Neutronic Analysis of Dual-Cooled Nuclear Fuel with Double Cylinder Guide Tube

Kang-Hee Lee[a], Hyung-Kyu Kim[a], Kyung-Ho Yoon[a], Yong-Sik Yang[a], Kang-Mok Bae[b]
[a] KAERI, Advanced Water Reactor Fuel Center, 1045 Daedeokdaero, Yuseong, Daejeon, leekh@kaeri.re.kr
[b]KHNP, KHNP Nuclear power Education Institute, 991 Sinam-ri, Suseng, Ulju, Ulsan

1. Introduction

In the currently proposed annular fuel assembly design, a flow area of around the guide tube is larger than fuel region. This flow area inequality can cause various neutronic and thermal hydraulic disadvantages [1~3]. To reduce or solve the above mentioned disadvantages, a new guide tube design has been proposed for double-cooled annular fuel assembly. In this concept, double cylinder type guide tube was introduced which inner space between two cylinder was filled by coolant or air. Due to the increased guide tube area, a flow area inequality was moderated. In addition, double cylinder guide tube is expected to enhance fuel assembly structural integrity. For the evaluation of neutronic characteristics of the proposed double cylinder type guide tube, parametric studies have been performed. According to guide tube dimension and intermediate material change, an infinite multiplication factor & peaking power variation in-between two cylinders were evaluated and analysis results are summarized in this paper.

2. Methods and Results

2.1 Neutronic Analysis

The multiplication factor and power distribution along with the fuel burnup are a representative indicator for the neutronic characteristics of the nuclear fuel design [4]. Multiplication factor and power distribution for the dual cooled were calculated according to the guide tube dimensions listed in Table 1 and the type of intermediate material(water or air) between inner and outer guide tube. HELIOS version 1.8 and 47-group neuron library were used as an analysis tools and library. 1/8 fuel assembly model was used. Fig. 1 shows analysis model.
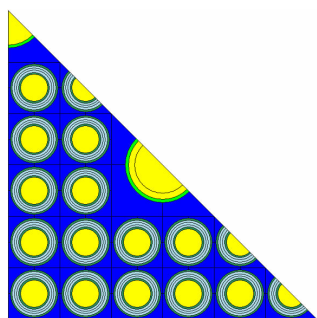

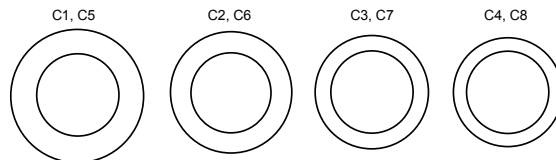Fig. 1 1/8 Model of 12x12 dual-cooled fuel assembly with single cylinder guide tube

Fig. 2 Schematic configuration of the C1 ~ C8(listed in Table 1) for dimensions of the double cylinder guide tube

Table 1 Dimensions (C1~C8) of the double-cylinder guide tube design for case study; C means Case.

	Ref.	Water Filled/Air Filled			
		C1/C5	C2/C6	C3/C7	C4/C8
IGT-OD	24.9	24.9	24.9	24.9	24.9
IGT-ID	22.89	22.86/	22.86	22.86	22.86
OGT-OD	-	34	32.48	30.48	28.48
OGT-ID	-	31.96	30.44	28.44	26.44
THK	1.02	1.02	1.02	1.02	1.02

Note) IGT-OD : Outer diameter of the inner guide tube,
　　IGT-ID : Inner diameter of the inner guide tube
　　OGT-OD : Outer diameter of the outer guide tube,
　　OGT-OD : Inner diameter of the outer guide tube,
　　THK　　: Thickness
　　Ref.　　: Guide tube of 12x12 fuel array, which is the same as the conventional guide tube of the 16x16 PWR fuel.

2.2 k_0 according to the guide tube dimensions and type of intermediate material

Fig. 3 shows the initial multiplication factor (k_0) according to the guide tube dimensions and a type of intermediate medium in-between inner and outer guide tube. Initial multiplication factor determines neutron economy of the fuel design and dimension. Since the material portion of double cylinder guide tube increased due to additional outer guide tube, k_0 decreased by 0.8% , which is not a small value considering k_0 of dual-cooled fuel(12x12 annular fuel array) having the 2% decrement from the conventional fuel(16x16 solid fuel array). Because the double guide tube without intermediate moderator lower the thermal neutron which is needed for the nuclear fission reaction, the type of intermediate medium between two guide tubes differentiate k_0 by the air filled 0.3% less than water filled case.

