Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, Oct. 30-31, 2014

Mechanical Design Concept of Fuel Assembly for Prototype GEN-IV Sodium-cooled Fast Reactor

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1. Introduction

The prototype GEN-IV sodium-cooled fast reactor (PGSFR) is an advanced fast reactor plant design that utilizes compact modular pool-type reactors sized to enable factory fabrication and an affordable prototype test for design certification at minimum cost and risk.

The design concepts of the fuel assembly (FA) were introduced for a PGSFR. Unlike that for the pressurized water reactor, there is a neutron shielding concept in the FA and recycling metal fuel.

The PGSFR core is a heterogeneous, uranium-10% zirconium (U-10Zr) metal alloy fuel design with 112 assemblies: 52 inner core fuel assemblies, 60 outer core fuel assemblies, 6 primary control assemblies, 3 secondary control assemblies, 90 reflector assemblies and 102 B_4C shield assemblies. This configuration is shown in Fig. 1. The core is designed to produce 150 MWe with an average temperature rise of 155 ℃. The inlet temperature is 390 ℃ and the bulk outlet temperature is 545 ℃. The core height is 900 mm and the gas plenum length is 1,250 mm.

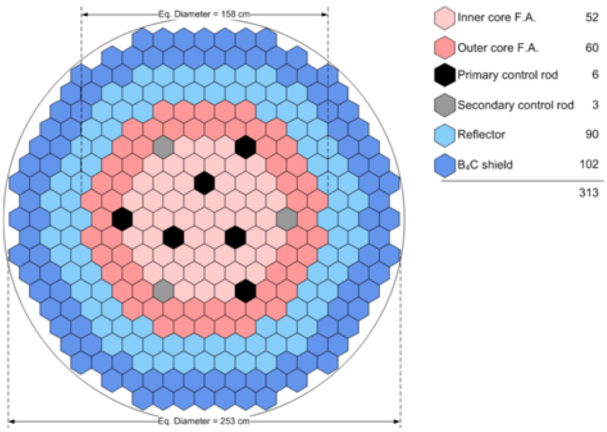


Fig.1 Core radial configuration of 150 MWe for PGSFR.

2. Mechanical design concepts

2.1 Overall fuel assembly

The fuel assembly composed of the structural parts, handling socket, hexagonal duct, inlet nozzle, and fuel rods[1]. In addition to these, there are upper and lower shields for neutron shielding. The fuel alloy is U-10%Zr. All of these structural parts material are HT9. This ferritic stainless steel is chosen for its low irradiation swelling characteristics. A schematic drawing of a FA is shown in Fig. 2[2].

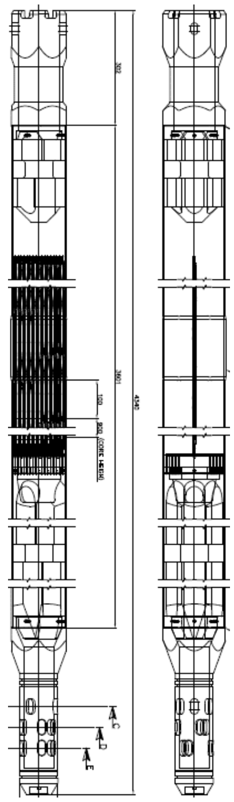


Fig. 2 Schematic drawing of a fuel assembly for PGSFR.

2.2 Handling socket

The top end of the hexagonal duct is located. Sodium exits the assembly through the handling socket and the refueling machine grapples the assembly by two thru-holes on the socket. An enlarged handling socket section, the top load pad (TLP), serves to space and position the assemblies at the top end. Four cutouts at the top of the handling socket prevent flow blockage by objects resting on the top of the core. In addition, the inside cylindrical hole has to supply the guide path for control rod driving line. Also, a schematic drawing of the handling socket is shown in Fig. 3.

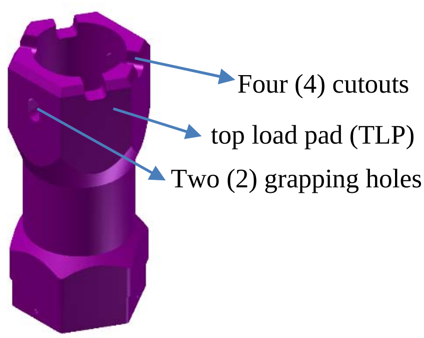


Fig. 3 Schematic drawing of a handling socket.

