Integral Comparison of Library Performance

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The 2003-2004 activities of Reactor Integral Test WG under Subcommittee on Reactor Constants of Japanese Nuclear Data Committee are presented. During this period, the WG carried out integral tests of JENDL-3.3, ENDF/B-VI and JEF 2.2 (JEFF-3.0) for reactor applications. Some results of integral tests for other latest libraries, JEFF-3.1 and ENDF/B-VII are also presented.

1. Introduction

The latest version of Japanese Evaluated Nuclear Data Library (JENDL-3.3) [1] was released in May, 2002. After the release of JENDL-3.3, the activities of Reactor Integral Test Working Group under Subcommittee on Reactor Constants of Japanese Nuclear Data Committee have been concentrated on the benchmark testing of JENDL-3.3 and other recent libraries to improve JENDL-3.3 for the next version, JENDL-4. This paper summarizes the 2003-2004 activities of the WG.*. During this period, the WG discussed on the following topics:

- Benchmark analysis for thermal systems
- Analysis of LWR MOX physics experiments MISTRAL/BASALA
- Sensitivity analysis for thermal systems
  -Dependence of criticality prediction accuracy on U-235 enrichment-
- Integral test for fast reactors at JNC with BFS, MOZART, SEFOR experiments
- PIE and burn-up calculation for MA irradiated at PFR
- Applicability of JENDL-3.3 to MOX critical experiments
- FUBILA project for full-MOX BWR and its preliminary analysis
- FCA Benchmark for JENDL-3.3 and ENDF/B-VII Preliminary
- Benchmark system for JENDL-4

Among these topics, the following 4 topics are briefly reported in this paper.

1. Integral test of JENDL-3.3 in U-fueled thermal reactors by K. Okumura (JAEA),
2. Integral test for FCA cores by S. Okajima (JAEA),
3. Integral test of latest libraries by K. Okumura (JAEA), and
4. Action plans now underway by Reactor Integral Test WG chaired by M. Ishikawa

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2. Integral Test of JENDL-3.3 in U-fueled Thermal Reactors by K. Okumura

Extended benchmark tests were carried out by K. Okumura for light water moderated uranium fueled systems, aiming at investigating dependence of criticality evaluation accuracy on U-235 enrichment. The benchmark cores selected are shown in Table 1. All the benchmark calculations were performed by using a continuous-energy Monte Carlo code MVP [2] and its four different nuclear data libraries generated from JENDL-3.2 [3], JENDL-3.3, JEF-2.2 [4] and ENDF/B-VI (R8) [5].

The results are summarized in Figs.1-4. The dependence of C/E values on U-235 enrichment is apparently seen in Fig.2 (JENDL-3.3) and Fig.3 (all nuclear data). The C/E values for all nuclear data increase with the enrichment. However, the U-235 enrichments for C/E value ~1.0 vary from 2.5% to 10%, depending on the libraries as shown in Fig.4. No apparent dependence of prediction accuracy is observed for other parameters such as H/U ratio and leakage. In order to solve the systematic dependence on U-235 enrichment, 4 factors of k_∞ were evaluated for the benchmark cores with MVP and JENDL-3.3. Only the η-value showed a similar dependence on the U-235 enrichment, as shown in Fig.5. It was concluded from this fact and some consideration that 3% decrease of $\sigma_\gamma^{238}/\sigma_a^{235}$ solves the dependence of prediction accuracy on u-235 enrichment.

Table 1 List of benchmark cores for integral test of JENDL-3.3 in U-fueled thermal reactors

