Core performance on nuclear data libraries for a 600 MWe TRU Burner

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1. Introduction

The conceptual core design for a sodium cooled fast reactor(SFR) for TRU burning is being developed by the Korea Atomic Energy Research Institute(KAERI) and the core design concept for a 600-MWe SFR for TRU burning has been implemented based on the design feature of the KALIMER-600[1].

In this paper, the impact of the evaluated nuclear data files on the core performance parameters of the KALIMER-600 core was investigated. The reference core used in the study is the 600 MWe TRU burner, which adapts a new core design concept for use of a single-enrichment.

2. Description of the Reference Core

The reference 600 MWe core has pursued the use of a single-enrichment fuel to simplify fuel fabrication processes and to eliminate the power shifting from the BOEC(beginning of equilibrium cycle) to the EOEC(end of equilibrium cycle). The ENDF/B-VI.6 library was used for the core design calculation of the reference core. The elimination of power shifting makes it possible to simplify the orifice design for the flow redistribution. The core design parameter is shown in Table I. In order to use a single-enrichment fuel, two different fuel slug diameters were applied to control power distribution at the inner/outer cores, respectively.

Table I: Core Design Parameter

	Reference Core
Core Thermal Power (MWt)	1,500
Coolant Temperature.(℃)' -Inlet/Outlet	390/545
Cycle Length (EFPD)	332
Active Core Height (cm)	89
Eq. Core Diameter (m)	3.08
Eq. Reactor Diameter (m)	4.43
Number of Fuel Assemblies	324
P/D Ratio	1.214
Fuel Cladding Thickness (mm)	0.56
Fuel Rod Outer Diameter (mm)	7
Smear Density (Inner/Outer core,%)	56/66

The constant cladding thickness of 0.56 mm is adopted in the core. Thicker sodium bonding was applied to fill up the thicker gap between a fuel slug and a cladding. A fuel with the smeared density of 56/66 v/o which is considered with a fuel slug and a sodium bonding gap is used in inner and outer core. The active core height was adjusted to make the sodium void worth around 6.15 $, and they are 89 cm. A clad outer diameter of 7.0 mm is adopted over all the designs, and the sodium bond thicknesses are adjusted to make TRU enrichment to be close to 29.4 w/o. Figure 1 shows the radial core configuration for the reference core.

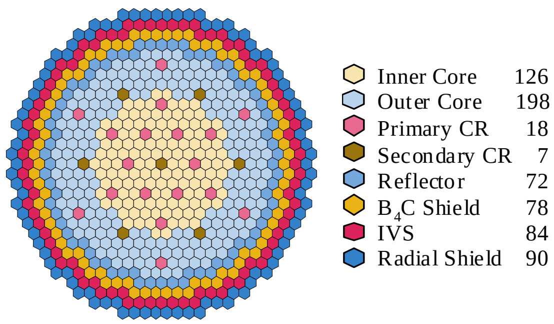

Fig. 1. Core Layout.

3. Caculation Method

Three up to date nuclear data files, ENDF/B-VII.0, JEFF-3.1 and JENDL-3.3 are used for the analysis in addition to the ENDF/B-VI.6 file which has been used for the analysis of the sodium cooled fast reactor in KAERI. All the evaluated nuclear data files are processed into a MATXS format by the NJOY code, in which KALIMER-150 neutron spectrum is used as a weighting function in the GROUPR module. The MATXS file contains 150 group neutron cross sections tabulated by infinite dilution cross sections and temperatures. TRANSX code is used for an effective cross section generation. Resonance self shielded effective cross sections are processed for the corresponding model by a narrow resonance approximation. The depletion analysis is done with an equilibrium model of the REBUS-3 code system where the DIF3D[2] module solves the neutron diffusion equation with the HEX-Z nodal method and uses a 25 group cross-section set to obtain the neutron flux and power distributions.

4. Results and Discussion

In this section, the results of burnup calculation with different libraries are compared and discussed. As shown in Table II, the burnup reactivity swings are similar between different libraries. The calculation result of ENDF/B-VII.0 shows the overestimation by

0.1%. On other hand, those of JEF-3.1 and JENDL-3.3 show the underestimation by 0.1% and 0.2%. As for the fissile conversion ratio with the different libraries, the calculation results of ENDF/B-VII.0 and JENDL-3.3 show the underestimation by 0.7% and 1.1%. On other hand, that of JEF-3.1shows the overestimation by 0.1%.

