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AXIAL BLANKET ENRICHMENT OPTIMIZATION OF THE NPP KRŠKO FUEL

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ABSTRACT

In this paper optimal axial blanket enrichment of the NPP Krško fuel is investigated. Since the optimization is dictated by economic categories that can significantly vary in time, two step approach is applied. In the first step simple relationship between the equivalent change in enrichment of axial blankets and central fuel region is established. The relationship is afterwards processed with economic criteria and constraints to obtain optimal axial blanket enrichment.

In the analysis realistic NPP Krško conditions are considered. Except for the fuel enrichment all other fuel characteristics are the same as in the fuel used in the few most recent cycles. A typical reload cycle after the plant power uprate is examined. Analysis has shown that the current blanket enrichment is close to the optimal. Blanket enrichment reduction results in an approximately 100 000 US$ savings per fuel cycle.

1 INTRODUCTION

Axial blankets operate in very low power regions at the top and bottom of the reactor core, where fuel utilization and importance are relatively poor. It is economically attractive to reduce the enrichment in this portion of the reactor and slightly increase enrichment in the central regions of the fuel rod. This enrichment compensation has small effect on overall assembly reactivity during fuel burnout. However, slightly higher enriched central part is located in a region where the fuel utilization is more efficient.

In the analysis realistic NPP Krško conditions are considered. A typical 12-month reload cycle with 36 fresh fuel assemblies is examined. Except for the fuel enrichment all other characteristics are the same as in the fuel used in the last several cycles. Nominal enrichment is 4.3 % in the central region and 2.6 % in the blankets. The axial blankets are made of annular Uranium pellets and nominally occupy 15.24 cm (6 in) at top and bottom of the fuel stack.

2 EQUIVALENT ENRICHMENT

In the analysis, enrichment of the axial blankets is varied around nominal value. To preserve core reactivity at the same level, enrichment of the central region is adjusted to compensate difference in the blanket enrichment. Results of equivalent enrichments (yielding to the same core reactivity) are presented in table 1 (figure 1). The smallest enrichment compensation occurs at the Beginning Of the Cycle (BOC). A slightly higher compensation is needed at the End Of the Cycle (EOC). For illustration purposes the line denoted with “U comp.” is added. It represents an enrichment compensation that preserves the total mass of U^{235} in the assembly. The correlation is derived solely from the ratio of blankets to central region masses.

It can be clearly seen that the importance of axial blankets is much lower than the importance of central region. However, core burnup increases blanket importance. To obtain realistic results in enrichment evaluation, an equilibrium cycle needs to be considered. The equilibrium cycle was simulated with the burnout of the core in 2 consecutive cycles, where only axial burnup distributions have been updated. Core average burnup distributions for 4.3 % blanket enrichment during two cycles burnout are presented in figure 2. Differences in axial distributions are showing that the two cycles are sufficient to obtain almost equilibrium axial burnup distributions. Results in table 1 (figure 1) labeled as “Eq. Ax. Bu” present final reactivity equivalent enrichment function obtained with EOC “equilibrium” axial burnup shapes.

Table 1: Equivalent enrichments.

BLANKET ENR.	CENTRAL ENR.			
	BOC	EOC	Eq. Ax. Bu	U comp.
[%]	[%]	[%]	[%]	[%]
0,7	4,329	4,352	4,415	4,435
1,6	4,317	4,331	4,364	4,371
2,6	4,300	4,300	4,300	4,300
3,6	4,278	4,258	4,244	4,229
4,3	4,260	4,223	4,212	4,179

