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A Strategy for Kori Unit 1 Pressure Vessel Fluence Reduction through a Modification of Outer Assembly Configuration Using Monte Carlo Analysis

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Abstract

The purpose of this study is to reduce the fast neutron fluence at the reactor pressure vessel (RPV) and to provide a basis for plant-life extension. In this study, different neutron absorbers were employed in the core outer assemblies of Kori Unit 1 Cycle 14. The modified assemblies were used to calculate fast neutron fluence at the RPV and to evaluate reduction of outer assembly power and total power in core. By comparison with the case of no suppression fixture, the fast neutron fluence of a case with two rows stainless steel around the assembly with natural uranium pins is decreased by 85.8%. It is noted that the modification of outer assembly is more efficient than the previous low leakage loading pattern (LLLP) applied to Kori Unit 1. Also, compared fast neutron fluence in Cycle 1 with Cycle 14, fast neutron fluence at the RPV between Cycle 1 and Cycle 14 is not significantly different. It is found that LLLP applied to the Kori Unit 1 has not contributed to fast neutron fluence reduction at the RPV.

Introduction

The life of a reactor and its possible extension are directly dependent on the embrittlement of the reactor pressure vessel (RPV) under neutron irradiation. By reducing the fast neutron fluence (E > 1.0 MeV) at the RPV, the useful life of power plant would be increased. The purpose of this study is to evaluate the several means of reducing the fast neutron fluence that is incident on the RPV of the Kori Unit 1 Cycle 14.

The core outer assembly configuration was, in this work, modified with replacement of UO_2 fuel rods by several types of neutron absorbers in the outer assemblies closest to the core barrel. The modified assemblies were used to calculate fast neutron fluence at the RPV and to evaluate reduction of outer assembly power and total power in core.

Computational calculations were performed for the fast neutron fluence at the RPV using a Monte Carlo code MCNP4A with ENDF/B-V cross-section library which has merit of explicit three-dimensional geometric representation.

Method

The Kori Unit 1 Cycle 14 consists of 121 fuel assemblies. Each fuel assembly consists of a 14×14 array of 179 fuel rods, 16 control rod guide thimbles, and one instrument thimble. Based on the Nuclear Design Report (NDR), the Kori Unit 1 Cycle 14 was modeled by using MCNP4A code for the calculation of criticality and fast neutron fluence at the RPV, respectively.

Total power reduction in core and the input data of source term for fast neutron calculation are obtained by using the criticality calculation model. The fluence calculation model is used to estimate the fast neutron fluence with energies greater than 1.0 MeV at the RPV.

The 8 cases of modified outer assembly to suppress the fast neutron fluence at the RPV are as follows:

Case 1: no suppression fixture (reference model, Kori Unit 1 Cycle 14 core)
Case 2: two rows stainless steel around the assembly
Case 3: two rows stainless steel facing the baffle
Case 4: two rows stainless steel around the assembly with natural U^{235} pins
Case 5: natural uranium assembly
Case 6: solid hafnium (16 rods per assembly)
Case 7: hafnium annulus (16 rods per assembly)
Case 8: Pyrex glass annulus (16 rods per assembly).

In the past, stainless steel rods were used to replace damaged fuel pins within an assembly. For this reason, stainless steel rods were considered in some cases. Hafnium and Pyrex is also considered in this study because the former has the same amount of reactivity holddown as Ag-In-Cd but better material characteristics and the latter has the highest reactivity holddown among depletable absorbers but less than hafnium. Material composition of hafnium reduces the chance of swelling within a rod. The utilization of a hafnium annular absorber would provide less reactivity suppression than solid hafnium but still a significant increase in reactivity suppression, and its reduced fabrication cost makes it economically appealing.

Results and Discussion

Table 1 shows that the amount of fast neutron fluence reduction for the case of two rows stainless steel around the assembly with natural uranium pins is larger than any others. It is noted that fluence reduction effect was largely big as outer assemblies with two rows stainless steel rods around the assembly were used. Although the content of assembly was changed, fast neutron fluence at edge direction of outer assembly was still higher than any other sector.

From the Fig. 1 and Fig. 2, it is found that the case with two rows stainless steel around the assembly with natural uranium pins was the most efficient case for fast neutron fluence reduction (case 4). The fast neutron fluence of case 4 is reduced by 85.8%, whereas total power reduction about 2.6%. Fig. 3 shows that fast neutron fluence at the RPV is not significantly different between Cycle 1 and Cycle 14. From this result, it is found that LLLP applied to the Kori Unit 1 has not contributed to the fast neutron fluence reduction at the RPV.

