Study of Heat Transfer by Internal Flow in Lubrication Film of Non-contact Mechanical Seals

Yuki Sato[1)*] and Masayuki Ochiai[2)]

[1)] Graduate School of Engineering, Tokai University, Japan
[2)] Department of Mechanical Engineering, Tokai University, Japan.
*Corresponding author: y-sato@fuji.tokai-u.jp

Non-contact mechanical seals are used to prevent fluid leaking in turbomachineries. On the sealing face of these, the fluid lubrication film, which is thin about a few micrometers, is formed by surface textures. Therefore, these seals have some advantages, but there is the risk of the damage by thermal deformation or thermal stress. The previous studies are discussed that the internal flow affects the distribution of the film temperature. However, the flow has not been observed. In this study, temperature distribution measurements and flow visualizations showed that the temperature is basically higher in the downstream of the flow.

Keywords: mechanical seal, fluid lubrication, temperature distribution, flow visualization

1. Introduction

Non-contact mechanical seals are the seal element used in turbomachineries. Because the thin lubrication film is formed to prevent abrasion, these seals are possible to use under high-speed and high-pressure conditions. However, there is the risk of the damage by heats, as the thin film is vulnerable to these. Therefore, thermal behavior was investigated, and in the papers, it is considered that the internal flow affects temperature distribution [1]. But the flow has not been observed. In this study, the experimental equipment capable of visualizing is designed, and experiment results is reported.

2. Methods

In this study. an experimental equipment is designed to be enable the temperature measurement and the flow visualization. And, three types of test seals of plain seal, Rayleigh step, and Spiral groove, are used.

2.1. Temperature distribution measurement

The film temperature at each measuring point is measured by thermocouples set on the test seals. Turbine oil VG32 are used as sealed fluid and outer of sealing face is pressurized to 20 kPa. Then, the temperature is measured when the rotation speeds is 2,000 and 2,500 rpm for 20 minutes from the start of operation.

2.2. Flow Visualization

After mixing red florescent particles with the oil, starting the equipment operation. The excited emission in the film by a green sheet laser is captured by a high-speed camera. The experimental conditions are the same as the temperature distribution measurement.

2.3. Results

Figure 1 shows the temperature distribution on the spiral groove. The data mean the temperature rise after 20 minutes from start of operation. At 2,000 rpm, the temperature rises of the inner side, S_1 and S_2, are less than that of the outer side, S_3 and S_4. In addition, at 2,500 rpm, the temperature rise at all the measurement points is greater than at 2,000 rpm. In terms on temperature difference between each measuring points, the temperature rise is the same at all three points except S_1.

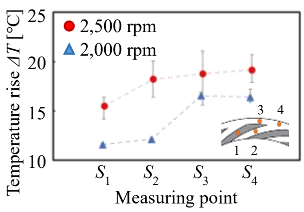


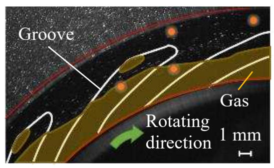
Figure 1: Temperature distribution

Figure 2 shows flow visualization results. Figure 2 (a) is a taken image at 2,000 rpm. Figure 2 (b) show the results of Particle Image Velocimetry (PIV) analysis at 2,500 rpm. And Figure 2 (c) indicates the flow caused by pressure gradient at 2,500 rpm. It is calculated from the difference between the theoretical shear flow and the result of the PIV analysis.

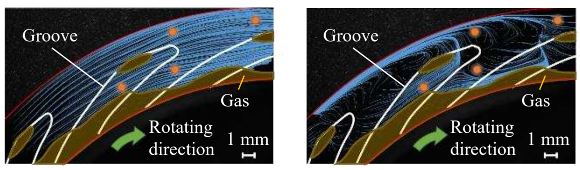
3. Discussion

At 2,000 rpm, it is confirmed that gas phase formed in the middle of the film in Figure 2 (a). So, S_1 and S_2, which have little temperature rise, are the temperatures of the gas phase. The presence of both the gas and liquid phases may cause a temperature difference.

The temperature distribution in the spiral groove at 2500 rpm was most uniform, including the other test seals. Figure 2 (b) and (c) show that circumferential shear flow is dominant in the film, while the oil flows along with the groove and gas phase, and then spreads radially at the tip of the groove by the pressure gradient. So, the mixing of hot and cold oil in the film is thought to have resulted in a uniform temperature distribution.



(a) Flow visualization at 2,000rpm



(b) Streamline at 2,500rpm

(c) Flow by pressure gradient at 2,500rpm

Figure 2: Flow visualization

4. References

[1] S. Blasiak et al., "A Numerical Analysis of the Grooved Surface Effects on the Thermal Behavior of a Non-Contacting Face Seal," Procedia Eng., 39, 2012, 315-326.