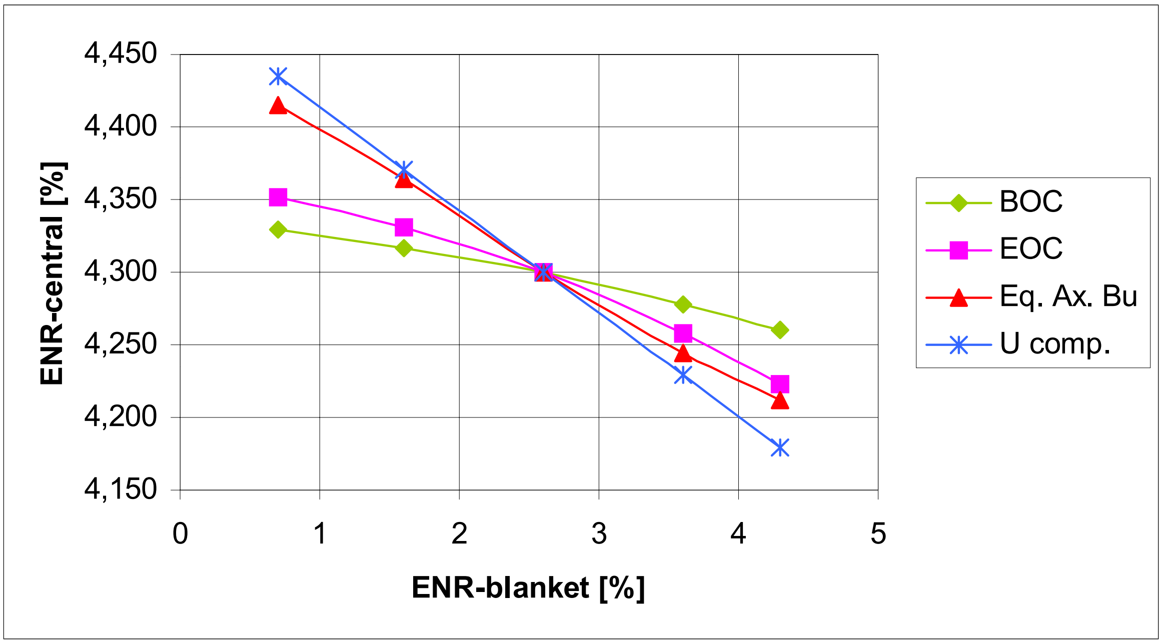

Figure 1: Equivalent enrichments.

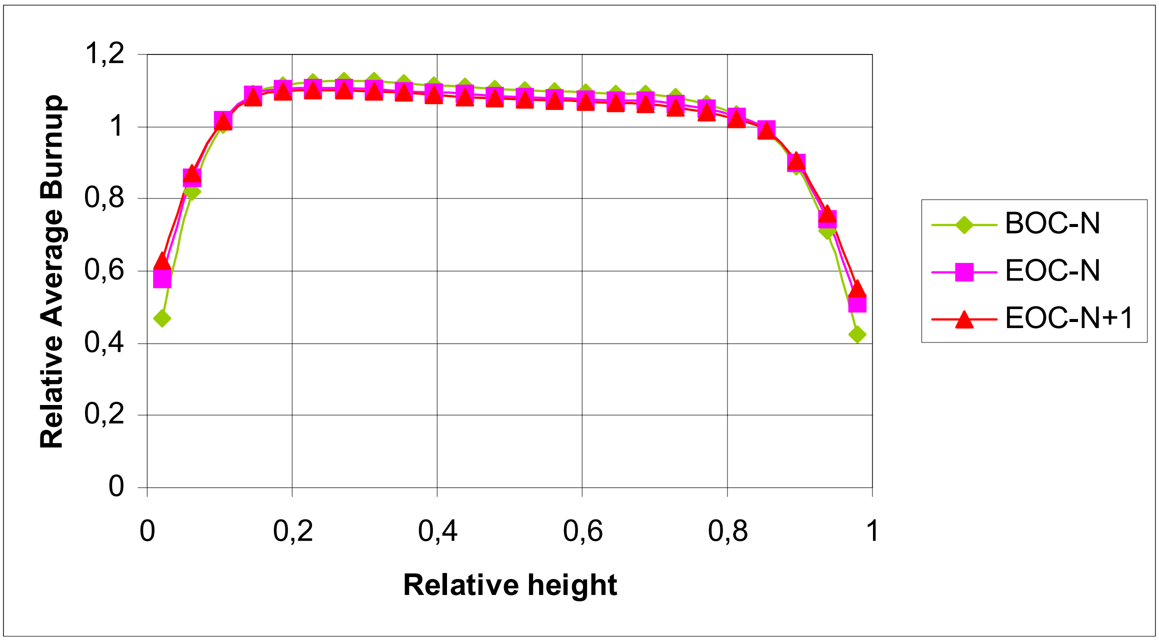

Figure 2: Average axial burnup distributions.

