028(0.97)			**1.000**	**1.005**	**0.998**	**1.000**
ZPR-6-6A							
F28/F25	0.024(2.99)	0.022	1.016	**0.973**	**0.999**	0.971	**0.984**
C28/F25	0.138(2.98)	0.142	1.011	**1.025**	**1.021**	**1.021**	1.032
ZPR-9							
F28/F49	0.030(1.33)	0.029	1.000	0.955	**1.002**	0.948	0.969
ZEBRA-LMFR-EXP-002 MZA							
				TWODANT (C/E)			
F25/F49	0.9780(1.9)			**1.012**	**1.007**	**1.013**	**1.012**
C28/F49	0.1291(1.4)			1.015	**1.004**	**1.011**	1.017
ZEBRA-LMFR-EXP-002 MZB							
F25/F49	1.0660(1.3)			**0.988**	0.984	**0.989**	0.843
C28/F49	0.1428(1.3)			1.018	**1.012**	**1.014**	0.797

Table Ⅲ shows the several kinds of spectral indices calculated by TWODANT. Most of results are in good agreement with measured value within 1σ or 2σ of measurement uncertainty.

2.2 Evaluation of Sensitivity

The sensitivity coefficients of selected benchmark problems were compared with those of reference core. The analysis was carried out with APSTRACT code which has been developed in KAERI for a fast reactor application[3]. Fig 1 and Table IV show example of sensitivity coefficient and integral sensitivity for selected benchmark problems. Although there is no benchmark problems similar to the reference core for all isotopes, ZPR-3-56B and ZEBRA problems could be used for U-238 cross section adjustment. There is also a possibility of using ZPR-6-6A and ZPR-3-56B for Na-23.

3. Conclusions

CSEWG and IRPhEP were analyzed using TWODANT code with four different libraries prior to choose opened reactor physic experiment. As a result, calculated k-effective are in agreement within 330 pcm Δk and predicted spectral indices are within 2σ of measured value. Some of selected benchmark problems had possibility of use in isotope-wise cross section adjustment.

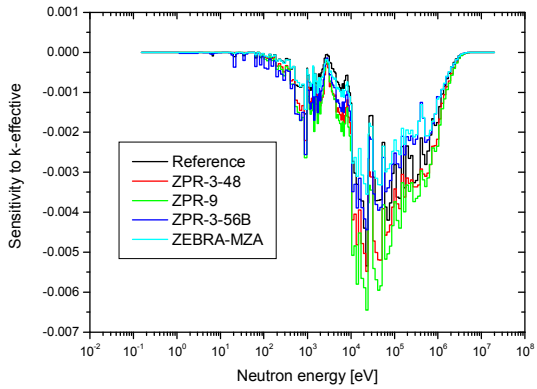

Fig. 1. Comparison of sensitivity coefficient of U-238 capture cross section to k-effective

Table IV: k-effective values comparison using TWODANT code R-Z Modeling and nuclear data files

		Ref.	ZPR-3-48	ZPR-6-6A	ZPR-9	ZPR-3-56B	ZEBRA-MZA
Pu-239	Fission	0.438	0.574	-	0.566	0.591	0.557
	Nu	0.619	0.822	-	0.786	0.858	0.783
	Capture	-0.036	-0.064	-	-0.052	-0.071	-0.048
U-238	Fission	0.057	0.085	0.073	0.095	0.065	0.062
	Nu	0.098	0.145	0.120	0.160	0.107	0.103
	Capture	-0.151	-0.205	-0.267	-0.230	-0.164	-0.129
PU-241	Fission	0.042	0.009	-	0.017	0.019	0.037
	Nu	0.063	0.014	-	0.025	0.028	0.053
	Capture	-0.017	-0.004	-	-0.007	-0.010	-0.012

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