Estimation for Effect of JENDL-3.3 on Neutronics Characteristics of Accelerator-Driven System

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The latest version of Japanese Evaluated Nuclear Data Library (JENDL-3.3) was released in last year. Primary purpose of this study was to estimate an effect of a revision of nuclear data library on neutronics characteristics of accelerator-driven subcritical system (ADS). The burnup calculations using both JENDL-3.3 and JENDL-3.2 were performed for JAERI proposed ADS. The detailed contribution of each nuclide and reaction on the difference of the calculation results, such as effective multiplication factor and burnup swing, were investigated. Moreover, to validate the nuclear data of actinides, the burnup analysis for the actinides samples irradiated at the Dounreay Prototype Fast Reactor were carried out.

1. Introduction

The Japanese long-term program called OMEGA has started in 1988 for research and development of new technologies for partitioning and transmutation of minor actinides (MA) and fission products. Under the OMEGA Program, for a dedicated transmutation system, the Japan Atomic Energy Research Institute (JAERI) has been proceeding with the research and development on accelerator-driven subcritical system ADS[1].

The ADS is a hybrid system that consists of a proton accelerator, a spallation target and a subcritical core. The proton beam current required to keep predefined power level is directly related to the effective multiplication factor (k_{eff}) of system. Therefore, calculational accuracies of k_{eff} and burnup change of k_{eff} are very important in neutronics design of ADS. In the latest version of Japanese Evaluated Nuclear Data Library, JENDL-3.3, nuclear data for many MA nuclides were revised from previous version, JENDL-3.2. In this study, the effect of a revision of nuclear data library on neutronics characteristics of ADS, especially k_{eff} and burnup swing, were investigated.

2. Effect of Nuclear Data on Nuclear Characteristics of ADS

The latest version of Japanese Evaluated Nuclear Data Library (JENDL-3.3) was released in last year. Primary purpose of this study was to estimate an effect of a revision of nuclear data library affects on neutronics characteristics of accelerator-driven subcritical system (ADS). The calculated neutronics characteristics were effective multiplication factor (k_{eff}) and burnup swing. The burnup calculations using both JENDL-3.3 and JENDL-3.2 were performed.

The calculated core was a lead-bismuth cooled ADS proposed by JAERI[2] for a dedicated transmutation system of MA. For the fuel, mixture of mono-nitride of MA (60%) and plutonium (40%) recovered from high-level waste from power reactor were used with inert matrix. In this study, two types fuel with different isotopic composition of MA were assumed. Case-1 and Case-2 corresponded to MA from spent fuel of UO_2 and MOX fuel PWR, respectively[3]. The isotopic compositions of MA for both cases are indicated in Table1. The burnup calculations were performed using revised ATRAS code system[4] under conditions of initial k_{eff} of 0.95 (results by

JENDL-3.2), core thermal power of 800MWth, and proton beam energy of 1.5GeV. Bunrup period was 600 effective full power days. After each burnup cycle, all fuel were removed from the core and recycled for next burnup cycle after cooling time. In the refabrication process, the fission products were removed and only MA of equal mass to the burnup fuel was added to the recycled fuel.

Time evolutions of k_{eff} during five burnup cycle are showed in Fig.1. In Case-1, difference between results using JENDL-3.3 and JENDL-3.2 for k_{eff} at initial state and the burnup swing is small. On the other hand, in Case-2, k_{eff} at initial state by JENDL-3.3 is about 2% smaller than that by JENDL-3.2, and difference of burnup swing is significant. To survey the reason of discrepancy between the results using JENDL-3.3 and JENDL-3.2, contribution of each nuclide for difference of k_{eff} at beginning and end of first cycle were calculated. The results are shown in Table 2. From Table 2, in Case-1, it is obvious that contributions of ^{237}Np and ^{241}Am are dominant and compensate each other, though k_{eff} values shows good agreement. In Case-2, contribution of ^{241}Am is emphasized since an amount of ^{237}Np is very small in MA. For ^{237}Np, ^{241}Am, and ^{243}Am which are main nuclides in MA, contribution of each reaction on difference of k_{eff} at BOC of first cycle are presented in Table 3. The results showed that the effects of capture reaction and □□$_f$ are dominant.

