Lateral Stiffness Analysis of Fuel Assembly as Contact Condition for PGSFR

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1. Introduction

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.

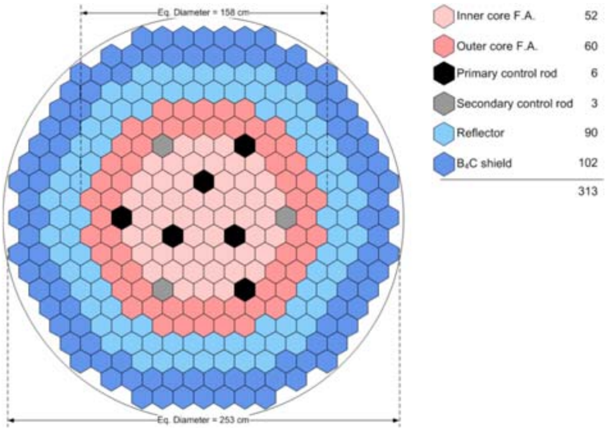

Fig.1 Core radial configuration of 150 MWe for PGSFR.

To evaluate the fuel assembly bowing in the core, the lateral stiffness analysis is needed. In the fuel assembly, there are two load pads. One is the top load pad (TLP) and the other is above the core load pad (ACLP). These load pads supply the impact surface among the fuel assemblies. In this paper, the lateral stiffness analysis of the fuel assembly as the core contact condition will be executed using the finite element method.

2. Lateral Stiffness Analysis

2.1 Overall fuel assembly

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

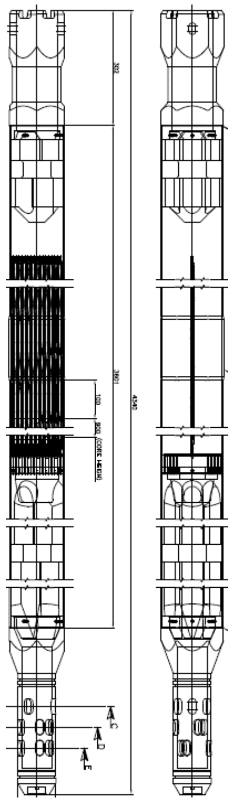

Fig. 2 Schematic drawing of a fuel assembly for PGSFR.

2.2 Core fixed condition

The fuel assembly is inserted in the receptacle of the core. This receptacle is fixed between the upper and lower grid plates. The receptacle has functions for fixing the fuel assembly with frictional force and a supply flow path for sodium coolant. There is no clearance between the inlet nose piece and the receptacle, as shown in Fig. 3.

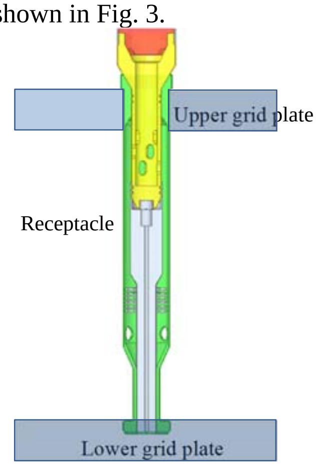

Fig. 3 Boundary conditions between nose piece and grid plates.

2.3 Fuel assembly analysis model

The finite element model is created with ANSYS Ver. 15.0[2]. The structural parts are modeled with SOLID186 and fuel rods are modeled with the BEAM189 element. In addition to this, the contact surfaces between the inlet nose and receptacle are modeled with the CONTA174 and TARGE170 elements. The total mass of the FE model is 295.86 kg, which has no discrepancy with the geometrical data[3].

