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An Analysis of Rotordynamic Characteristics of a SMART Reactor Coolant Pump

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1. Introduction

SMART reactor coolant pump(RCP) is shown in Figure 1. It makes circulate coolant heated by rector core to transfer to steam generator for heat exchange. SMART RCP is one of the key components for a stable operating of SMART[1].

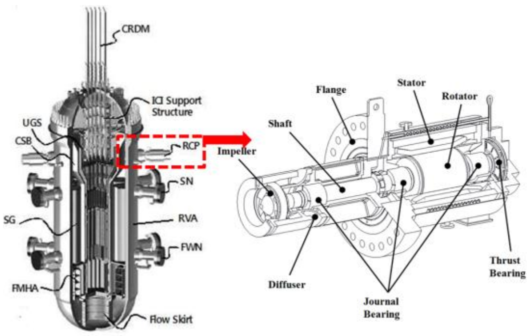

Fig. 1. SMART reactor internal configuration(left) and schematic diagram of RCP(right)

Submerged type pumps in the state of high-temperature and high pressure coolant are required for more than 10 years lifetime. Such an extreme environment, detailed rotor-dynamic analysis must be carried out in order to ensure stability and lifetime at the design step[2]. Park[3] discussed rotordynamic characteristics and stability for vertical MCP(main coolant pump).

In this study, rotordynamic characteristics of SMART RCP are analyzed, especially, to ensure reliability of rotor-bearing system. The rotordynamic analysis includes the critical map, Campbell diagram and unbalance response.

2. Modeling and conditions

2.1 Rotor modeling

A schematic diagram of the RCP is shown in Figure 1. The strong restoring force occurs to the radial direction due to the pressure drop because the working fluid passes through the annular seal installed at the entrance to impeller and balance drum[4]. This restoring force should be considered of rotordynamic analysis because of effect of the stiffness and damping on the rotor. Figure 2 shows the FE analysis model, including the effects in the annular seal(wet-run model).

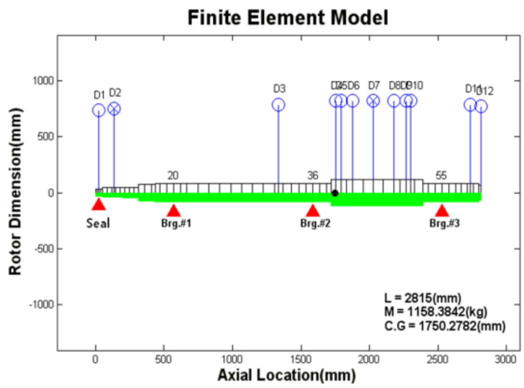

Fig. 2. FE rotordynamic analysis model(wet-run condition)

2.2 Annular seal modeling

The linearized stiffness and damping coefficients for the annular seal's data are presented in Table 1. Calculated stiffness and damping are shown in Table 2. Dynamic coefficients were calculated using the Black[4]'s model. In the analysis, working fluid is hot water(150℃) where the density is 918kg/m^3 and viscosity is 0.186cP.

Table 1: Data of seal

Lt.	△P(MPa)	L(mm)	D(mm)	C(mm)
Imp.	8	20	385	0.3

※Lt.:location, △P:Pressure difference, L:length, D:diameter, C:radial clearance

Table 2: Dynamic coefficients of seal at rated speed

Lt.	K(N/m)	k(N/m)	C(N.s/m)	c(N.s/m)
Imp.	3.307e7	2.974e6	3.322e4	3.637e1

※K=Kxx=Kyy, k=Kxy=-Kyx, C=Cxx=Cyy, C=Cxy=-Cyx

2.3 Bearing modeling

In this study, 4-axial groove bearings were used. Bearing loads were calculated by static analysis. Depending on the speed of rotation, the linearized stiffness and damping coefficients were extracted. The average temperature of water is 150℃ for the bearing analysis, and the specification is shown in Table 3.

Table 3: Specification of the bearing

Design Parameters	**Applied values**		
Lubricant	150℃, Water		
Axial Length, L	200mm		
Diameter, D	160mm		
Radial clearance, Cb	60 ㎛		
Load	Brg.#1	Brg.#2	Brg.#3
	2402.1N	4383.5N	4573.6N

3. Rotordynamics Analysis

3.1 Critical map

The critical speed map of 1, 2, 3 order forward whirl is shown in Figure 3(without seal effect). Results of critical speed analysis are estimated to be approximately 3,045rpm of the 1^{st} order and 3,757rpm of the 2^{nd} order. It is predicted that enough separation margin exists between rated speed and critical speed.