For ^{237}Np and ^{241}Am, sensitivity analysis were carried out using SAGEP code[5] to investigate more detailed information which is depend on neutron energy. The sensitivity coefficients, difference of cross section between JENDL-3.3 and JENDL-3.2, and the energy breakdown of reactivity change are shown in Fig.2. The sensitivity coefficients of fission cross section and □-value have peak values about 1MeV because the threshold fission cross section, while that of capture cross section are large from 10keV to 1MeV. From energy breakdown of reactivity change of ^{237}Np and ^{241}Am, differences of cross section above 10 keV are dominant for the difference of k_{eff}. Moreover, the contribution of □-values overcome the effect of fission cross sections, since □-values changed about 3% for both ^{237}Np and ^{241}Am. The results showed that the effect of a revision of nuclear library on neutronics characteristics of ADS is significant.

3. Validation of Nuclear Data using Integral Experiment

For evaluation and improvement of nuclear data, not only differential experiments but also integrated experiments are indispensable. Actinide samples which were irradiated in the Dounreay Prototype Fast Reactor (PFR) are precious experimental data for MA[6,7]. The samples were milligram quantities of actinide oxides of 21 different isotopes from thorium to curium. The results of chemical analyses and comparison with calculational results by JENDL-3.3 and JENDL-3.2 are shown in Fig.3. In Fig.3, fission per initial metal atom (FIMA) for samples and difference between beginning and ending of chemical analyses for main isotopes in samples are presented for some typical samples. The calculations were done by ORIGEN-2 code[8].

The results showed that differences between C/E values using JENDL-3.3 and JENDL-3.2 are small for FIMA. On the other hand, for difference during irradiation for main isotopes, the C/E values for ^{235}U and ^{241}Am by JENDL3.3 are improved, though the result of ^{237}Np shows underestimation. Large disagreement for ^{238}Pu sample does not change. Therefore, from the burnup analysis for actinide samples irradiated at PFR, further improvement is needed for nuclear data of MA while JENDL-3.3 shows relatively good result.

4. Conclusion

The effect of the revision of nuclear data in JENDL-3.3 on neutronics characteristics of ADS, such as k_{eff} and burnup swing, was investigated. The results showed that the effect of the revision was significant. The contribution of the capture cross section and the □-value of ^{237}Np and ^{241}Am were especially large. Moreover, for the validation of nuclear data, the burnup calculations for the actinide samples irradiated at PFR were performed. For ^{235}U and ^{241}Am, the calculation results by

JENDL-3.3 are improved though the result of ^{237}Np shows underestimation. For MA nuclides, further improvement of nuclear data is needed.

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Table 1 Plutonium and MA compositions resulting from reprocessing of UO_2(Case-1) and MOX(Case-2) fuel from PWR (nuclide atom%)

	Case-1	Case-2
^{238}Pu	2.7	4.1
^{239}Pu	55.3	41.9
^{240}Pu	23.9	30.5
^{241}Pu	9.5	10.6
^{242}Pu	7.1	11.3
^{241}Am	1.5	1.7
Total	100	100
^{237}Np	46.4	4.4
^{241}Am	37.1	58.3
^{243}Am	12.7	26.1
^{244}Cm	3.8	11.3
Total	100	100

Table 2 Contribution of each actinide nuclides for difference of k_{eff} by JENDL-3.3 and JENDL-3.2 at BOC and EOC of first cycle (%Δk/k)

Nuclides	Case-1 BOC	Case-1 EOC	Case-2 BOC	Case-2 EOC
^{237}Np	-0.908	-0.717	-0.091	-0.075
^{238}Pu	0.051	0.403	0.084	0.035
^{239}Pu	0.016	0.072	0.010	-0.038
^{240}Pu	-0.078	-0.117	-0.105	-0.146
^{241}Pu	-0.010	0.099	-0.014	0.117
^{242}Pu	-0.011	-0.026	-0.019	-0.040
^{241}Am	1.304	0.980	2.140	1.640
^{242m}Am	—	-0.218	—	-0.302
^{243}Am	0.120	0.088	0.249	0.198
^{242}Cm	—	-0.074	—	-0.099
^{243}Cm	—	-0.011	—	-0.009
^{244}Cm	0.010	-0.011	0.030	-0.004
^{245}Cm	—	-0.061	—	-0.115