No	Core	U-235/U	H/U	Remarks
1	TRX-1	1.3	3.3	Metal-U, Hexagonal lattice, Al clad. (11.506mmϕ)
2	TRX-2	1.3	5.6	Metal-U, Hexagonal lattice, Al clad. (11.506mmϕ)
3	KRITZ2:1	1.89	3.4	Zry-2 clad (12.25mmϕ), Boron:218ppm
4	KRITZ2:13	1.89	5.0	Zry-2 clad (12.25mmϕ), Boron:452ppm
5	B&W-XI*	2.46	5.4	Al-6061 clad (12.06mmϕ), Boron:1511ppm
6-8	TCA-1.50U*	2.6	4.3	3 cases of different loading patterns, Al clad (14.17mmϕ)
9-13	TCA-1.83U*	2.6	5.3	5 cases of different loading patterns, Al clad (14.17mmϕ)
14-18	TCA-2.48U*	2.6	7.2	5 cases of different loading patterns, Al clad (14.17mmϕ)
19-23	TCA-3.00U*	2.6	8.6	5 cases of different loading patterns, Al clad (14.17mmϕ)
24	DIMPLE3*	3.0	3.0	SS clad (10.937mmϕ)
25	MISTRAL-C1	3.7	5.1	By NUPEC, Zry-4 clad (9.5mmϕ), Boron:300ppm
26	DIMPLE7*	7.0	8.4	SS clad (8.324mmϕ)
27-33	STACY* 001-007	10.0	72~ 103	Nitrate solution in water reflected 600mmϕ cylindrical tank, 7 cases of different U concentrations: 310.1~225.3 gU/liter,
34	TRACY	10.0	7.2	Nitrate solution, 430g/liter, critical level:45.3cm with CR
35	JRR4-U20	20.0	-	U_3Si_2-Al dispersed fuel, minimum critical core (12 elements)
36	JRR4-U93	93.0	-	U-Al alloy, minimum critical core (12 elements)
37	KUCA-B(1:1)	5.4	9.56	EU:NU=1:1, B3/8”P33EU-NU-NU-EU(5)
38	KUCA-B(1:1)	9.6	13.4	EU:NU=2:1, B3/8”P36EU-NU-NU-EU(3)
39	KUCA-B(1:1)	93.0	9.3	EU:NU=1:0, B1/8”P80EU(2)

*Experimental data and benchmark models are taken from the ICSBEP Handbook[6]

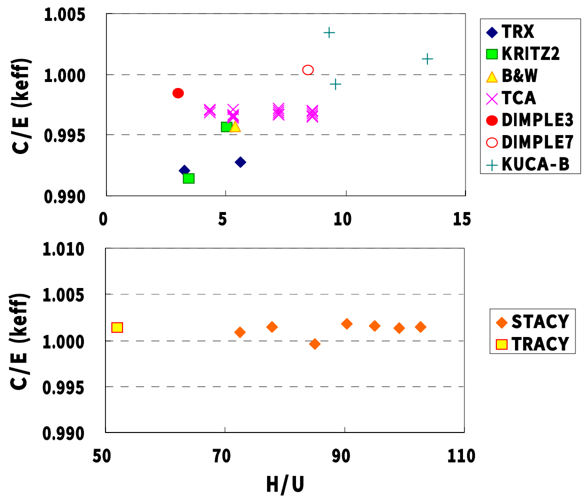

Fig.1 Prediction accuracy of keff vs. H/U ratio (JENDL-3.3)

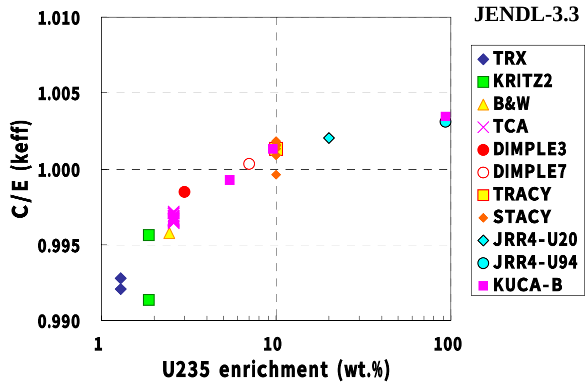

Fig.2 Prediction accuracy of keff vs. U-235 enrichment (JENDL-3.3)

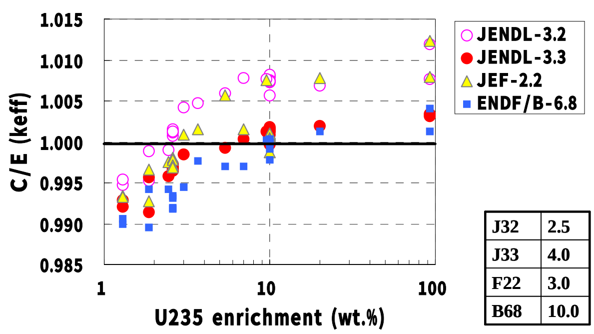

Fig.3 Comparison of 4 libraries (keff vs. U-235 enrichment)