2.3 k_{inf} according to the type of intermediate material

Fig. 4 shows infinite multiplication factor(k_{inf}) according to the type of intermediate material between inner and outer guide tube. Rare difference was shown in the resulting multiplication factor with respect to the material type, but the discrepancy of the multiplication factor from one of the reference(12x12 dual cooled fuel

with single cylinder guide tube) increased slightly along with the fuel burnup. From the viewpoint of the design of high burnup fuel, there are rare difference of double guide tube from the reference fuel based on 'B1 point' in the linear reactivity model.
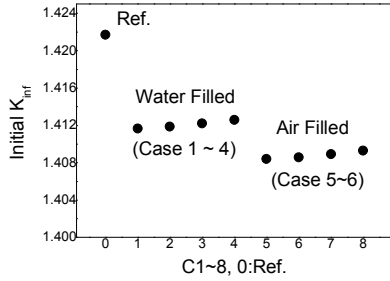

Fig. 3 Initial multiplication factor with respect to the guide tube dimensions and types of intermediate medium.
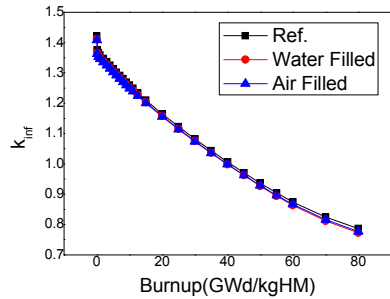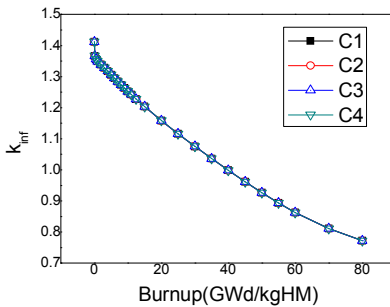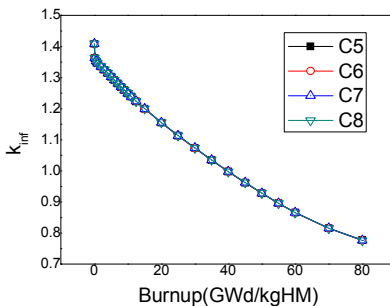

Fig. 4 Multiplication factor according to the type of intermediate medium between inner and outer guide tube.

(a)

(b)

Fig. 5 Infinite multiplication factor according to the guide tube dimensions; (a) annular gap with water filled, (b) annular gap with air filled.

2.4 k_{inf} according to the guide tube dimensions

Fig. 5 shows the infinite multiplication factor according to dimensions of double cylinder guide tube. The dimensional change of the guide tube doesn't affect multiplication factor for the both cases of intermediate materials. This is because the small change of guide tube's cross sectional dimension doesn't change the total volume in guide tube enough to vary multiplication factor remarkably.

2.5 Power peaking

The location of power peaking was the closest to the center guide tube due to the high moderation. The peaking factor was nearly same irrespective of the guide tube dimensions and the intermediate material between inner and outer guide tube. The discrepancy from dimensional differences was under 1%. So, the power peaking issue was not a technical problem on the application of the double cylinder guide tube.

3. Conclusion

The results from the neutronic analysis of the dual-cooled fuel with the double-cylinder guide tube were summarized as following;

1) Except a neutron economy which was decreased due to addition of the outer cylinder tube as expected, neutronic design characteristics of the double cylinder guide tube seemed to be within allowable design margin.

2) From the engineering sense of view, infinite multiplication factor was insensitive to the guide tube's cross sectional dimensions.

3) Power peaking location and value seemed to be irrelevant to the intermediate material around the center guide tube and its dimensions; water or air was valid as an intermediate material if excessive moderation or heating didn't occur.

Acknowledgement

References

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