Feasibility Study of Double-cooled Annular Fuel with KSNP (II)

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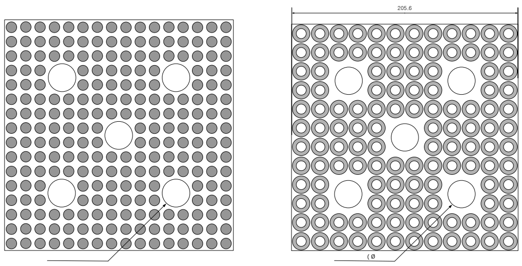
1. Introduction

Annular fuel pin concept, which is internally and externally cooled fuel, has been proposed by NERI (Nuclear Energy Research Initiative) to obtain a significant increase of the core power density and simultaneously improve the safety margin [1]. Annular fuel, has a low temperature distribution in a pellet when compared with the conventional pin type fuel due to a thin pellet thickness, decreased fission gas release and which allows for a higher burnup. The dimension of the fuel assembly had been proposed for the fuel assembly with six guide tubes and an instrumentation tube occupied on a fuel pin for each guide and instrumentation tube however the applicability of the fuel assembly geometry with a large diameter fuel assembly which is loaded in a KSNP (Korea Standard Nuclear Plant) has not yet been considered. In this paper, we proposed the fuel bundle geometry with an annular fuel applicable to the KSNP control system and we compared the geometric parameters with the data of the KSNP's fuel.

2. Proposed Geometry

The ratio of the pitch to diameter of the annular fuel assembly between 1.07 and 1.08 is smaller than that of the conventional PWR pin array with 1.33[2]. The narrow pin array increases the uranium quantity while balancing the hydraulics between the inner and outer channel.



(a) KSNP 16X16 (b) Proposed Annular Fuel

Figure 1. Cross Sectional View of Fuel Bundle

The fuel assembly loaded into the KSNP is a quadratic rotational symmetry with three layers of fuel pins surrounding a guide tube as shown in Fig. 1-(a). The proposed fuel array with a annular pin is shown in Fig. 1-(b). The fuel array accepts the small ratio of the pitch to diameter and the quadratic rotational symmetry with two layers of fuel pins around a guide tube.

3. Parameter Comparison

The geometric parameters of the KSNP 16X16, MIT 13X13, and proposed annular fuel are shown in Table-1. The overall dimension of the proposed annular fuel are a little higher than the number of the MIT 13X13 while the pitch to rod outer diameter ratio maintains a similar ratio.

Table 1. Geometric Parameters for the Different Fuel Assemblies

Parameter	KSNP Fuel	MIT		Proposed Annular Fuel
Rod Array	16 X 16 (Fig. 1-a)	13 X 13 (Ref. 2)		12 X 12 (Fig. 1-b)
Cladding Diameter [mm]	9.5	Outer	15.37	15.90
		Inner	8.63	9.00
Fuel Diameter [mm]	8.18	Outer	14.10	14.63
		Inner	9.90	10.27
Pin Pitch [mm]	12.85	16.51		17.13
Array Pitch [mm]	205.60 (207.77)[*1]	214.60		205.60

[*1] : Fuel Assembly Pitch

The major parameters have been compared in Table 2. The heat transfer area of the proposed annular fuel is increased by 30% when compared with the KNSP's fuel. The increase the heat transfer area decreases the heat flux of the fuel bundle and allows for an increased safety margin. The fuel volume of KSNP's fuel is 15% higher than that of the proposed fuel. The uranium quantity in the fuel, which influences the fuel burnup, can be increased by increasing the uranium enrichment. The flow are of the two fuel assemblies are comparable with each other. The hydraulic diameter of the KSNP's fuel is 25% higher than that of the proposed fuel. The small hydraulic diameter will increase the frictional pressure drop. A low pressure drop spacer grid design is needed to satisfy the total fuel assembly pressure drop requirement in the design phase.

Table 2. Comparison of Design Parameters between KSNP's fuel and Proposed Annular Fuel

Parameter	KSNP 16X16	Proposed Annular Fuel
Heat Transfer Area in FA [m^2]	26.84	36.96
Fuel Volume in FA [cm^3]	47386	40310
Flow Area in FA [cm^3]	240	240
Hydraulic Diameter of FA [mm]	12.90	9.50

4. Power Peaking Factor

The power peaking factor for the KSNP's fuel and the proposed annular fuel has been calculated by using the HELIOS code[4]. The power peaking factor of the quadrant fuel assembly has been shown with a variation of the burnup in Fig. 2. The peaking factor of the proposed annular fuel is a little higher than that of the a KSNP's fuel with 1% difference and the difference between two fuel assemblies is reduced as burnup increasing. The difference is due to the wide flow area around the guide and instrument tube. The multiplication factors of the proposed annular fuel with various U-235 enrichments are compared to those of the KSNP's fuel in Fig. 2.

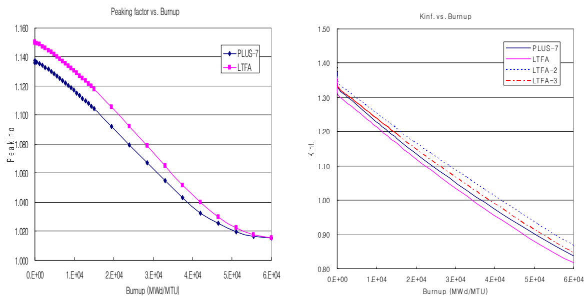


Figure 2. Comparison power peaking factor and Multiplication factors between KSNP's fuel and proposed annular fuel with variation of burnup

The proposed annular fuel U-235 enrichments is 4.5 w/o same as the KSNP's fuel, the proposed annular fuel U-235 enrichments is 5.28 w/o to conserve the total amount of U-235 in the fuel assembly, and another proposed annular fuel U-235 enrichments is 4.95 w/o to meet the maximum enrichment for the commercial power plant. As shown in Fig. 2, the neutron performance of the proposed annular fuel is better than that of the KSNP's fuel.

4. Concluding Summary

The annular pin array to acceptable the control system of the KSNP has been proposed and the major parameter has been generated and compared with the data of PLUS-7. The results are summarized as follows;

1) The wide heat transfer area will allow increasing safety margin
2) The frictional pressure drop of annular fuel will be increased due to the low hydraulic diameter so the low pressure drop spacer grid design is needed in design phase.
3) The high uranium enrichment is needed to compensate the low pellet volume. Under the condition of uranium mass conservation, the neutron performance of the proposed annular fuel is better than that of KSNP's fuel.
4) The more detail feasibility study on the proposed fuel array including thermal hydraulics and nuclear physics analysis is needed.

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