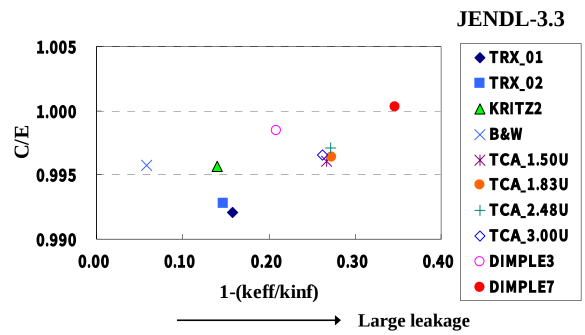

Fig.4 Prediction accuracy of keff vs. leakage (JENDL-3.3)

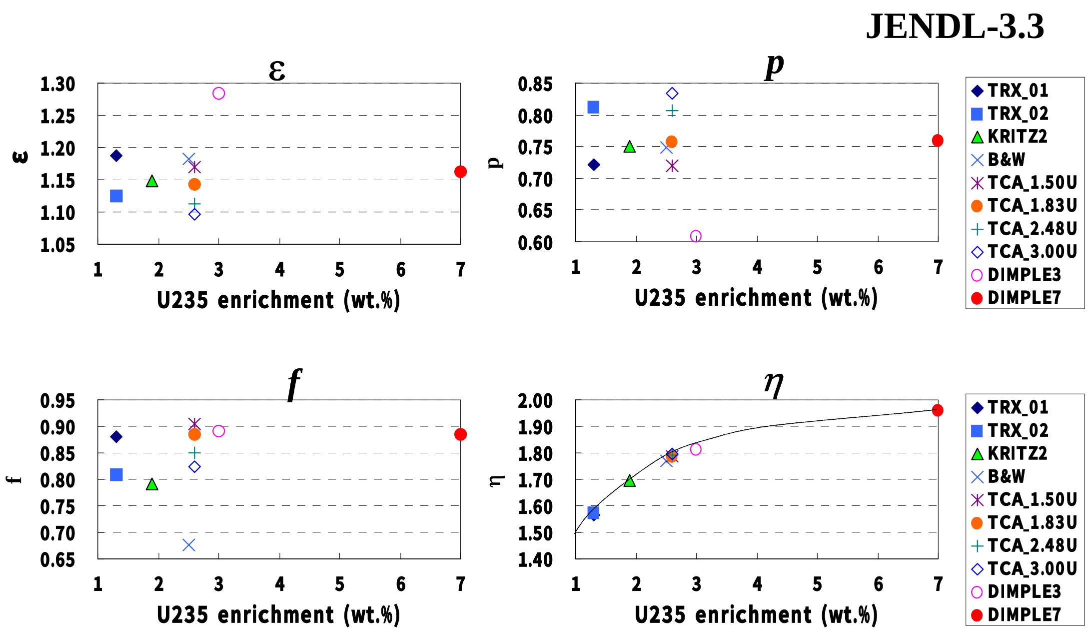

Fig.5 4 factors of k_{∞} evaluated with MVP and JENDL-3.3

3. Integral Test for FCA Cores by S. Okajima

Eight different FCA cores were selected from a viewpoint of benchmark test for the main revision in JENDL-3.3: the IX-1 to IX-6, X-1 and X-2 cores. These cores were simple in geometry. Each core was composed of a core region and axial and radial blanket regions. The characteristics of these cores were summarized in Table 2.

The IX series cores were constructed for the integral test of actinide nuclides cross sections. Figure 6 shows the calculated neutron spectra at the core center. The spectrum is soft in the IX-1 core and becomes harder for a core of later number.

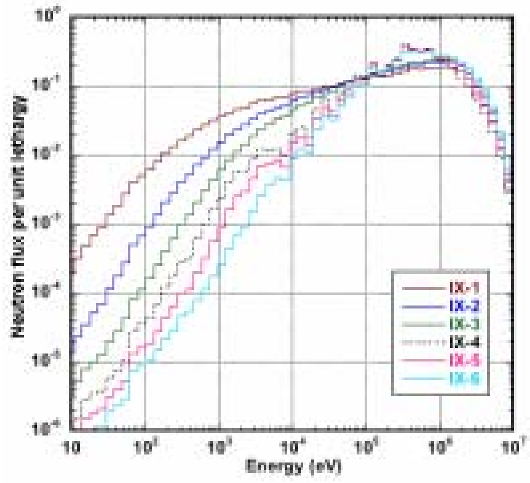

Fig.6 Neutron spectra in FCA IX cores

The X-1 and X-2 cores were constructed for the mockup experiment of the Fast Experimental Reactor "JOYO" Mark II Core. The X-1 core had a cylindrical core surrounded by a depleted uranium blanket, while the X-2 core consisted of the core and reflector regions comprised of sodium and stainless steel. Both cores had a similar geometry and fuel configuration in core cells.