Table 3 Contribution of each reaction of ^{237}Np, ^{241}Am, and ^{243}Am for difference of k_{eff} by JENDL-3.3 and JENDL-3.2 at BOC of first cycle (%Δk/k)

Case-1

	Total	σ_c	σ_f	$\nu\sigma_f$	σ_s
^{237}Np	-0.908	-0.573	0.040	-0.395	0.030
^{241}Am	1.304	0.639	0.009	0.544	0.112
^{243}Am	0.120	0.131	0.004	-0.012	-0.004

Case-2

	Total	σ_c	σ_f	$\nu\sigma_f$	σ_s
^{237}Np	-0.091	-0.055	0.004	-0.041	0.002
^{241}Am	1.640	1.014	0.016	0.939	0.174
^{243}Am	0.198	0.275	0.008	-0.027	-0.010

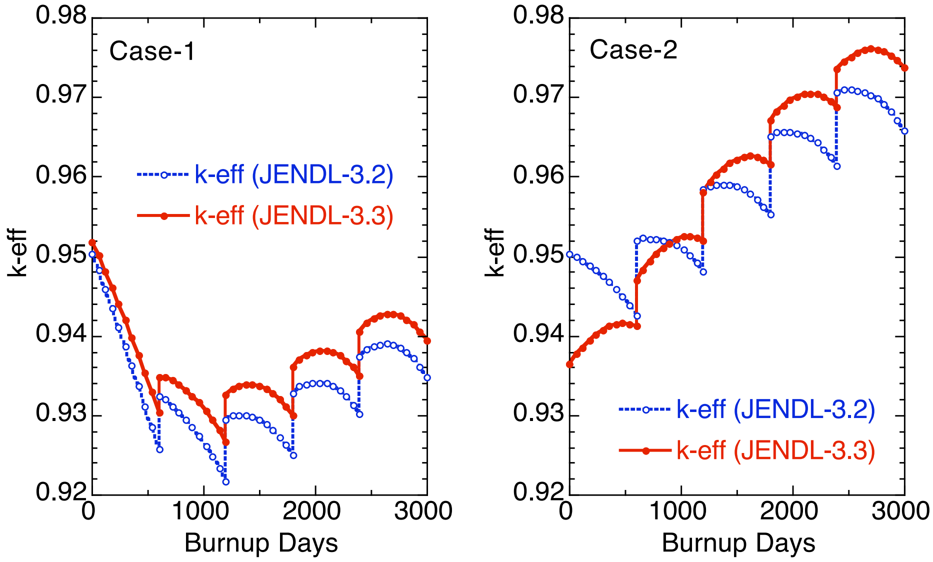
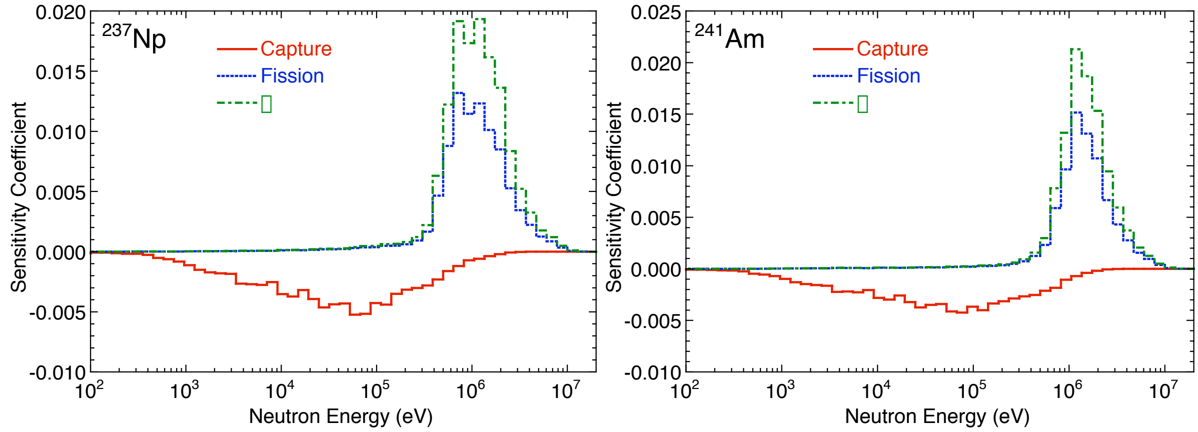
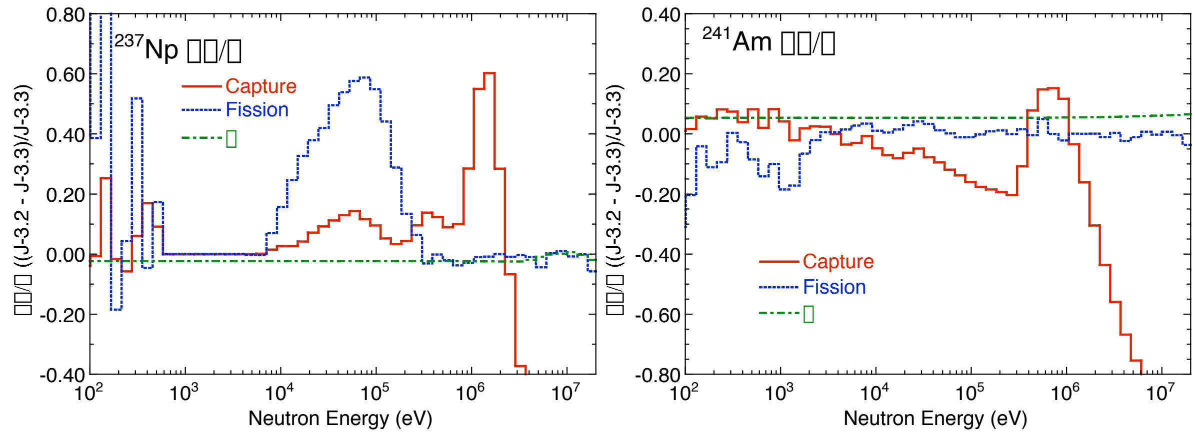


