

Improvement of PWR performance with Reflector

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1. Introduction

There have been lots of studies to improve the core performance of commercial Pressurized Water Reactors (PWRs) [1]. They have been mostly focused on the design of nuclear fuel assemblies for increasing the core cycle length and improving the safety margin. This paper has been focused on the design of not only burnable absorber but also reflectors due to the uranium enrichment limitation of the commercial fuel. The performances of different reflectors are analyzed with equilibrium cycle of PWR. Reflector materials used for the tests are water, Stainless Steel (SS), and Zircaloy. The Studsvik's design code system, which is CASMO-4E/CMSLINK/SIMULATE-3, is used for this study with ENDF/B-VI library.

2. Methods and Results

European Pressurized Reactor (EPR), which has been developed by AREVA [2], applies SS as reflector, while all the PWRs in Republic of Korea use water reflector with thin steel baffle. Zircaloy reflector has been studied at several research centers [3]. Most research results are provided at the first cycle or Beginning of Cycle (BOC). However, in this paper, the performance tests of the reflector materials have been performed with equilibrium cycle core of OPR-1000 with 16x16 Combustion Engineering (CE) fuel type.

2.1 Reflector Model

Fig. 1 describes longitudinal cross sectional view of PWR core. Reflector geometries with total thickness of 30 cm, consisting of two regions: 15cm inner reflector region and 15cm reflector region. Reflector materials are homogenized mixtures of metal and water. The volume ratio of water to metal is 5:95 in the inner reflector region and 15:85 in the outer reflector region. Two tested metal materials are SS and Zircaloy. Water reflector is similar with the existing model consisting of SS baffle of 2.22 cm and water. Reflectors and FAs are designed by CASMO-4E [4] and two-group cross section libraries are generated for CMSLINK and SIMULATE-3 [5,6]. The loading pattern of equilibrium core is as shown in Fig. 2 which uses 3-batch fuel loading [7]. The average uranium enrichment in the core is 4.5 w/o. The reference case uses existing FA for OPR-1000 core and water reflector. The other cases use hybrid FA using R-BA for advanced PWR core [8].

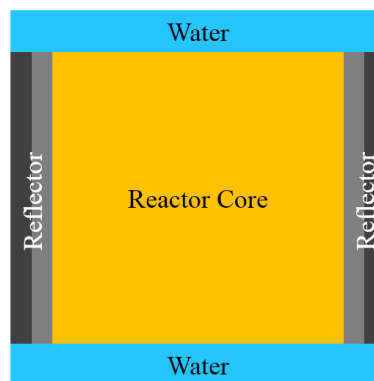


Fig. 1. PWR Core Cross Sectional View

| Y/X | H | J | K | L | M | N | P | R | |
|-----|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------|
| 8 | TY00 0 | P-08 0 | TY02 0 | K-08 0 | N-08 0 | TY04 0 | R-08 0 | TY00 0 | REF. |
| 9 | H-14 0 | M-08 0 | J-11 3 | TY04 3 | K-12 3 | P-11 0 | TY02 3 | N-11 3 | REF. |
| 10 | TY02 1 | L-09 1 | TY06 3 | K-09 3 | TY04 0 | N-12 0 | TY02 3 | L-10 3 | REF. |
| 11 | H-10 0 | TY04 3 | J-10 3 | M-12 2 | K-14 1 | P-09 3 | TY00 0 | REF. | REF. |
| 12 | H-13 0 | M-10 1 | TY04 3 | P-10 3 | TY04 0 | TY01 0 | K-13 0 | REF. | |
| 13 | TY04 0 | L-14 0 | M-13 0 | J-14 1 | TY01 0 | N-09 3 | REF. | REF. | |
| 14 | H-15 0 | TY02 1 | TY02 1 | TY00 0 | N-10 0 | REF. | REF. | | |
| 15 | TY00 1 | L-13 1 | K-11 1 | REF. | REF. | REF. | | | |
| | REF. | REF. | REF. | REF. | | | | | |

| Previous Location Rotation |
|----------------------------|
| Fresh Fuel |
| Once Burned Fuel |
| Twice Burned Fuel |
| Reflector |

