Improvement of Fission Product Cross Section Generation Procedure for Sodium Cooled Fast Reactor Depletion Analysis

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1. Introduction

A fission product has been treated as a lumped form through burn cycle in a fast reactor depletion and backend cycle analysis [1-3]. The fission product is separated into two parts, one is an ordinary fission product and the other is rare earth element. This is mainly because the recovery factors of those elements are different in the pyro-processing.

This paper describes the results of an assessment of the lumped fission product cross section in depletion analysis and suggests the new procedure for enhancing the accuracy.

2. Methods and Results

2.1 Reference Core and Assessment

300 MWe TRU burner core has been selected as a reference core for the evaluation of the effect by lumped fission product cross section. The TRU burner is one of candidate core for demonstration SFR. Fig. 1 shows radial layout of the reference core. The core is divided into two enrichment zones and has cycle length of 332 EFPD with 5 batch cycles.

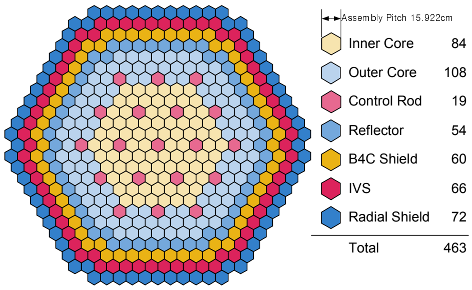

Fig. 1. 300 MWe TRU burner radial layout

The reference fission product burnup chain has been constructed by using ENDF/B-VI yield data (ENDF6FPY) and cross section. The burnup chain consists of 172 nuclides including all decay terms. The lumped fission product cross section was calculated by total sum of fission yield and microscopic cross section as followings:

$$\sigma_{LFP} = \sum_{i \in G} \gamma_i \sigma_i$$

where, γ_i is fission yield of fission product isotope i, σ_i is microscopic cross section of the isotope and G is fission product group such as rare earth nuclide. The lumped fission product is assumed to be accumulated during the cycle without destruction.

Fig. 2 shows the results by REBUS3 depletion calculation by using reference burnup chain with the comparison with that by lumped fission product burnup chain. The calculation was carried out by REBUS3 non-equilibrium mode. The core composition is clean at the BOC without fission product.

The difference in k-effective at the first cycle is less than 60 pcm, however, the difference in the reactivity gets larger up to 734 pcm at the end of the fuel life. Since the depletion analysis is carried out directly from the clean core to the end of fuel life without a fuel management, the difference in an equilibrium core will be smaller than that of this result as 60% of the difference for 5 batch cycle.

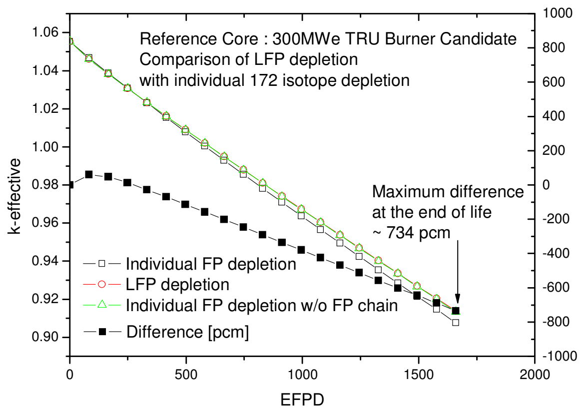

Fig. 2. Comparison of k-effective by different fission product burnup chain model

In order to check the total concentration of fission product, the individual fission product burnup chain model is modified so that the all destruction reaction is eliminated. The result of this test calculation is almost same as that of lumped fission product model (designated as greed line and symbol in Fig. 2). This confirm the total concentration of fission product is kept as same between 172 fission product burnup chain and lumped model.

2.2 Improved Procedure for Lumped Fission Product

The difference in k-effective is mainly come from the change of the fission product concentration through the burn cycle. Fig. 3 shows the comparison of fission product yield and with saturated relative concentration and its relative contribution to total capture reaction. Several isotopes (Ru-101, Rh-103, Rh-105, Pd-107, Sm-149, etc) have large contribution to total capture reaction and it relative concentration largely vary through burn cycle.