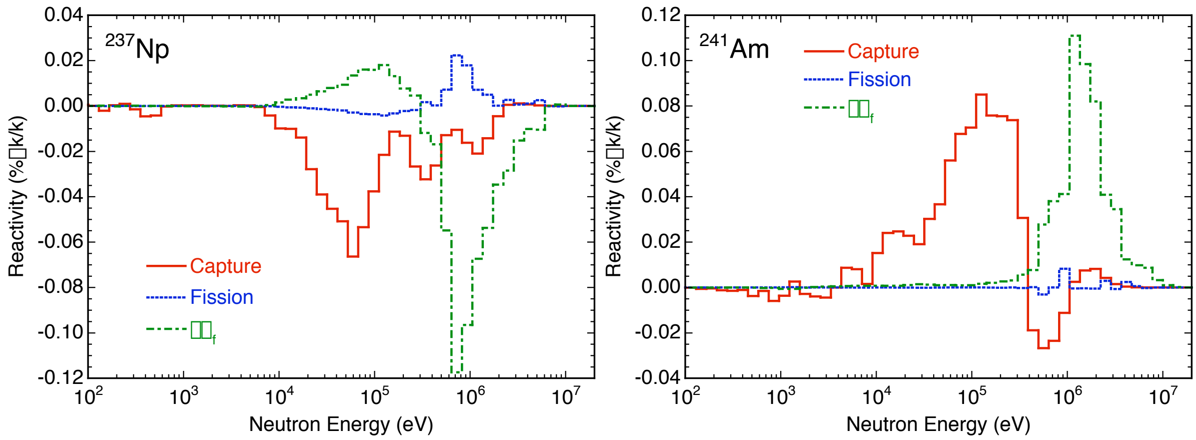
Fig.1 Time evolutions of k_{eff} during five burnup cycle



