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Core Design of a 600 MWe Uranium Fueled TRU Burner Reactor

Hoon Song [a*], Won Seok Park [a], Sang Ji Kim [a]
[a]*Korea Atomic Energy Research Institute, 150 Duckjin-Dong, Yuseong-Gu, Daejon*
[*]*Corresponding author: hsong@kaeri.re.kr*

1. Introduction

The conceptual core design of the demonstration sodium cooled fast reactor (SFR) for TRU burning is being developed by the Korea Atomic Energy Research Institute (KAERI). The main objective of demonstration reactor for the construction and operation is to test and demonstrate TRU fuel, and the operation of the large sized (1500 MWth) sodium fast reactor and the TRU burning capability of commercial burner reactor.

In this paper, a core design progress for the start core of the demonstration reactor is presented. It is scheduled to use the uranium fuel for the start core due to the uncertainty of the TRU fuel demonstration, and to change the LTRU core fuel from LWR spent fuel to the MTRU core fuel which consists of the LMR spent fuel and the self recycled fuel progressively.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

The uranium core was designed maintaining the same dimension of core with reference core[1] to replace the TRU fuel of the reference TRU core to uranium fuel. Fig. 1.D shows the layout of 600 MWe core as a uranium core in full loading pattern. In the figure, the core consists of two regions of driver fuel. It consists of 126 fuel assemblies in the inner core and 198 fuel assemblies in the outer core. The TRU enrichments of the inner/ outer cores for the radial power control are 16/20 wt. %, in which the enrichment of 20 wt. % is the maximum allowable enrichment in the commercial market for the uranium core.

Instead of a single fuel enrichment scheme, an enrichment zoning approach was used to flatten the power distribution. The hexagonal driver fuel assembly consists of 271 rods within a duct wrapper. The rod outer diameter is 7 mm. The core configuration is a radial homogeneous one that incorporates annular rings with a zone-wise enrichment variation. Active core height was adjusted to make the enrichment of the outer core 20 wt. %, and that height is 89 cm. The core design is limited to the optimization of three design parameters; the fuel loading pattern of the core region, the uranium enrichment of equilibrium core, and the fuel exchange strategy. To investigate the change of core performance in related to fuel enrichment variations, the calculation was performed in case that the enrichment in the outer core was fixed to 20% and the enrichment in the inner core was varied to 14%, 15%, 16%, and 17%. In addition to these investigation, the change of core performance for the dimension variation effect of inner core region and outer core region was investigated; the original core(B case), the reduced inner core(A case), and the extended inner core(C case) as shown in Fig. 1.

