Comparison of ENDF/B-VIII.0 and ENDF/B-VII.1 in Criticality and Depletion using PWR Pin Cell by STREAM

Kyeongwon Kim[a], Sooyoung Choi[a], Kiho Kim[b], Wonkyeong Kim[a], Deokjung Lee[a*]
Department of Nuclear Engineering, Ulsan National Institute of Science and Technology 50 UNIST-gil, Ulsan 44919, Republic of Korea
Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejeon 34142, Korea
[*]Corresponding author: deokjung@unist.ac.kr

1. Introduction

This paper presents the criticality and depletion comparison of nuclear data library ENDF/B-VIII.0 and ENDF/B-VII.1 using pressurized light water reactor (PWR) pin cell by STREAM. In this study, several different temperatures of fuel and coolant are used

The new version of ENDF/B library, ENDF/B-VIII.0 was released in 2018 [1-2]. ENDF/B is a raw evaluated nuclear data library containing the neutron cross section. Generally, the neutron cross section data is processed by a nuclear data processing code for a neutron transport analysis code. Then, the output of nuclear data processing code is processed again into the data and the format required for the library of a neutron transport analysis code. In this study, NJOY2016 is used to process nuclear data ,and NTOS (NJOY to STREAM) is used to process the output of NJOY into library of STREAM [3]. STREAM has been developing by Computational Reactor Physics and Experiment laboratory (CORE) in Ulsan National Institute Science and Technology (UNIST) [4-5].

2. Methods and Results

STREAM, reactor physics analysis code, based on method of characteristics (MOC). For this comparative analysis, five cases of pin-cell problem are considered. The temperatures of fuel and coolant are shown in Table I. MOC parameters for these calculations in STREAM is set to use 0.01 cm of average ray spacing, 96 azimuthal angle and 12 polar angle. Fuel region is divided into 3 rings for considering rim-effect in the depletion calculation. The boron concentration in the coolant is 700 ppm.

Table I: Temperature of fuel and coolant

	Fuel Temperature (K)	Coolant Temperature (K)
Case 1	293.6	293.6
Case 2	600	500
Case 3	600	600
Case 4	900	600
Case 5	1400	600

2.1. ENDF/B-VIII.0

In ENDF/B-VIII.0 library, 557 nuclides are included. On the other hand, ENDF/B-VII.1 have 423 nuclides. ENDF/B-VIII.0 includes 33 thermal scattering data in comparison with 21 data in ENDF/B-VII.1 Particularly, the library improved six nuclides, named ^{1}H ^{16}O ^{56}Fe ^{235}U ^{238}U ^{239}Pu through the Collaborative International Evaluation Library Organization (CIELO) project [1-2]. For example, significant differences in the data are observed for fission and capture of ^{235}U, ^{238}U and ^{239}Pu, as well as the neutron multiplicities(nu-bar) of ^{235}U and ^{239}Pu. The scattering and capture cross section of ^{1}H, ^{16}O and ^{56}Fe also show significant differences [6]. Since those six nuclides are mainly contained in the fuel, the coolant, the structure materials, the impact on the improvement of cross section data for those nuclides would be significant on criticality in reactor physics calculations.

2.2. NTOS

ENDF/B library is processed in the group-wise cross section using NJOY depending on nuclide, temperature and neutron reaction. Then, NTOS reads the GENDF file of NJOY output and classifies by a temperature, a reaction and an energy group for a nuclide. The type of neutron reactions is processed according to MF and MT number. Finally, STREAM neutron library is generated. The procedure for generating STREAM neutron cross section library is shown in Fig. 1.

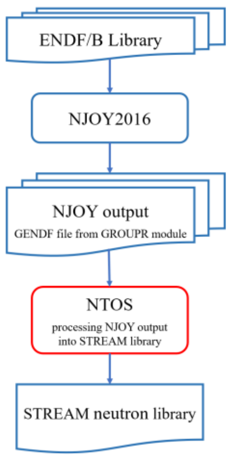

Fig. 1. Flowchart of STREAM neutron library generation system

2.3. PWR Pin cell

The typical PWR pin cell is used to compare the effective multiplication factor (k_{eff}). The pin cell has 3.1 wt%-enriched uranium oxide fuel and pitch of 1.26 cm. The configuration of pin cell is shown in Fig. 1.

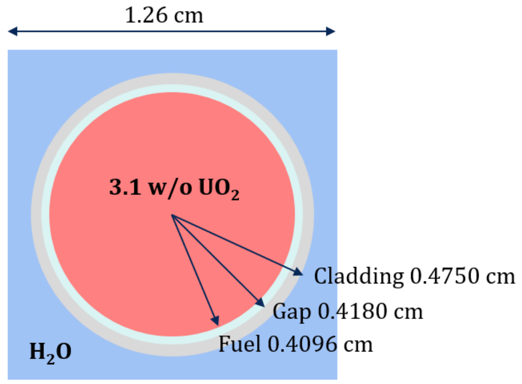

Fig. 2. Configuration of PWR pin cell

2.4. Results

The k_{eff} of pin cell using ENDF/B-VIII.0 and ENDF/B-VII.1 are compared on Case 1 to 5. The results of BOC, MOC and EOC are shown in Table II-VI. The $\Delta\rho$ and Δk are calculated by eq. (1) and (2).

$$\Delta\rho = \left(\frac{k_{8.0} - k_{7.1}}{k_{8.0}k_{7.1}}\right) \times 10^5 \qquad (1)$$

$$\Delta k = (k_{8.0} - k_{7.1}) \times 10^5 \qquad (2)$$

Where $k_{8.0}$ and $k_{7.1}$ are the k_{eff} of pin cell using ENDF/B-VIII.0 and ENDF/B-VII.1 respectively.