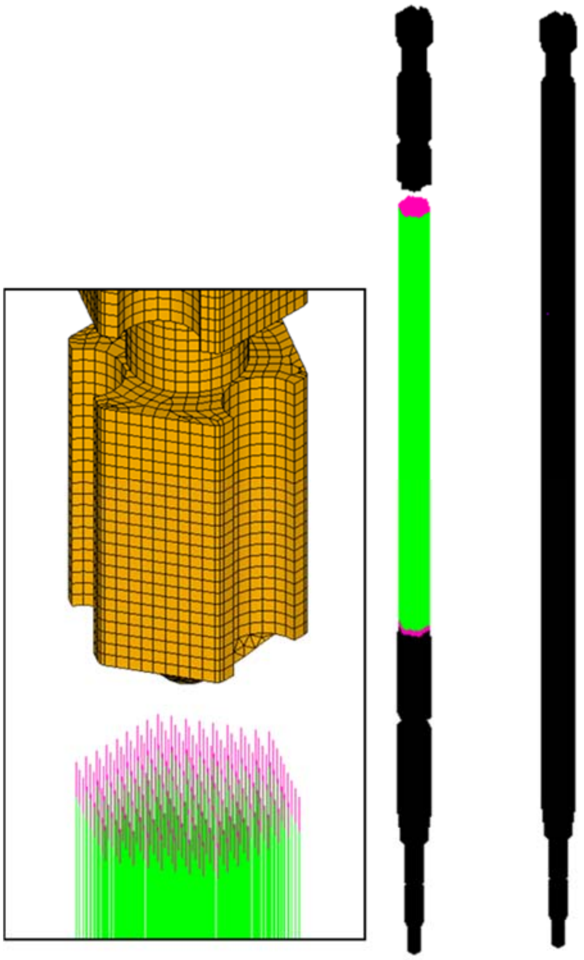

Fig. 4 Finite element model of fuel assembly.

The FE model of a fuel assembly for a lateral stiffness analysis are summarized in Table 1.

Table 1. FE model of fuel assembly.

Element type	# of node	# of element
SOLID186	900,024	270,050
CONTA174	10,967	3,567
TARGE170	7,235	2,323
Total	918,226	275,940

2.4 Contact condition

The whole contact conditions are defined with the standard contact condition. In a normal contact problem, the FKN (normal contact stiffness factor) value is within 0.01 to 1.0. If the normal bending is the most dominant, this FKN is defined as 0.1. In addition, the friction coefficients among the structural parts are 0.3.

These grid plates are fixed because the stiffness of these plates is relatively larger than that of the contact parts.

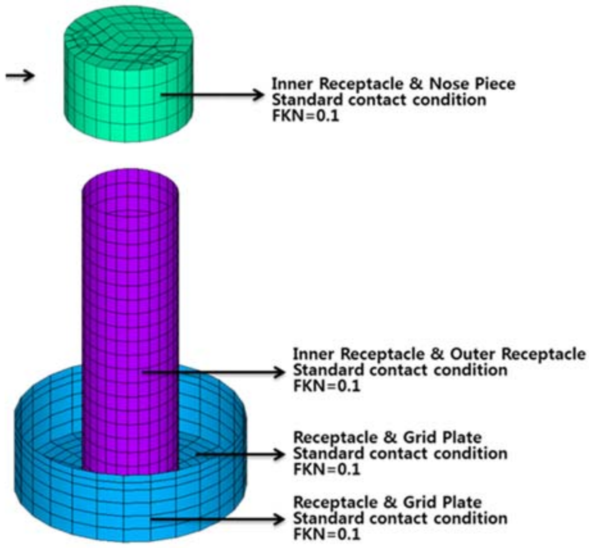

Fig. 5 Applied boundary condition for analysis.

3. Analysis results

The applied load is 445 N at one surface of the TLP. In Figure 6, the maximum lateral deflection is 11.68 mm. Therefore the lateral stiffness is about 38.12 N/mm.

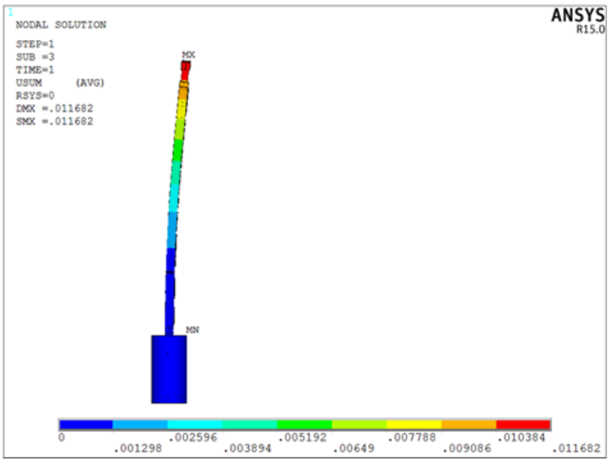

Fig. 6 Deflection contour of fuel assembly @ 445 N

4. Conclusion

The lateral stiffness of a fuel assembly is established by the FE method. These analysis results will be utilized in a fuel assembly bowing analysis in the core.

ACKNOWLEDGEMENTS

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REFERENCES

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[3] ANSYS Ver. 15.0 User's Manual, ANSYS Inc., 2014.