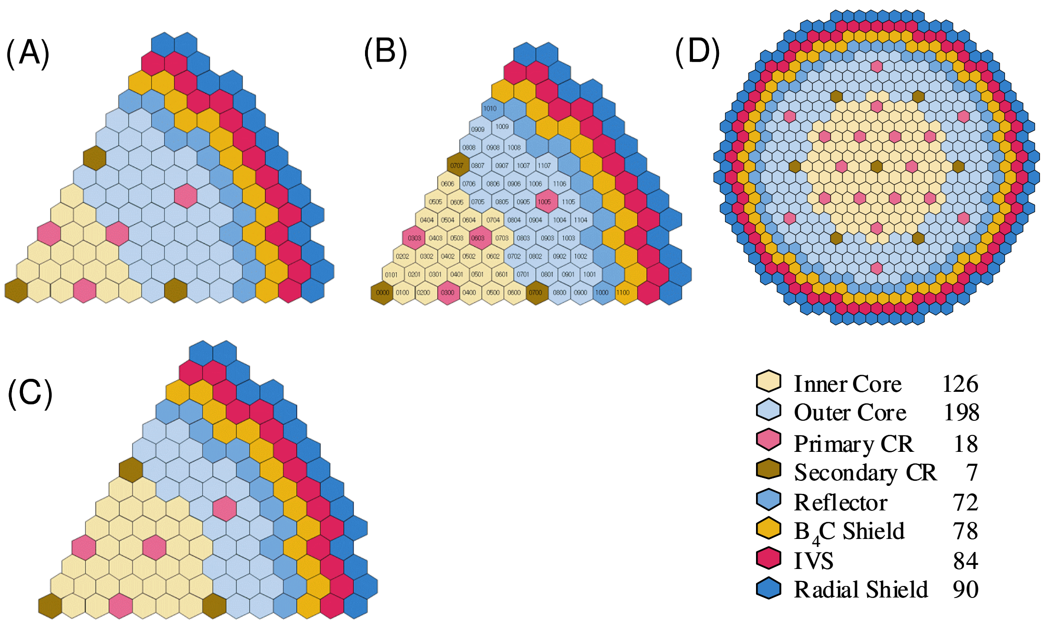

Fig. 1. Core Layout: (A) A case (B) B case (C) C case in 1/6 symmetry core (D) reference case in full core.

Table 1: Core Performance

Case (Outer/inner in 1/6 sym.)	Batch	Enrichment (Inner/outer,%)	Cycle length (EFPD)	Peaking factor (BOEC/EOEC)	Peaking assembly	Burnup reactivity swing(pcm)
A(40/14)	3	15/20	377	1.61/1.59(~Y)	0602(Y)	2,928(Y)
		16/20	426	1.60/1.57(Y)	0602(Y)	3,486(Y)
		17/20	467	1.63/1.61(N)	0100(N)	4,037(N)
	4	16/20	338	1.60/1.57(Y)	0602(Y)	2,794(Y)
		17/20	373	1.63/1.62(N)	0100(N)	3,259(Y)
B(33/21)	3	16/20	332	1.57/1.57(Y)	0100(N)	2,494(Y)
		17/20	409	1.69/1.65(N)	0100(N)	3,364(Y)

2.2 Result and Analysis

The REBUS-3 equilibrium model with a 25 group cross section was used to perform the core depletion analysis. The calculation results show that uranium fueled cooled fast reactors for TRU burning, of which power is 600 MWe can be successfully designed, while meeting the optimization of the three design parameters.

After calculations, the various core performance parameters were examined, including the cycle length, the power distribution and the peaking factor, the discharged burnup and the core burnup reactivity swing, and the easy way of the replacement for fuel assemblies. The cycle length is important factor for the economical performance. To demonstrate the commercial reactor system, the minimum of the cycle length is at least above 11 EFPM(effective full power month). In addition, the prolonged cycle length is advantageous for the operation of demonstration reactor for the aspect of economic feasibility.

The summarized results of the calculations were showed in Table 1. The condition of the minimum cycle length was not satisfied in C case with all cases of enrichment variations. For B case, the cycle length was satisfied only in case that the enrichment was above 16% but the A case in 3 batch mode was satisfied with above 15% enrichment in the inner core and A case in 4 batch mode was satisfied with above 17%. From base selection conditions; the core cycle length was at least above 11 month(330 EFPD), the power distribution and power peaking factor. Only A case was satisfied in conclusions that the average enrichment difference with inner and outer core region had to be above 4% so that the position of the peak power can be located in outer core; the peaking factor is not sensitive to the core loading pattern and the core enrichment variations, and it is necessary to have 3 or 4 batch concept for the securement of the sufficient cycle length. For the above calculation results and analysis, we suggested the core optimization plan in the conclusion, as it was stated.

3. Conclusions

To make the optimization plan of the core design for the uranium core from the reference core, various core design option were performed. From the analysis of the preliminary core design results, we suggest the optimization plans.

First, the number of fuel assembly in inner core has to maintain from 14 to 21 in 1/6 symmetry. Second, the exchange of the fuel numbers in the outer core region have to operate in 3 batch mode and the inner core in 3 batch or 4 batch mode. Therefore, the inner core has to adjust three times or four times the number of fuel assembly to be placed in the core and for the numbers of fuel assembly in the outer core have to maintain 3 times plus alpha considering the test site for LTRU fuel. Third, the enrichment has to maintain 20% in the outer core region and the enrichment of inner core has to determine from the search of the cycle length after fixing the number of inner and outer core region. Using the selected optimization plan, a future optimization will be required.

Acknowlegement

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REFERENCES

[1] H. Song et al., "600~1,800 MWe Sodium Cooled Reactor Core Design for a TRU burning ", Proceedings of the Korean Nuclear Society Autumn Meeting(2008).