3 FUEL COST EVALUATION

To evaluate the effect of annular axial blanket enrichment to fuel cost, today's typical values for fuel cycle parameters are taken into account. The value of uranium hexaflouride as a feed material is set to 30$/kg. The cost of separation work is 100$/SWU and tails enrichment is taken as a widely used value of 0.3. Standard cost evaluation functions [1] are used. The amount of feed material required is a function of desired enrichment level while the cost of enrichment services (isotope separation) is a complex function of feed, product, and tails enrichment.

U cost for reactivity equivalent enrichments of the "Eq. Ax. Bu" case are presented in figure 3. Optimal blanket enrichment lies between 1,6 % and 2,6 % with estimated minimum around 2.2 %. Current NPP Krško blanket enrichment of 2,6 % is close to the optimal value. This reduction in blanket enrichment contributes to around 100 000 US$ savings per fuel cycle.

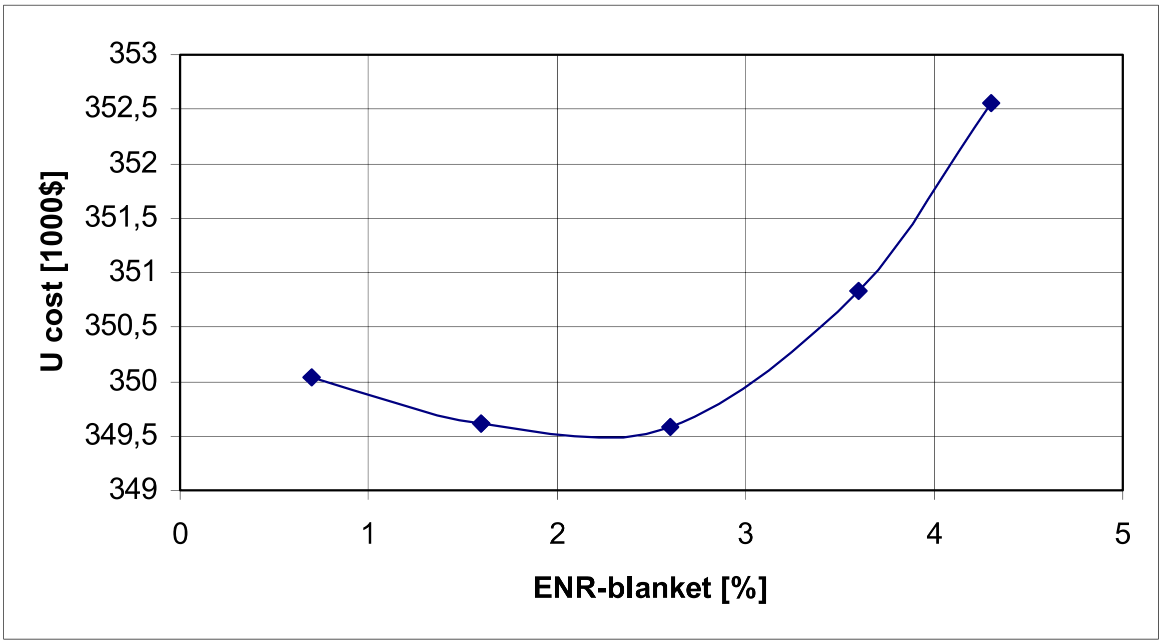

Figure 3: U cost per assembly.

4 CONCLUSIONS

Optimal axial blanket enrichment of the NPP Krško fuel is investigated. Two step approach is applied. In the first step relationship between the reactivity equivalent change in enrichment of axial blankets and central fuel region is established. The relationship is afterwards processed with economic functions to obtain optimal axial blanket enrichment. It was found that the current NPP Krško blanket enrichment already lies close to the optimum. Reduced Uranium enrichment in blanket regions lowers fuel assembly costs for approximately 100 000 US$ per cycle.

REFERENCES

[1] H. W. Graves, Jr., *Nuclear Fuel Management*, John Wiley&Sons, Inc., 1979, pp. 257-261.