The results of the TRU conversion ratio with the different libraries show the underestimation by 1.3% and 2.5% in the ENDF/B-VII.0 and JENDL-3.3 libraries. On other hand, that of JEF-3.1 shows the overestimation by 0.7%. The calculation results of ENDF/B-VII.0 and JEF-3.1 show the underestimation by 0.4% and 2.7% for the charged TRU enrichment. On other hand, that of JENDL-3.3 shows the overestimation by 1.4%. In case of the peak fast neutron fluence with the different libraries, the calculation results of ENDF/B-VII.0, JEFF-3.1 and JENDL-3.3 show the overestimation by 1.3%, 4.8 and 0.2%.

The global reactivity feedbacks resulting from expansion show the minor difference. The calculation results of ENDF/B-VII.0, JEFF-3.1 and JENDL-3.3 show the overestimation by 4.1%, 5.0% and 0.4% for the radial expansion coefficient, and by 3.8%, 6.0% and 3.4%. The effective delayed neutron fraction(β_{eff}) of ENDF/B-VII.0, JEFF-3.1 and JENDL-3.3 show the overestimation by 0.3%, 0.5% and 0.4%.

Large difference comes from the results for the sodium void worth and sodium density coefficient. The calculation results of ENDF/B-VII.0, JEFF-3.1 and JENDL-3.3 show the underestimation by 25.7%, 34.0% and 6.5% for the sodium void worth and by 18.6%, 18.0% and 14.7%. The large differences of sodium void and density coefficient are attributed to the revision of the sodium scattering cross section in ENDF/B-VII.0, JENDL-3.3 and JEFF-31[3].

Table II: Core Performance

	ENDF/B-VI.6	ENDF/B-VII.0	JEFF-3.1	JENDL-3.3
Burnup Reactivity Swing(pcm)	4,002	4,007 (0.1)[(a)]	4,000 (-0.1)	3,995 (-0.2)
Conversion Ratio(Fissile/TRU)	0.74/0.57	0.73/0.56 (-0.7/-1.3)	0.74/0.57 (0.1/0.7)	0.73/0.55 (-1.1/-2.5)
Charged TRU enrichment(w/o)	29.42	29.30(-0.4)	28.63(-2.7)	29.84(1.4)
Average Linear Power(W/cm)	178	178	178	178
Power Peaking Factor	1.50	1.55(3.3)	1.55(3.3)	1.56(4.0)
Peak Fast Neutron Fluence(10^{23} n/cm^2)	5.21	5.28(1.3)	5.46(4.8)	5.22(0.2)
Sodium Void Worth($) at EOEC	6.15	4.57(-25.7)	4.06(-34.0)	5.75(-6.5)
Soidum Density Coefficient(pcm/℃)	0.668	0.544(-18.6)	0.548(-18.0)	0.570(-14.7)
Expansion Reactivity at EOEC Radial Coefficient(pcm/℃) Axal Coefficient(pcm/℃)	 -0.994 -0.235	 -1.035(4.1) -0.244(3.8)	 -1.044(5.0) -0.249(6.0)	 -1.020(0.4) -0.243(3.4)
β -effective(pcm)	324.7	325.7(0.3)	326.4(0.5)	325.9(0.4)

(a) (Library-ENDF/B-V1.6)/ENDF/B-VI.6x100

3. Conclusions

A new conceptual TRU burner core on the design feature of KALIMER-600 was analyzed by using the burnup code, REBUS-3, with four evaluated data files, ENDF/B-VII.0, JEFF-3.1, JENDL-3.3 and ENDF/B-VI.6, and compared the core performance parameters of the equilibrium cycle.

The results show that the most of core performance parameter are similar between different libraries expect sodium void worth and sodium density coefficient: the burnup reactivity swing by 0.2%, conversion ratio by 2.5%, charged TRU enrichment by 2.7%, power peaking factor by 4%, peak fast neutron fluence by 4.8%, expansion reactivity coefficient by 6% and β -effective by 0.5%. The largest differences of sodium void and density coefficient are attributed to the revision of the sodium scattering cross section in ENDF/B-VII.0, JENDL-3.3 and JEFF-3.1.

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