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Optimization of Sodium cooled Fast Reactor on different power level

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1. Introduction

The KAERI (Korea Atomic Energy Research Institute) is planning to build a prototype Sodium cooled Fast Reactor (SFR). Due to the importance of the power capacity of prototype SFR, the power level should be determined carefully. To determine the power level, it was needed to optimize the candidate core on different power level. In this study, those cores would be optimized by parametric studies to enhance the performance as high as possible.

2. Methods and Results

The initial core of prototype SFR will be constructed as uranium core. And then it will be changed the Transuranics (TRU) burner step by step. In order to approach the core optimization, we focus on the uranium core because the prototype SFR has constraint of enrichment (< 20 wt.%) for non-proliferation and bundle pressure drop (< 0.25 MPa) for decay heat removal by natural circulation. To enhance the core performance as high as possible, the enrichment and bundle pressure drop were fixed 20 wt.% and 0.25 MPa, respectively.

2.1 Computational method

The prototype core design was carried out by using the REBUS-3 code which was based on nodal diffusion theory with 25-group hexagonal-z geometry [1]. And the equilibrium fuel cycle was analyzed to compare the each core. The fuel cycle length of 290 days which was assumed the 80 % of availability and 5 batches were adopted for enrichment search about 20 wt.%. For this calculation, the cross section library was used ENDF/B-VII of 150-group cross section library. The cross section library was collapsed to 25 energy group by TRANSX and TWODANT code [2]. P_3 scattering order and S_8 angular quadrature set were adopted in R-Z geometry of TWODANT calculation. And the bundle pressure drop was calculated by SLTHEN code in order to set the condition of the pressure drop about 0.25 MPa.

2.2 parametric study of fuel pin diameter

Fuel economy was estimated with change the fuel pin diameters as to design the core compactly. The range of fuel pin diameter was 0.88 ~ 1.04 cm while the number of fuel assembly was fixed. To compensate the enrichment and pressure drop, Pitch to diameter ratio and active core height were modified. It was evaluated with the core contained 72 fuel assemblies at 400 MWt. Figure 1 showed that the volume of an assembly and volume fraction of fuel following the fuel pin diameter. The volume of an assembly decreased with the increasing fuel pin diameter. But the volume fraction of fuel increased with the increasing fuel pin diameter. This trend effects on optimization of the fuel volume and the fuel inventory as shown in Figure 2.

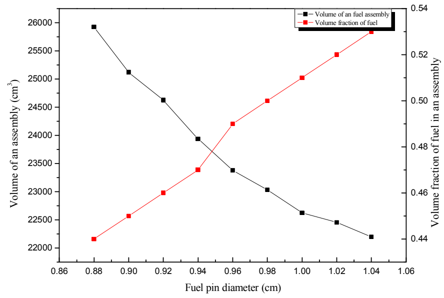

Fig. 1. Volume of an assembly and volume fraction of fuel following the fuel pin diameter

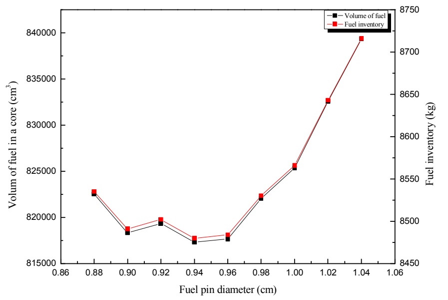

Fig. 2. Fuel volume and fuel inventory following the fuel pin diameter

The parametric study of fuel pin diameters was performed with change the number of fuel assemblies at each power level as shown in Figure 3 ~6.

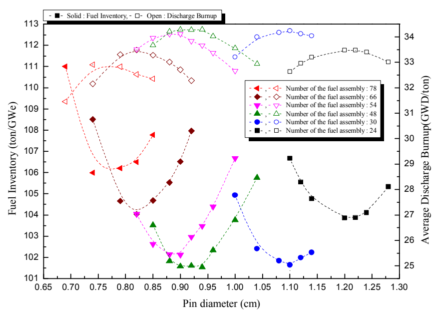

Fig. 3. Inventory and discharge burnup at 125 MWt

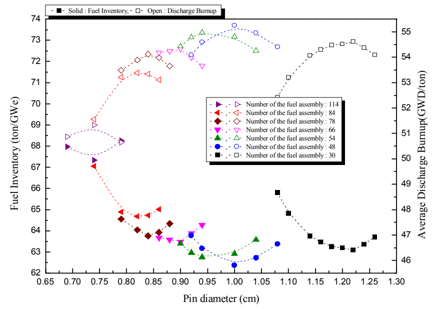

Fig. 4. Inventory and discharge burnup at 250 MWt

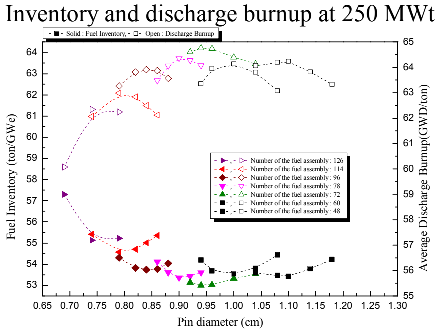

Fig. 5. Inventory and discharge burnup at 400 MWt

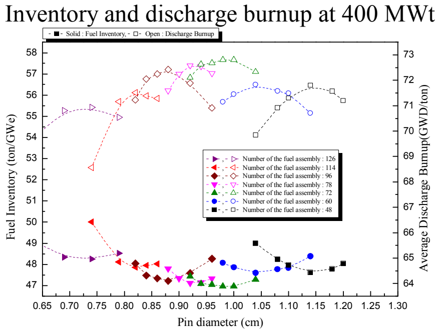

Fig. 6. Inventory and discharge burnup at 500 MWt

Various cores were designed in order to search the optimum size of fuel pin diameter among the different cores. The fuel pin diameter was evaluated in the range of 0.69 to 1.20 cm.

The fuel pin diameter increased with the decreasing fuel assemblies as to compensate the enrichment and pressure drop. The fuel economy was optimized 0.94 and 1.10 cm at 125 MWt, 1.0 cm at 250 MWt, 0.94 cm at 400 MWt and 1.0 MWt at 500 MWt, respectively.

These results showed inconsistency about optimum fuel pin diameter following the power level. However, the range of optimum fuel pin diameter was about 0.84 ~ 1.10 cm. Therefore the optimum fuel pin diameter could be selected about 0.94 cm. And the optimum number of fuel assemblies could be 48 at 125 MWt, 54 at 250 MWt, 72 at 400 MWt and 78 at 500 MWt, respectively.

3. Conclusions

In conclusion, two kinds of parametric study were evaluated in order to optimize the candidate cores on different power level as follows: First, the parametric study of fuel pin diameters was carried out with fixed the number of fuel assemblies. It is found that this trend of assembly volume and volume fraction of fuel effected on optimization of the fuel volume and the fuel inventory. Second, the parametric study of fuel pin diameters was carried out by changing the fuel assemblis. It is found that the optimal choice was the number of fuel assemblies of 48 at 125 MWt, 56 at 250 MWt, 72 at 400 MWt and 78 at 500 MWt. And the fuel economy was inconsistent but the range of fuel pin diameter was about 0.84 ~ 1.10 cm. Because it was compared the core performance with each other on different power level, the optimal fuel pin diameter was selected 0.94 cm following the power level.

Acknowledgement

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