Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Fuel to Moderator Ratio Sensitivity Study Using Water Rod Moderator in SCWR Conceptual Core Design

Seong Man Bae*, Yong Bae Kim, Dong Hwan Park ,Kwang Ho Lee
Korea Electric Power Research Institute, 65 Munji-ro Munji-dong, Yuseong-gu, Daejeon 305-380
**Corresponding author: smbae@kepri.re.kr*

1. Introduction

The conceptual operating condition of Super Critical Water-cooled Reactor (SCWR) is above critical point of water, such that the coolant temperature ranges from 280°C to 510°C with a pressure of 25MPa [1]. This operating condition makes an SCWR have both merits and demerits when compared with current Light Water Reactors (LWRs).
One of the demerits of SCWR is degradation of neutron moderation due to a lower water density from ~0.1g/cm^3 to ~0.7g/cm^3 under a high coolant temperature condition. Therefore it is necessary to enhance the moderation capability for SCWR to slow down the fast fission neutrons.
Many SCWR designs have a water rod concept as an additional moderator, because water has a good moderation capability.
Through reviewing the previous water rod assembly designs, it was identified that a sensitivity study is required to optimize fuel assembly pitch to increase the neutron economy.
In this paper, the results of the conceptual assembly design sensitivity study which focuses on the comparison of sensitivity for the fuel pitch to diameter (P/D) ratio using water rod moderator, are presented.

2. Methodology

2.1. A core neutronic analysis code system

The HELIOS code system has been used for this study to calculate the infinite multiplication factors of the fuel assemblies using cruciform of water rod moderator. HELIOS is a two-dimensional neutron transport analysis code using the current coupling collision probability method for a neutron transport calculation [2]. To evaluate the sensitivity of fuel P/D ratio in this fuel assembly, single fuel assembly calculations for different fuel pitch and diameter have been performed with HELIOS code. HELIOS code system was validated prior to apply the SCWR design by calculating a benchmark problem which was proposed by Argon National Laboratory [3].

2.2. Design concept of fuel assemblies

The reference fuel assembly design for this study has been directly come from Ref. 4, which is designed to have both the cruciform and the single-pin solid moderator with ZrH_2.
The geometrical design parameters for fuel assembly are listed in Table 1.

Table 1: Design parameters of reference fuel assembly

Assembly Geometrical Design Parameter	Value
Fuel Assembly Array	21X21
Assembly Pitch, cm	25.25
Number of Fuel Rods in a FA	272
Number of Cruciform Solid Moderator in a FA	25
Number of Single-pin Solid Moderator in a FA	16
Number of Poison Rod in a FA	28
Number of Instrument Tube in a FA	1
Number of Control Rod Guide Tube in a FA	24
Fuel Pitch, cm	1.15
Pellet Diameter, cm	0.82
Clad Outer Diameter, cm	0.95
Clad Thickness, cm	0.057
Enrichment of UO2, %	7.0

From this reference fuel assembly, the solid ZrH_2 moderator rods have been replaced by water rods. Figure 1 shows the geometry of reference assembly.

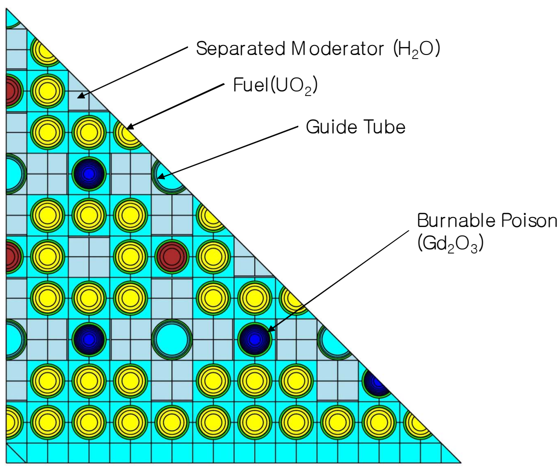

Figure 1: Reference fuel assembly with a cruciform H_2O moderator

3. Infinite Multiplication Factor Behavior

The infinite neutron multiplication factor(k_∞) calculation was performed for a single fuel assembly with HELIOS-

1.8 code. System pressure was set to 25Mpa, and the coolant temperature were set to 280C, 357C 380C, 388C and 510C, representing subcritical, pseudo-critical and supercritical condition for this calculation. The corresponding water densities were 0.08709g/cc, 0.23825g/cc, 0.45079g/cc, 0.60107g/cc and 0.77700g/cc for each case.

The k_∞ calculation was performed that fuel pin pitch varies from 0.96cm to 2.4cm with fixed fuel pin diameter of 0.95 cm.