Table II: k_{eff} difference of Case1 problem

	Burnup [MWd/kg]	ENDF/B -VIII.0 k_{eff}	ENDF/B -VII.1 k_{eff}	Δρ [pcm]	Δk
BOC	0.0	1.27189	1.27312	-76	-123
MOC	30.0	0.91509	0.91894	-458	-385
EOC	60.0	0.73532	0.74013	-884	-481

Table III: k_{eff} difference of Case2 problem

	Burnup [MWd/kg]	ENDF/B -VIII.0 k_{eff}	ENDF/B -VII.1 k_{eff}	Δρ [pcm]	Δk
BOC	0.0	1.25464	1.25504	-25	-40
MOC	30.0	0.93047	0.93346	-344	-299
EOC	60.0	0.77714	0.78208	-813	-494

Table IV: k_{eff} difference of Case3 problem

	Burnup [MWd/kg]	ENDF/B -VIII.0 k_{eff}	ENDF/B -VII.1 k_{eff}	Δρ [pcm]	Δk
BOC	0.0	1.23600	1.23634	-22	-34
MOC	30.0	0.93325	0.93579	-291	-254
EOC	60.0	0.80895	0.81341	-678	-446

Table V: k_{eff} difference of Case4 problem

	Burnup [MWd/kg]	ENDF/B -VIII.0 k_{eff}	ENDF/B -VII.1 k_{eff}	Δρ [pcm]	Δk
BOC	0.0	1.22335	1.22361	-17	-26
MOC	30.0	0.92990	0.93237	-285	-247
EOC	60.0	0.81280	0.81708	-644	-428

Table VI: k_{eff} difference of Case5 problem

	Burnup [MWd/kg]	ENDF/B -VIII.0 k_{eff}	ENDF/B -VII.1 k_{eff}	Δρ [pcm]	Δk
BOC	0.0	1.20560	1.20574	-10	-14
MOC	30.0	0.92476	0.92714	-278	-238
EOC	60.0	0.81736	0.82140	-602	-404

All cases, the reactivity difference ($\Delta\rho$) depending on depletion is shown in Fig. 3. At the beginning of the cycle (BOC), the difference of reactivity within ± 80 pcm and the maximum value is -76 pcm. In case of the middle of the cycle (MOC), the difference is increased from -76 pcm to -458 pcm and -884 pcm for the end of the cycle (EOC). The burnup 0.0 MWd/kg, 30.0 MWd/kg and 60.0 MWd/kg are considered for BOC, MOC and EOC respectively.

At room temperature (293.6K), difference is maximum, however, with increasing the fuel temperature to 1400K and coolant temperature to 600K, difference is decreased from -76 pcm to -10 pcm at BOC. In case of MOC and EOC, it goes from -458 pcm to -278 pcm and -884 pcm to -602 pcm respectively.

Similar trends of difference are founded in k_{eff} difference and it shown in Fig. 4.

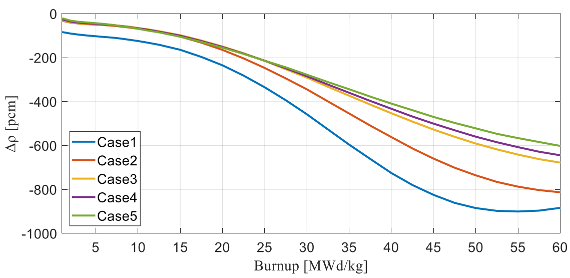

Fig. 3. Difference of Δρ using ENDF/B-VIII.0 and ENDF/B-VII.1 for Case 1-5

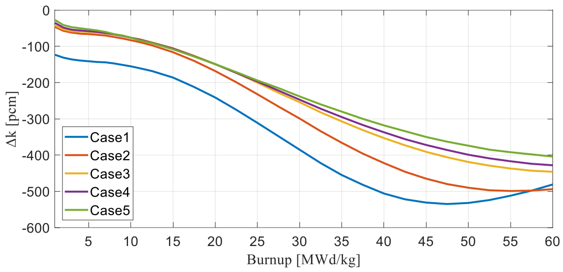

Fig. 4. Difference of Δk_{eff} using ENDF/B-VIII.0 and ENDF/B-VII.1 for Case 1-5

3. Conclusions

This paper analyzes the difference of k_{eff} for PWR pin cell using ENDF/B-VIII.0 and ENDF/B-VII.1 by STREAM. The difference of $\Delta\rho$ and Δk increase as depletion and decrease with increasing temperature. But in this analysis, only the cross section and point wise library is generated using ENDF/B-VIII.0. The depletion, decay and yield library used in this study is made using ENDF/B-VII.1.

Future work will be generation of depletion, decay and yield library using ENDF/B-VIII.0 and comparison of the reaction rates with nuclide, reaction and temperature. Furthermore, it will be analyzed which nuclides made the difference in $k_{eff.}$

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (No. NRF-2019M2D2A1A03058371).

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