Design for Hydrostatic Bearing of Vertical Type Pump

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1. Introduction

The primary pump of PGSFR(Prototype Gen IV Sodium Fast Reactor) performs an important safety function of circulating the coolant across the core to remove the nuclear heat under all operating conditions of the reactor. Design and selection of materials and manufacturing technology for sodium pumps differ to a large extent from conventional pumps because these pumps operate relatively at high temperatures and have high reliability.

The configuration of the primary pump of PGSFR is shown in Figure 1. In order to provide guide to the shaft at the bottom part, there is a hydrostatic bearing above the impeller level. In this paper, the FEM(Finite Element Method) analysis was performed to evaluate the unbalance force for the rotary shaft for the design of the hydrostatic bearing and the design methodology and procedures for the hydrostatic bearing are established.

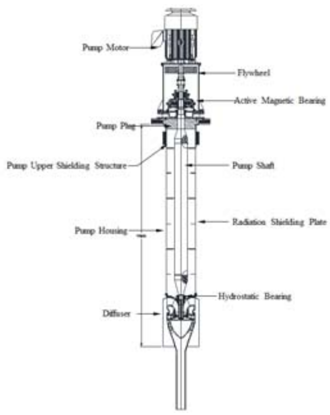

Figure 1 Configuration of the primary pump

2. Methods and Results

The hydrostatic bearing is applied to the unbalance force by non-homogeneous materials, manufacturing and assembly errors of the rotary shaft assembly. A FEM dynamic calculation was conducted to evaluate the unbalance force for the rotary shaft assembly. The finite element model by the ANSYS code is shown in Figure 2. The equivalent diameters were used for the upper and bottom shaft due to the geometric complication. The detailed calculations are represented at the reference 1. After analysis, the reaction force for the hydrostatic bearing is 4000 N[1]. Geneally, the reaction force of the hydrostatic bearing for the vertical type pump genally is taken 10% of the reaction force for upper trust bearing in order to design conservatively. Since the weight of shaft and impellor is 62181 N, the reaction force of the hydrostatic bearing is 6218. N. For conservative design, this value was used for the design of the hydrostatic bearing. The viscosity of sodium(η) at 100 ℃ and 400 ℃ are 0.682 cp, 0.278 cp respectively[2]. 0.278 cp = 0.000278 Pa.s = 0.278×10^{-9} kg. sec/mm^2.

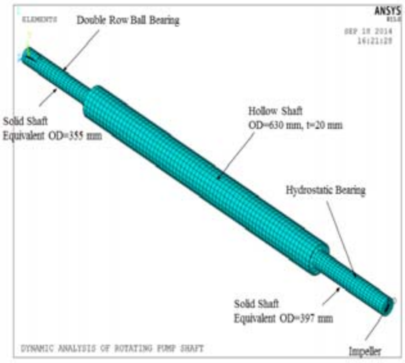

Figure 2 FEM model for the unbalance force

2.1 Bearing Pressure Calculation

The sodium flow way due to the pressure difference is shown in Figure 3. The sodium discharged from the impellor flows through the diffuser and then, the small part of sodium flows from the diffuser oriffice to the hydrostatic bearing due to the pressure difference.

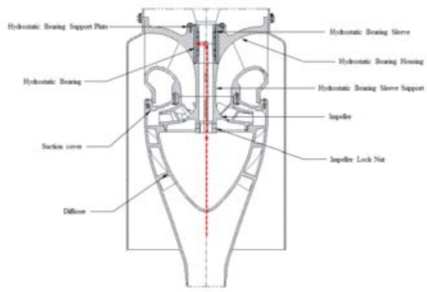

Figure 3 Sodium flow way

The pressure difference near impellor is calculated by the CFD code. The result of analysis is shown in Figure 4. The pressure at each location is as follows[3].

Location	Pressure (bar)
Impellor inlet	3
Impellor outlet	8
Diffuser inlet	10
Diffuser outlet	8
Above bearing	1

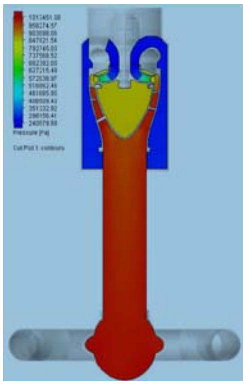

Figure 4 Pressure distributions near impellor

2.2 Bearing Design

1) Length of the bearing

The length of the bearing is generally 0.6~3.0 time of the diameter of the shaft(213 mm). We determined the length of the bearing as 420 mm.

2) Sommerfeld number(S)

Sommerfeld number is expressed as

$$S = \left(\frac{r}{c}\right)^2 \cdot \frac{\eta N}{p}$$

where $\eta$is viscosity of sodium, r is shaft radius N is shaft speed and p is bearing pressure. Each Sommerfeld number(S) value for each the bearing clearance(c) value is as follow.

C(mm)	S
0.1	0.6590
0.2	0.1650
0.3	0.0732
0.4	0.0412

When the bearing clearance(c) value is 0.2 mm, Sommerfeld number is 0.1650. This value is proper as Sommerfeld number of the sleeve bearing because Sommerfeld number 0.15~0.2 is generally used. Therefore, we determine the bearing clearance as 0.2 mm.

3) Bearing friction coefficient(μ)

$$\mu = \frac{\pi^2}{30} \cdot \frac{\eta N}{p} \cdot \frac{r}{c}$$

Each bearing friction coefficient value (μ) for each the bearing clearance(c) value is as follow.

C(mm)	μ
0.1	0.0122
0.2	0.0061
0.3	0.0041
0.4	0.0031

When the bearing clearance(c) value is 0.2 mm, the bearing friction coefficient value is 0.0061. This value is proper as bearing friction coefficient value for the sleeve bearing. Therefore, we determine the bearing clearance as 0.2 mm.

4) Apply flow(Q)

Apply flow within the hydrostatic bearing is expressed as

$$Q = \frac{\pi P_s r c^3}{3 \eta l'} (1 + 1.5\epsilon^2)$$

Where P_s is the apply pressure of sodium(7 bar) and ε is eccentricity ratio. The apply flow within the hydrostatic bearing is 0.0126 m^3/sec. This value is proper as the apply flow of the sleeve bearing in case of the impellor flow 1.231 m^3/sec. The summary of the calculated results is as follows.

Items	Calculated values
Reaction force of bearing (N)	6218.1
Shaft of diameter (mm)	213
Length of bearing (mm)	420
Clearance (mm)	0.2
Bearing pressure (kg/mm^2)	0.0071
Heat generation coefficient (kg/mm^2·m/sec)	0.07
Viscosity of sodium (cp)	0.278
Coefficient of friction	0.0061
Sommerfeld number	0.1650
Min. sodium film thickness (mm)	0.132
Power loss by friction (kw)	0.375
Heat generation ratio (kcal/sec)	0.09
Max. sodium film pressure (bar)	1.27
Apply pressure within bearing (bar)	7
Apply flow within bearing (m^3/sec)	0.0126
Impellor flow (m^3/sec)	1.231

3. Conclusions

The hydrostatic bearing of the primary pump of PGSFR is designed. Thus, the design methodology and procedure for the hydrostatic bearing of the vertical type pump are established. In future plans, we will manufacture the prototype hydrostatic bearing and perform the test of that at the fit conditions of PGSFR.

Acknowledgements

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REFERENCES

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