Table 2 Characteristics of the FCA cores for a benchmark test

Core name		IX-1	IX-2	IX-3	IX-4	IX-5	IX-6	X-1	X-2
Geometry dimension	(cm)								
Core	Radius	30.4	23.1	17.9	27.6	20.4	22.9	28.6	28.0
	Height	61.0	40.6	35.6	50.8	40.6	40.6	50.8	50.8
Blanket thickness	Radial	31.2	35.1	39.6	32.5	37.1	36.0	33.1	33.8*
	Axial	35.6	35.6	35.6	35.6	35.6	35.6	30.5	35.6*
Fuel material (Enrichment)		EU (93%)	EU (93%)	EU (93%)	EU (93%)	EU (93%)	EU (93%)	Pu+EU (35%)	Pu+EU (35%)
Principal diluent material		C	C	C	SUS†	SUS†	SUS†	Na	Na
Volume fraction of fuel		0.06	0.13	0.19	0.13	0.19	0.19	0.5	0.5

* : Reflector thickness, † : Stainless steel

Figure 7 compares calculated results (C/E values for criticality) between JENDL-3.3 and JENDL-3.2. No large discrepancy is seen between both the libraries, except for IX-1 to –3 cores. For IX-1 to –3 cores, neutron spectrum dependence is observed in the results with JENDL-3.3, while no spectrum dependence is seen in JENDL-3.2. This tendency is caused by the revised capture cross section of U-235.

In Fig.8, calculated results are compared between ENDF/B-VI.8 and JEFF-3.0, together with JENDL-3.3. Both libraries give a similar tendency of C/E values. The ENDF/B-VI.8 gives C/E values of 0.999 ~ 1.017, while the JEFF-3.0 results are 0.996 ~ 1.010. In the IX-1 to –3 cores, similar spectral dependence is found among the three libraries including JENDL-3.3. On the other hand, spectral dependence in the IX-4 to –6 cores, which is found in the JENDL-3.3 results, is not observed in the

ENDF/B-VI.8 and JEFF-3.0 results.

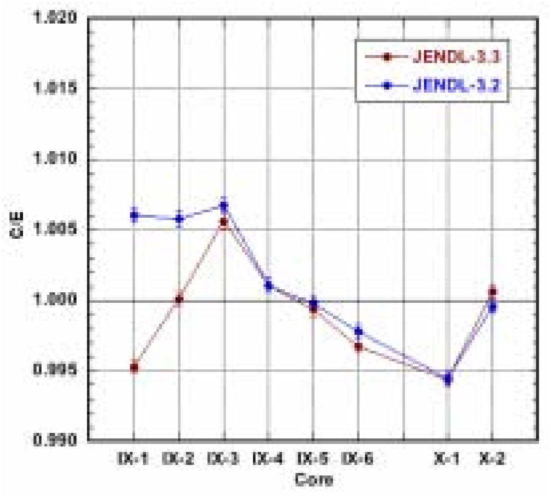

Fig.7 Comparison between JENDL-3.3 and JENDL-3.2

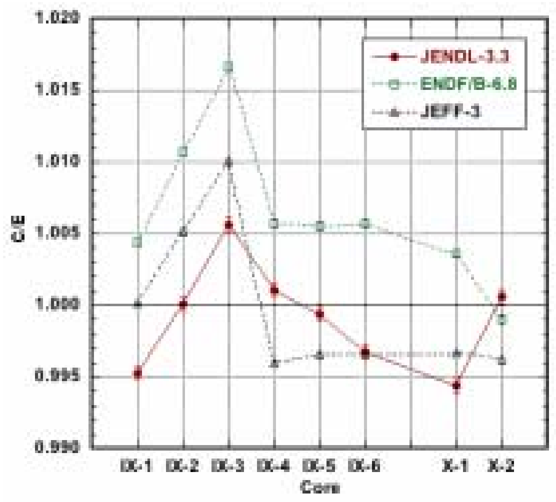

Fig.8 Comparison between ENDF/B-VI.8, JEFF-3.0 andJENDL-3.3 and JENDL-3.2

4. Integral Test of Latest Libraries by K. Okumura

Benchmark test of latest libraries JEFF-3.1[7] and ENDF/B-VIIβ1.2[8] were carried out by K. Okumura with the MVP code for typical thermal and fast cores with U or Pu fuel. The results are shown in Fig.9, together with those of JENDL-3.3 and ENDF/B-VI.8. As for the thermal systems with U fuels, both the latest libraries improve the U-235 enrichment dependence of prediction accuracy. However, the underestimate in lower enrichment remains.