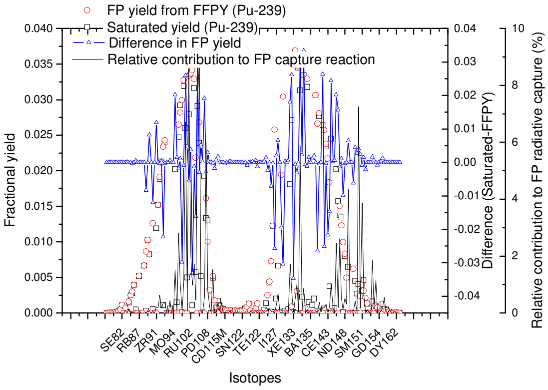

Fig. 3. Comparison of fission product relative concentration

In order to resolve this discrepancy, the fission product yield data is adjusted to be consistent with the saturated fission product concentration. Fig. 4 shows an example of the variation of fission product relative concentration. Most of all fission products are saturated within the first cycle in which the total absorption of fission product is not significant.

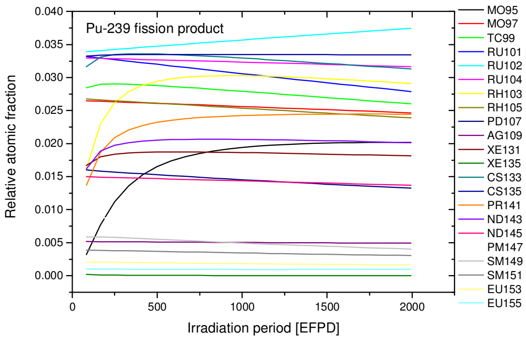

Fig. 4. Relative change of fission product concentration during burn cycle

The saturated fission product concentration is calculated by 0-dimensional depletion model for each parent isotope and renormalized to the total fission product yield of each parent nuclide and classified as two fission product types, ordinary fission product and rare earth isotope, for backend fuel cycle. The normalized fission product concentration is used for producing the lumped fission product cross section by TRANSX code.

Fig. 5 shows the result of depletion analysis by improved procedure. The reactivity difference at the end of life is reduced by 50%.

The equilibrium core performance with new lumped fission product cross section was compared with the old one. The new lumped fission product tends to overestimate capture reaction, which makes the burnup reactivity swing larger and increases charged fuel enrichment. Because power fraction of burnt fuel gets smaller by increase of fission product capture, the power peaking factor was increased by 12%.

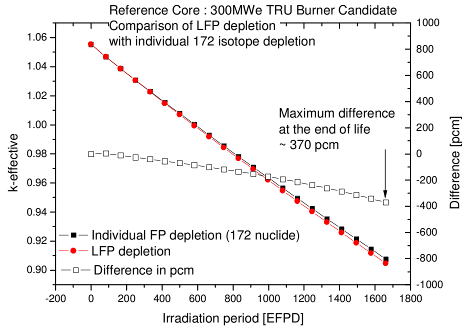

Fig. 5. Comparison of k-effective through burn cycle with improved lumped fission product cross section

Table I. Comparison of core performance parameter between lumped fission product models

	Old LFP XS	New LFP XS
Burnup reactivity swing [pcm]	2538.5	2841.6
Conversion ratio	0.76 /0.60	0.74 /0.58
Charged TRU enrichment (Inner/Outer) [wt%]	24.07 /30.08	24.63 /30.79
Peak power density [W/cm^3]	350.2	391.8
TRU consumption [kg/cycle]	92.2	96.9
Average discharge burnup [GWd/tHM]	107.06	107.18
Peak discharge burnup [GWd/tHM]	156.83	171.09
Peak fast neutron fluence [10^{23} n/cm^2]	4.28	4.22

3. Conclusions

The reference burnup chain model including 172 fission product isotopes was constructed. The lumped fission product cross section that has been used in SFR core depletion analysis was assessed with the reference burnup chain model. The difference in the burnup reactivity could be reduced up to 50% by using the saturated fission product concentration obtained from 0-dimensional depletion as the effective yield.

Acknowledgement

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