(a) Sensitivity coefficients for k_{eff}



(b) Difference of cross section between JENDL-3.3 and JENDL-3.2



(c) Energy break down of reactivity change

Fig.2 Sensitivity coefficient for keff, difference of cross section between JENDL-3.3 and JENDL-3.2, and energy break down of reactivity change for ^{237}Np and ^{241}Am

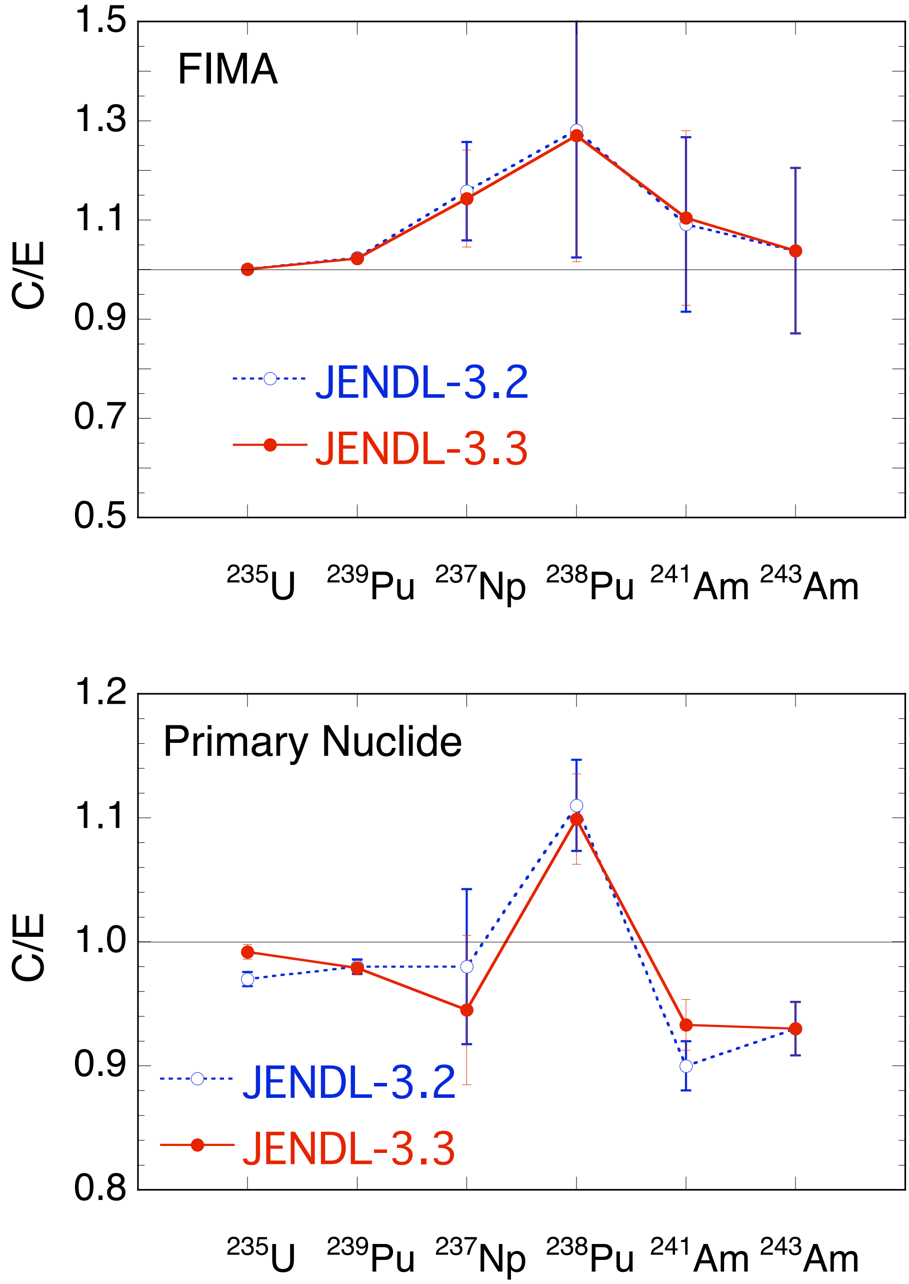


Fig.3 C/E values by JENDL-3.3 and JENDL-3.2 for some actinide samples irradiated at PFR