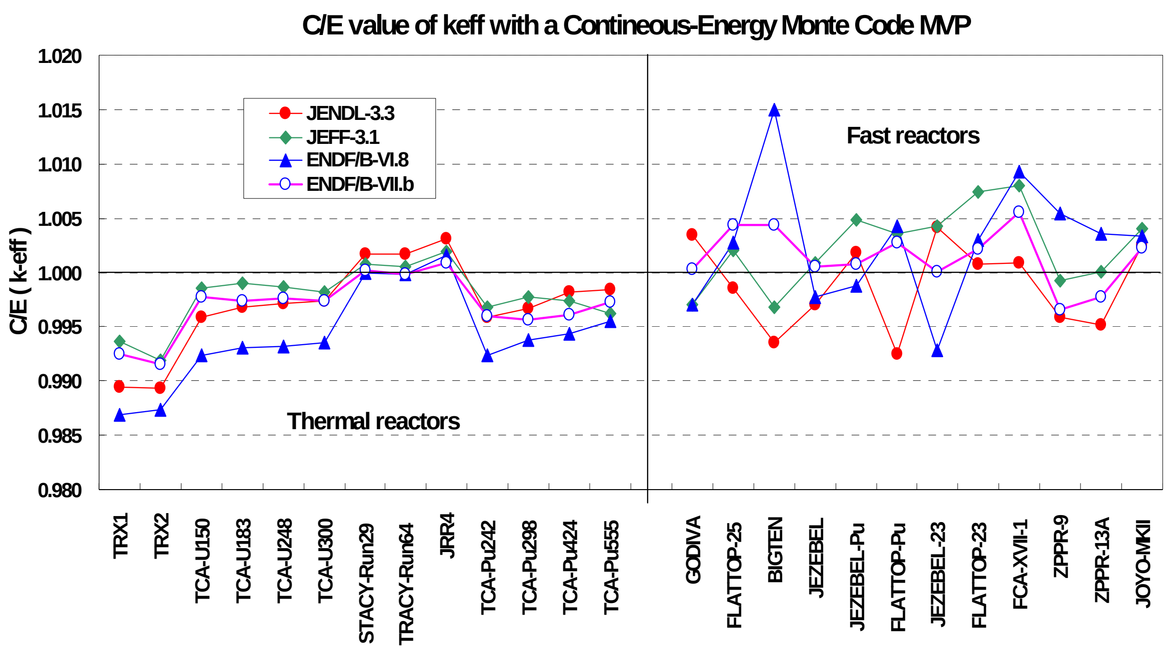

Fig.9 C/E values of k_{eff} with the latest libraries, JEFF-3.1, ENDF/B-VIIβ1.2, together with those with JENDL-3.3 and ENDF/B-VI.8

5. Action Plans Now Underway by Reactor Integral Test WG Chaired by M. Ishikawa

The Reactor Integral Test WG has been chaired by M. Ishikawa since FY2005. It is carrying out extended benchmark tests for JEFF-3.1, ENDF/B-VII, JENDL-3.3. etc. to clarify problems in current nuclear data and to give recommendation to the evaluation work for JENDL-4. For this purpose, the following benchmark cores are selected:

- FUBILA and REBUS experiments with JEFF-3.1
- NCA
- Small fast cores: FCA-IX-1, -2, -3, -4, -5, -6, -7, FCA-X-1、-2
- Benchmark cores with metal or oxide fuel: FCA-XVI-1, -2, FCA-XVII-1
- Large Na-MOX cores: ZPPR-9 ~ -19B (19 cores)
- Large Na-UO2 cores: BFS-62-1~5, BFS-66-1 (6 cores)
- JOYO MK-I, -II
- Experiments in ICEBEP
- etc.

References

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[8] Cross Section Evaluation Working Group (CSEWG), National Nuclear Data Center, Broohaven National Laboratory, http://www.nndc.bnl.gov/csewg_members/index.html.