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Thermal Hydraulic Assessment of Two Types of Prismatic Fuel Assemblies

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1. Introduction

Two types of fuel assemblies, "multi-hole" or "pin-in-hole", are considered in the development of a prismatic core concept for a very high temperature gas cooled reactor (VHTR). The multi-hole type assembly was developed by General Atomics (GA) and it was used for the Fort St. Vrain reactor. The same type of a fuel assembly is adopted for the GA's GT-MHR design [1]. On the other hand, the pin-in-hole type is used in the Japanese HTTR and GTHTR300 designs [2].

In this paper, a comparative thermal hydraulic assessment has been made for the two types of fuel assemblies using a computational fluid dynamics (CFD) code.

2. Two Concepts of Prismatic Blocks

A typical multi-hole type fuel assembly is shown in Fig. 1. The hexagonal graphite assembly contains many blind holes for fuel compacts and flow channels for helium coolant. A unit cell chosen for the CFD calculation is shown in Fig. 2. The heat generated in the fuel compact is conducted through the graphite block and it is finally cooled down by the helium coolant. There is no direct contact between the fuel compact and the coolant. A very small gap with a thickness of 0.127 mm exists between the fuel compact and the graphite block.

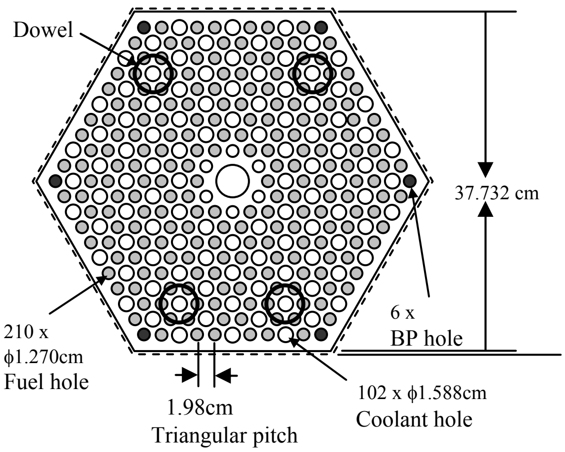

Figure 1. Typical multi-hole type fuel assembly.

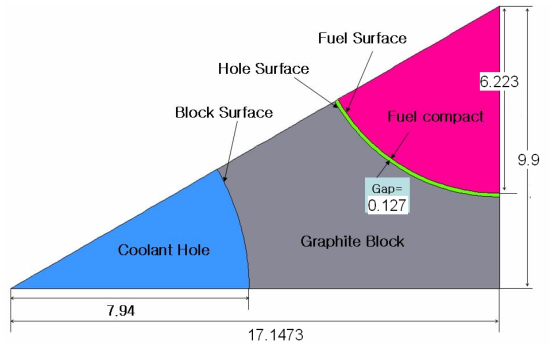

Figure 2. Unit cell of multi-hole type for CFD analysis (unit: mm).

Fig. 3 shows the pin-in-hole type fuel assembly used in the GTHTR300 design. The graphite hexagonal block has 57 holes for annular fuel compacts and coolant channels. A helium coolant flows downward in the annular space around fuel compacts and removes the heat from fuel compacts. The fuel compacts are coated with a 1 mm-thick graphite material (sheath). A unit cell of this type for the CFD analysis is shown in Fig. 4.

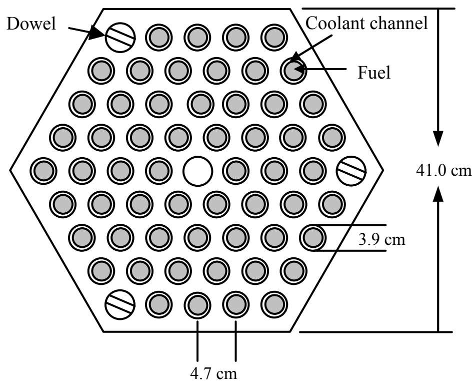

Figure 3. Pin-in-hole type fuel assembly.

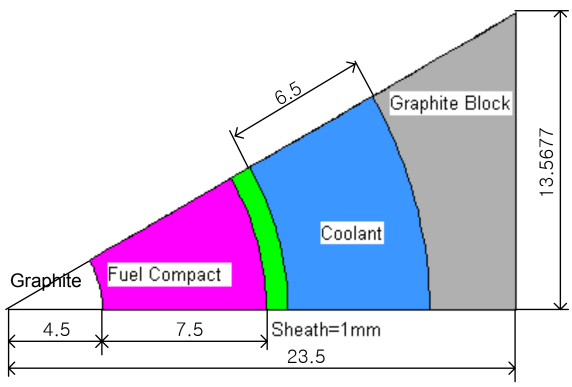

Figure 4. Unit cell of pin-in-hole type for CFD analysis (unit: mm).