2.3 Hexagonal duct

The hexagonal duct functions to control the coolant flow and isolate each fuel rod bundle from its neighbors. It is also a structural assemble between the top and bottom end structural parts of the fuel assembly. And the above core load pad (ACLP) is positioned at the middle axial location, and serves to maintain the fuel assembly spacing and prevent compaction due to the FA bowing. This is shown in Fig. 4.

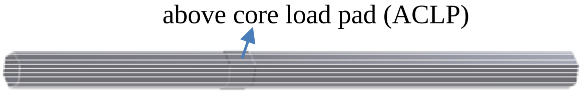


Fig. 4 Hexagonal duct for PGSFR.

2.4 Nose piece

The bottom end of each assembly is formed by a 580 mm long nose piece which provides the lower restraint function and the coolant inlet. 217 fuel rods attach to the nose piece with 17 mounting rails. Also there are nine (9) flow holes on the cylindrical surface at different elevations for reducing the loss of coefficient. This is shown in Fig. 5.

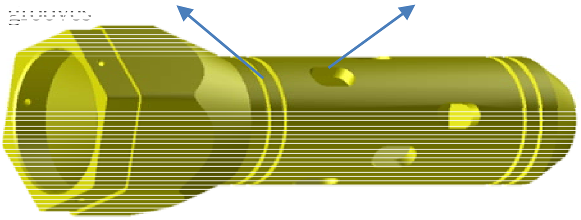
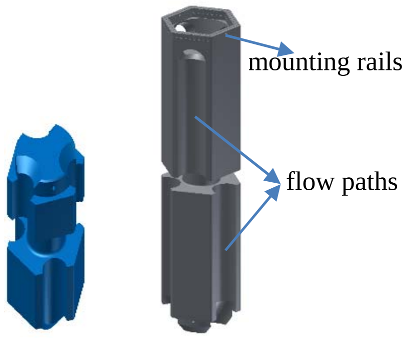


Fig. 5 Nose piece for PGSFR.

2.5 Upper and lower shields

The upper and lower shields are essentially components for preventing the high neutron activation for a fast reactor. In this design, the block type shields are adopted for the PGSFR. For economical nuclear and breeding performance in a physically small core, a high fuel volume fraction and long fuel lifetime is necessary. Thus, a low swelling material that permits a compact core is used. The somewhat lower thermal creep resistance of HT9 compared to austenitic steels is compensated for by the low core operating temperatures.

The volume fraction of these upper and lower shields are 70 vs. 30, solid and fluid, respectively. These shields are shown in Fig. 6.



(a) upper shield (b) lower shield

Fig. 6 Schematic drawings of upper & lower shields

2.6 Fuel rod

The active fuel length is 900 mm, and the outside diameter is 5.54 mm. The density of the metal slug is 15.9 g-U/cm^3, and its enrichment is 19.75 wt%. To maintain the spacing and enhance the cooling performance, the wire wrap process is adopted. The number of turns and the initial tensile force are 10 and 30 N, respectively. The total fuel rod length is 2,240 mm, and the schematic drawing is shown in Fig. 7[3].

Fig. 7 Detail drawing of a fuel rod for PGSFR.

3. Geometrical basic data

In table 1, the geometrical dimension of FA are summarized. The total mass of a fuel rod and a FA are about 563 g and 296 kg, respectively.

Table 1. Geometrical dimension data[4] for PGSFR.

item	value(mm)	material
fuel rod length	2,240	HT9
fuel rod pitch	8.436	
fuel slug length	900	U-10Zr
slug diameter	5.54	
clad diameter	7.4	HT9
thickness	0.5	
plenum length	1,275	
FA length	4,550	HT9
FA pitch	136.36	
duct inside distance	126.36	HT9

4. Conclusion

A mechanical design of a fuel assembly for a PGSFR was established. The mechanical design concepts are well realized in the design. In addition to this, the analytical and experimental works will be carries out for verifying the design soundness.

ACKNOWLEDGEMENTS

This project has been carried out under the nuclear R&D program by MISP (Ministry of Science, ICT and Future Planning in Republic of Korea).

REFERENCES

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