The results of sensitivity study are shown in Figure 2 and Figure 3. Figure 2 shows the variation of k_∞ versus fuel pitch to diameter ratio for the water rod moderated fuel.

In Figure 2 the peak k_∞ values can be seen at the fuel pitch to diameter ratio between 1.8 and 2.2 for the five different moderator temperature conditions. In the under-moderated region the supercritical condition gives the lowest excess reactivity value which means the least moderation capacity compared to those of the pseudo-critical or subcritical condition. With fixed fuel diameter of 0.95cm, the pitch to diameter ratio of 1.8 and 2.2 correspond to around 1.7 cm and 2.1 cm of fuel pitch, respectively.

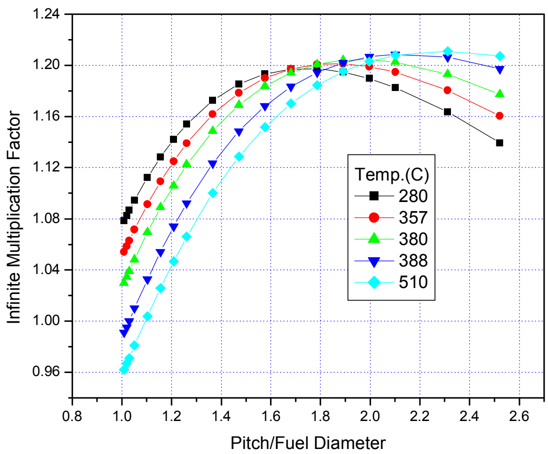

Figure 2: k_∞ versus fuel pitch to diameter ratio in water rod moderated fuel assembly

Figure 3 shows the variations of k_∞ versus moderator for the water moderated fuel assembly.

Comparing the k_∞ versus temperature curves of five different P/D types of water moderated fuel assemblies, we can see that the fuel assembly of larger P/D ratio gives better excess reactivity and moderation in the region of P/D ratio of less than around 1.7. In Figure 3, we can also see that the k_∞ value is rapidly changed in the pseudo-critical region due to a degradation of moderation. In the case of P/D ratio of 1.68, SCWR core can be designed and operated in the same way of conventional PWR because of no severe degradation of moderation in the core.

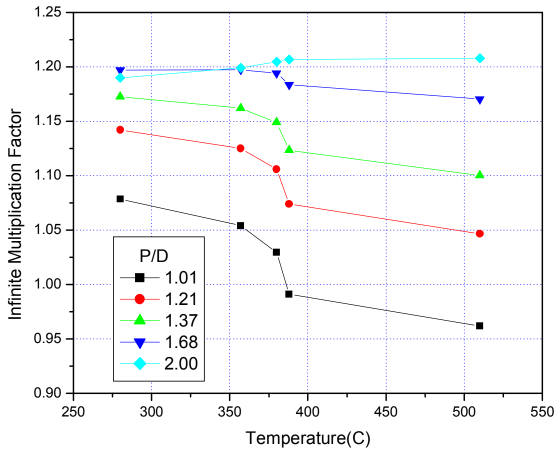

Figure 3: k_∞ versus moderator temperature in water rod moderated fuel assemblies

4. Conclusion

A sensitivity study has been performed for conceptual design of SCWR fuel assembly with water rod moderator. Water rod moderated fuel assembly deals with five different moderator temperature cases to see their effect under subcritical, pseudo-critical and supercritical conditions. In the region of pitch to fuel diameter ratio is less than around 1.7, the fuel assembly of larger P/D ratio shows better performance from the moderation enhancement point of view only. The optimal fuel pitch to diameter ratio has been found to around 1.68 with fixed pellet diameter of 0.95cm in cruciform water rod moderated fuel assembly.

Acknowledgements

This work was funded by the MEST(Korean Ministry of Education, Science & Technology) and KEPCO(Korea Electric Power Corporation) under the Nuclear Technology Development Program in Korea.

References

[1] Y. Ishiwatari, Y. Oka, and S. Koshizuk, "Safety of super LWR," *Nuclear Engineering and Technology,* Vol.39 No.4 (2007).

[2] R. STAMMLER et al., "User's manual for HELIOS, " Scandpower, (1994).

[3] Y. Y. Bae, *et al.*, "Preliminary study on the high efficiency supercritical pressure water-cooled reactor for electricity generation," KAERI/RR-26/2004, KAERI, (2004).

[4] K. M. Bae, H. K. Joo, Y. Y. Bae, " Conceptual design of a 1400 MWe supercritical water cooled reactor core with a cruciform type U/Zr solid moderator," *Proceeding of the International Congress on Advances in Nuclear Power Plants (ICAPP2007)*, Nice, France (2007).