Table 1 Fast neutron fluence reduction at the RPV and total power reduction

Case	Description	Fluence Reduction* (%)	Total Power (MWt)
1	No suppression fixture	-	1723.5
2	Two rows stainless steel around the assembly	69.1	1682.5 (-2.4%)**
3	Two rows stainless steel facing the baffle	25.6	1711.5 (-0.8%)
4	Two rows stainless steel around the assembly with natural uranium pins	**85.8**	1677.9 (-2.6%)
5	Natural uranium Assembly	64.8	1686.5 (-2.1%)
6	Solid hafnium (16 rods per assembly)	33.2	1689.7 (-2.0%)
7	Hafnium annulus (16 rods per assembly)	48.5	1688.1 (-2.1%)
8	Pyrex glass annulus (16 rods per assembly)	32.0	1702.1 (-1.2%)

* $\frac{\textit{modified value} - \textit{reference value}}{\textit{reference value}} \times 100\ \%$

** total power reduction

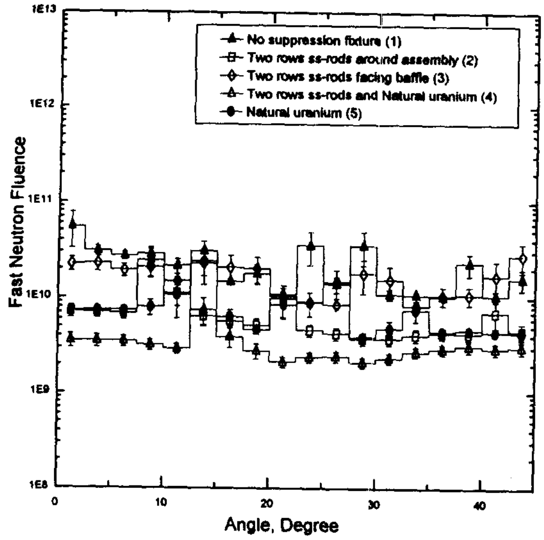

Fig. 1 **Fast Neutron Fluence on the RPV from the Case 2 to Case 5**

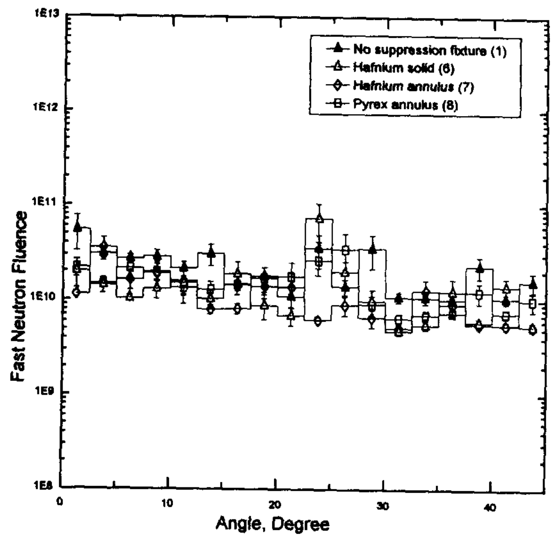

Fig. 2 Fast Neutron Fluence on the RPV from the Case 6 to Case 8

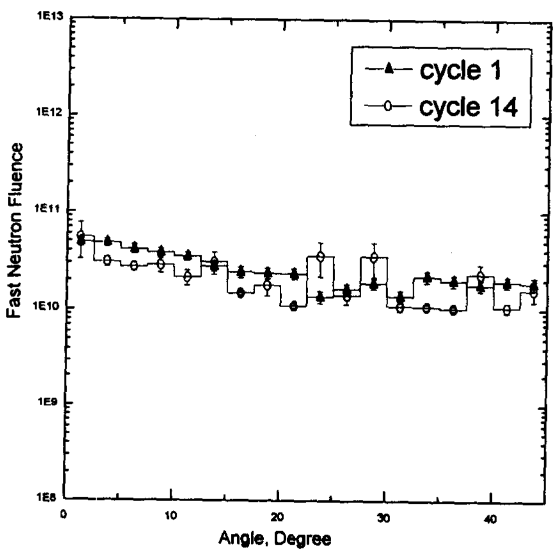

Fig. 3 Fast Neutron Fluence on the RPV in the Cycle 1 and Cycle 14

Conclusions

An effort was performed for fast neutron fluence reduction at the RPV by modifying outer assembly. As the result of this study, it was concluded that the effect of fast neutron fluence reduction using the modified outer assembly was more efficient than the previous LLLP. For all cases of modified outer assemblies, total power reduction was also small within 3%. Therefore, it can be concluded that power reduction due to modified outer assembly is not serious. It may be that the LLLP applied to Kori Unit 1 largely has not contributed to life extension of RPV through fast neutron fluence reduction.

Acknowledgement

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