Ultra Long Life Core Using Direct Refabrication Concept

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1. Introduction

Most of ultra long cycle cores are designed to have a low power density, so that the core volume is three or four times larger than that of the general core and the core average and maximum burnup is low. For that reason, this kind of core is nowhere near the aspect of economy. To overcome these aspects, the feasibility design work for the ultra long cycle cores which have the same core size as that of ordinary core had been performed[1]

In this paper, with the equal average power density of three kinds of capacity on 1000MWe, 500MWe and 300MWe to see the possibility of ultra long cycle core, the study on the possible design which can satisfy the design goal was performed in terms of cycle length, burnup, maximum power density and burnup reactivity swing.

2. Analysis Method and Model

A nuclear evaluation process was initiated by the generation of regionwise microscopic cross sections, based upon the self-shielding f-factor approach. Composition-dependent, regionwise microscopic cross sections were generated by utilizing the effective cross section generation module composed of the TRANSX and TWODANT codes. Cell homogenization over each region was performed to obtain the cross section data for a homogenized mixture. The neutron spectra for collapsing the cross section data to fewer group libraries was obtained from the S_N approximation flux solution calculations for a two-dimensional reactor model as desired. Fuel cycle calculations were carried out with the neutron flux and burnup calculation module consisting of the DIF3D[2] and REBUS-3[3] codes.

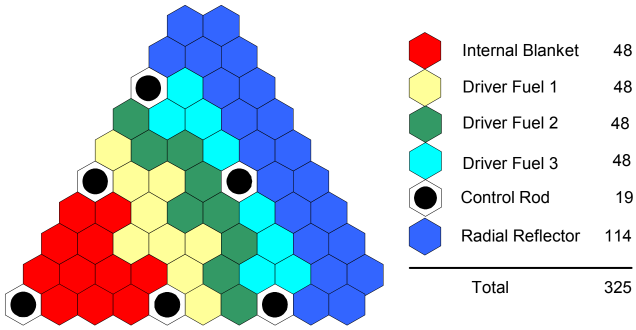

Figure 1. Layout of 500MWe core

3. Result

As seen from Table 1, The nuclear characteristic parameters of ultra long life cores finally selected in a preliminary study show that the 1000MWe core can be operated up to 33 years without refueling, the 500 MWe up to 31 years and the 300MWe up to 36 years. The burnup reactivity swing of the 300MWe core is 3.25% which is largest among the three kinds of cores compared with 2.5% of 1000MWe and 2.1% of 500MWe. The minimum fuel volume fraction necessary for a long life was satisfied under 0.5 except 300MWe core which has 0.55, so that the 300MWe is a disadvantage position compared with the other two cores. The comparison between the 500MWe and 1000MWe core showed that the 500MWe core has a premium on the operation aspect on a capacity factor which is 0.75.

Table 1. Core Specifications and Characteristics

Core electric power (MWe)	1000	500	300
Cycle length (year)	33	31	36
Volume fraction (fuel//structure/coolant)			
Driver	0.50/0.22/0.28	0.50/0.22/0.28	0.55/0.22/0.23
Blanket	0.50/0.22/0.28	0.50/0.22/0.28	0.55/0.22/0.23
TRU percent (Inner/middle/outer core)	9.2/12.2/14.4	12/14/16	14.5/15.5
Burnup reactivity swing (%Δ k/k)	2.5	2.1	3.25
Peak power density (W/cc)(BOL/EOL)	379/358	348/284	292/228
Average power density (W/cc)	94.74	95.76	87.46
Peak fast fluence (10^{24} n/cm^2)	1.8	1.59	1.57
Peak discharge burnup (MWD/kg)	425.4	403.9	404.3

Therefore, we have selected the 500MWe core as final core. Figure 1 shows the layout of the 5000MWe core. For actual reprocessing, it was assumed that the cladding tube was replaced at the 4 x10^{23} n.cm^2 that is the maximum neutron fluence design limit where the volatile fission products can be removed for the reprocessing. A homogenous redistribution at axial direction was preformed at following reloading for actual calculation. The actual calculation results showed that cladding tube needs to be replaced every 5-7 years in contrast with 10 years as it is expected as shown in Figure 2. For the purpose of increasing a cycle length, five times reprocessed fuel position was varied and it leads to the improvement of cycle length resulting from increased effective multiplication factor. This aspect implies the inclusion of shuffling scheme might reduce burnup reactivity swing.

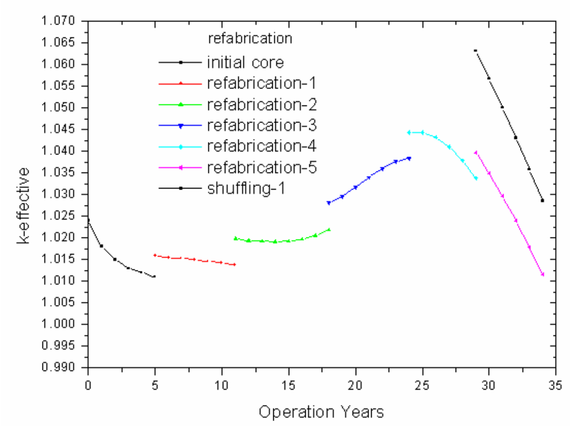

Figure 2. A variation of k-effective of the 500MWe core with the direct refabrication

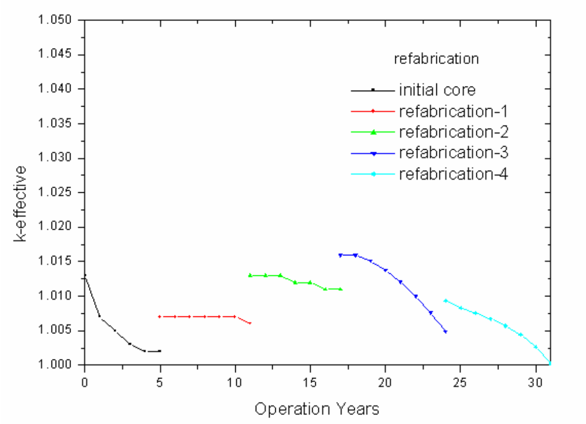

Figure 3. A variation of k-effective of the 500MWe core with application of shuffling to direct refabrication

Figure 3 shows the results of shuffling application over the entire cycle length. The burnup reactivity swing was reduced at reasonable level. It was observed that the time span for refabrication depends on the power level and density.

4. Conclusion

The feasibility design work for the ultra long cycle cores which have the same core size as that of ordinary core had been performed and the final core was selected through the comparison of nuclear characteristic parameters for the cores with three kinds of power levels.

The calculation results of the actual direct refabrication showed that cladding tube needs to be replaced every 5-7 years and the burnup reactivity swing can be reduced at reasonable level through the suffling scheme over the entire cycle length.

Acknowledgments

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