Fig. 2. Equilibrium core loading pattern

2.2 Results

The boron letdown curves of all the cases are as shown in Fig. 3 and the power peaking factors, F_q , of the all the cases are as shown in Fig. 4. Initial boron concentration of reference case is around 1300 ppm but that of other cases are 300 ppm lower than that. The cycle lengths are also different. Even though initial boron concentration of 'Water Ref.' case is lower than that of reference case, the cycle length of 'Water Ref.' is

shorter than that of reference case due to lots of BAs loading for low soluble boron concentration. Three reflector materials with R-BA FA are tested for the increase of the cycle lengths: Zircaloy, SS, and water. It is shown that the cycle length of the core with Zircaloy is longer than the others. Compared to the water reflector, the fast neutrons of the core with metal reflectors are more reflected into the core due to their low absorption cross sections. Zircaloy reflects more neutrons than SS because of its higher scattering cross section in the fast energy region. In addition, Zircaloy reflects more neutrons at low energy range because of the low absorption cross section. These two phenomena cause the advantages to use Zircaloy as the reflector. Table I summarizes the comparison of core parameters depending on the type of reflector material.

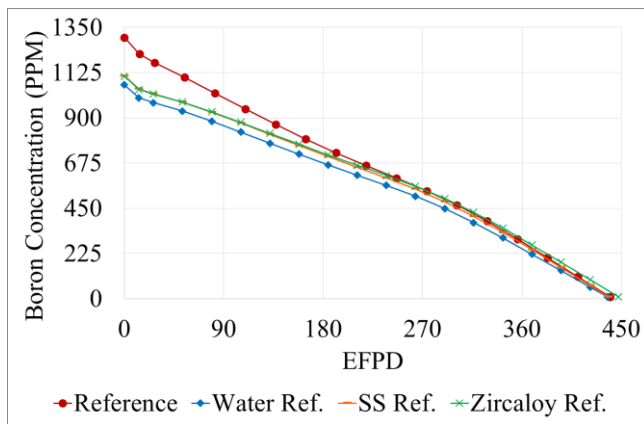


Fig. 3. Boron letdown curves

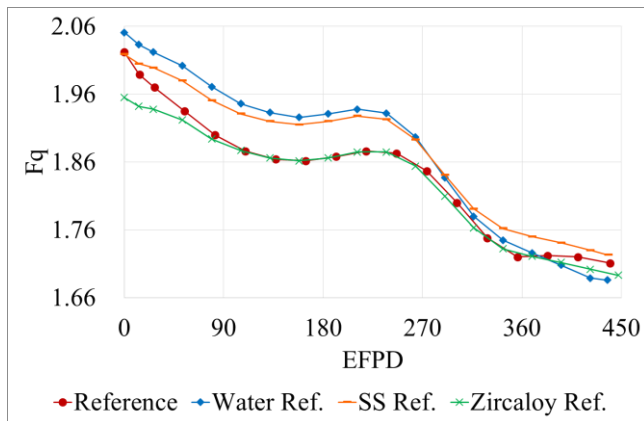


Fig. 4. Fq vs. burnup

Table I: Comparison of Reflector Materials

| Cases | Reference | Water Ref. | SS Ref. | Zircaloy Ref. |
|---------------------|-----------|------------|---------|---------------|
| Cycle Length (EFPD) | 440 | 437 | 438 | 447 |
| Maximum Fq | 2.02 | 2.05 | 2.02 | 1.96 |

3. Conclusions

To sum up the advantages of Zircaloy as reflector, the twice burned fuels located at core periphery could be burned more by neutrons reflected by Zircaloy reflector. Therefore, the cycle length is extended by 7 days compared to that with existing core in spite of using more BAs. The cycle length is also 9 days longer than that with SS reflector. In conclusion, Zircaloy looks to be competitive in its performance as reflector material for advanced PWRs.

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