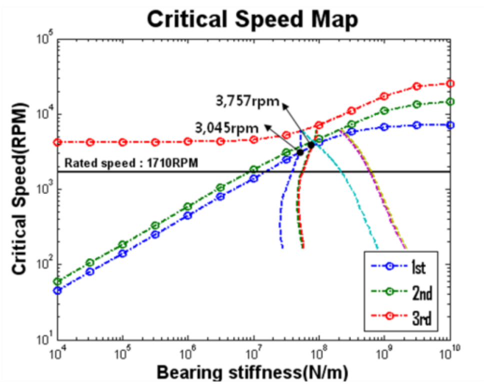

Fig. 3. Critical speed map of RCP rotor system (dry - run condition)

3.2 Campbell diagram

Considering the seal effect, the critical speed of rotor-bearing system has a tendency to increase due to effect of similar bearing. Evaluating result of analysis that rotational speeds up to 6,000rpm, does not cross 1X and eigenfrequencies(Figure 4). This means that the forward whirling frequency is not excited by the unbalance force. In other words, it is safe about rotational frequency(1X).

3.3 Unbalance response

Unbalance response of the rotor-bearing system is calculated with a total of G2.5 unbalance. The bearing housing vibration limit(63.5 ㎛, Pk.-Pk.) is applied to the specification stands. At the rated speed, the maximum displacement has occurred at the end of impeller. Its value is predicted to 5.2 ㎛ (Pk.-Pk.) to meet the criteria(Figure 5).

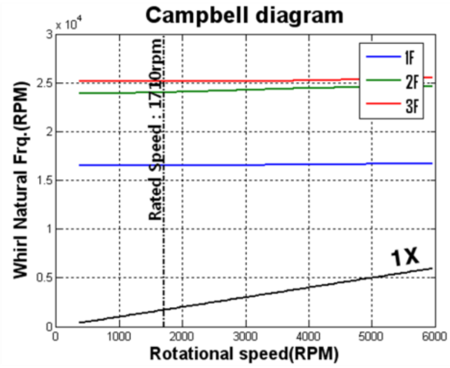

Fig. 4. Campbell diagram of RCP rotor system (wet - run condition)

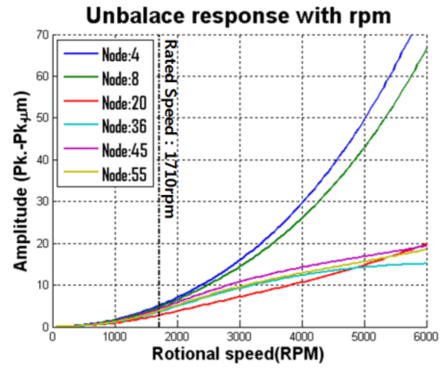

Fig. 5. Unbalance response of RCP rotor system (wet - run condition)

4. Conclusions

This study was performed to SMART RCP rotordyanmic analysis. A rotordynamic analysis includes the critical map, Campbell diagram, and unbalance response. As a result, this system has sufficient separation margin between the rated speed and the critical speed regardless of the seal effect. When considering the seal effect, the critical speed does not exist within twice the rated speed. And unbalance response analysis results, vibration level was stable at the rated speed.

REFERENCES

[1] Kwon, Park and Yu, Prediction of Hydraulic Performance of Scaled-Down Model of SMART Coolant Pump, Transactions of the Korean Society of mechanical engineers, Vol. 34, No. 8, p.1059-1065, 2010.
[2]Kim, Lee, Lee and Kim, Rotodynamics Analysis procedure of Rotating Machinery for the Reliability, Journal of fluid machinery Vol.10, No.5, pp.64-73, 2007.
[3]Park, Park and Kim, Unbalance response and stability analyses of the rotor of SMART Main Coolant Pump, Korea Nuclear Society, Transactions of the Korean Nuclear Society Autumn Meeting, 2001.
[4]Black, H.F., and Jenssen, D.N., Dynamic Hybrid Bearing Characteristics of Annular Controlled Leakage Seals", Proc. International Mechanical Engineers, Vol. 184, pp. 92-100, 1970.