3. CFD Analysis and Results

In order to compare the thermal hydraulic performance, it is assumed that the thermal power and the helium flow rate within these assemblies are the same. For both types, the height of the active core is chosen as 8 m and a uniform power density profile is used. Above the active core, a reflector part with a height of 2 m is placed. Table 1 shows the main thermal hydraulic data of the two fuel blocks. The CFX 5.7 code [3] has been used for the CFD analysis.

Table 1. Main T/H data of two types of assemblies

	Multi-hole type	Pin-in-hole type
Assembly power	5.882 MW	5.882 MW
Fuel power density	28.78 W/cc	33.18 W/cc
Flow area (assem.)	208 cm^2	378 cm^2
He inlet velocity	23.9 m/s	13.1 m/s
Inlet temperature	491 ^oC	491 ^oC

The calculated temperature profiles at the outlet plane of the active core are shown in Figs. 5 & 6. The results of the CFX 5.7 calculations are summarized in Table 2.

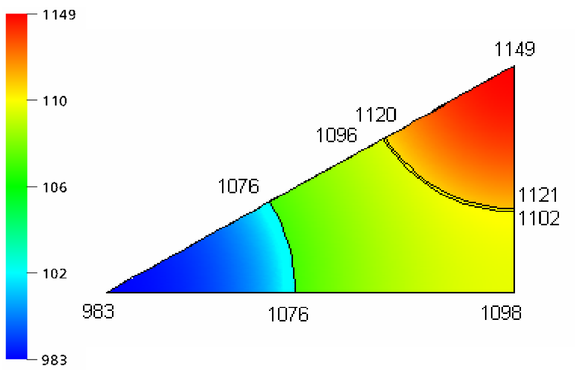

Figure 5. Temperature profile at outlet plane of multi-hole type assembly.

The maximum fuel temperature of the pin-in-hole type is higher than that of the multi-hole type by 74 ^oC and it is close to the design limit (~1250 ^oC). However, the pressure drop of the multi-hole type is double as high as that of the pin-in-hole type. This seems to be mainly due to the large difference in the flow area. Therefore, the reference assembly in Figs. 3 & 4 was modified to get the same flow area and an additional CFX calculation was made. The results are shown in the fourth column of Table 2. With the modified geometry, the maximum fuel temperature is reduced by 46 ^oC, which is still higher than that of the multi-hole type. The pressure drop is now dramatically increased. Therefore, it is expected that the maximum fuel temperature of the pin-in-hole type will be higher than that of the multi-hole type with the same pressure drop condition.

In addition, it should be noted that the use of the thin graphite coating may be a very challenging issue in terms of fuel integrity. In stead of the sheath, a graphite sleeve 3.5 mm in thickness is used in HTTR. In case that a 3.75 mm-thick graphite sleeve and a 0.25 mm-thick helium gap are adopted for the assembly in Figs. 3 & 4, the maximum fuel temperature is increased by ~80 ^oC, which makes further worse the thermal performance of the pin-in-hole type.

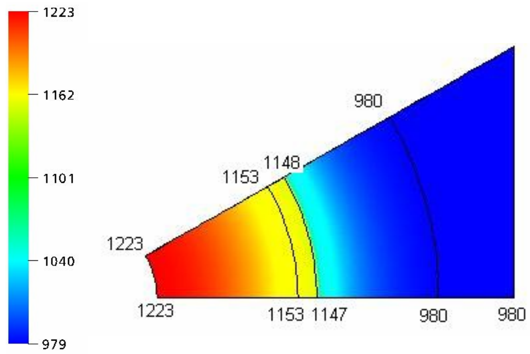

Figure 6. Temperature profile at outlet plane of pin-in-hole type assembly.

Table 2. Summary of CFX 5.7 Results

	Multi-hole type	Pin-in-hole type	
		Reference	Modified
Pressure drop (across 10 m)	24.2 kPa	10.8 kPa	55.4 kPa
Max. He velocity	50.6 m/s	25.9 m/s	46.0 m/s
Max. fuel temp.	1149 ^oC	1223 ^oC	1177 ^oC
Ave. fuel temp.	892 ^oC	950 ^oC	890 ^oC
Max. He temp.	1036 ^oC	1147 ^oC	1102 ^oC

4. Conclusions

The CFX calculations for two types of prismatic fuel assemblies have been made. The results show that the multi-hole type has an advantage over the pin-in-hole type in terms of the thermal hydraulic performance. However, the other aspects such as fabrications, waste treatments, etc. have to be also considered to compare overall merits and demerits of the two.

ACKNOWLEDGMENTS

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REFERENCES

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