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Frictional and Electrical Characteristics of Herringbone Grooved Bearing for Scanner motor

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Abstract : Recently, laser printers have been developed to have high-speed laser scanner with hydrodynamic bearings. Among the bearings, herringbone grooved bearing (HGB) produces hydrodynamic pressure by high-speed rotating and so make the surfaces between the shaft and sleeve separated. Accordingly, the bearings with non-contact rotation are suitable to high-speed rotating and have long bearing life and reliability. HGB is a kind of journal bearing and uses oil for a lubricant. HGB has excellent stiffness and load carrying capacity. Also, HGB is leakage-free due to groove pumping action. Consequently, HGB is valuable to be applied to high-performance devices such as hard disk drive, copier, and so on.

Key words : Herringbone grooved bearing (HGB), scanner motor, contact voltage, seizure, cavitation

Introduction

The bearings used in machinery equipped with high-speed rotating parts, such as laser printers and hard disk drives, require to have high-accuracy, high-performance, and a relatively clean environment. Especially, the bearings for laser printers have been increasingly required to have higher-speed and lower-cost. To satisfy these requirements, hydrodynamic bearings have been developed such as grooved bearing. The grooved bearing is suitable for scanner motor due to high stiffness and leakage-free [1-2]. In this paper, the herringbone-grooved bearings were studied experimentally, the friction force and the contact voltage were measured in room and high temperature and the wear tests were also conducted.

Experiments

Herringbone grooved bearing

The herringbone-grooved bearing used in high-speed scanner motor is a sort of journal bearing with grooves on the surfaces of either the shaft or sleeve to produce the hydrodynamic pressure. As the shaft rotates, the bearing can support radial loads with the oil pressure produced from the pumping action of the groove. Also, the bearing can be designed as a leakage-free mechanical element due to the grooves pumping action. Table 1 appears the geometry of the bearing.

Measurement of frictional forces and contact voltages of the bearings

In order to measure the frictional forces of the bearings, the journal-bearing tester shown in Fig. 2 was used. The tester had an air spindle with a controller, which could rotate up to 50,000 rpm. There was a kind of the tachometer inside, which can measure rpm up to 100,000 revolutions. At each different test with varying loads and speeds the frictional forces were measured using a load cell and an indicator with a data acquisition system. The experimental range of the normal load was 0.05 N 2.5 N and that of rotating speed was 1,000 rpm~ 35,000 rpm. To verify the floating characteristics of the bearings, the electrical contact voltages between the bearing and the shaft were measured [3]. The output voltage of 3 V with non-contact and 0 V of contact were obtained by

Table 1. Bearing geometry

Bearing parameter	Herring-grooved bearing
Number of groove	12
Radial clearance	5 μm, 7 μm
Groove depth	6 μm (a)
Groove/ridge ratio	1 : 1 (b : c)
Groove angle	25°
Shaft diameter	3 mm
Oil viscosity	8cSt, 12cSt

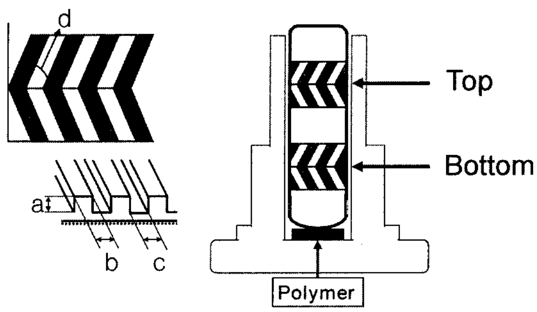

Fig. 1. Geometry of HGB.

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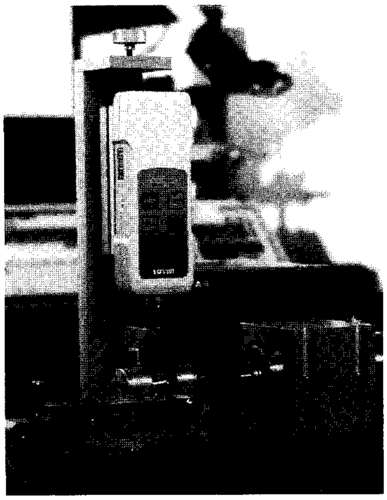


Fig. 2. Configuration of bearing tester.

supplying DC 6V between the shaft and the bearing, and recorded them on the recorder in a computer.

Measurement of temperature variation of the bearing

The bearing is used at a temperature more than 60°C in an airtight box. The bearing has to have efficient load carrying capacity and high stiffness in such environment. [4] In this experiment the bearing was preserved at 60°C and when the surface temperature of the bearing reached 40°C, the friction and contact voltage was measured. Because the bearing is composed of copper over 90%, the thermal conductivity of the bearing is very high and the inside of the bearing is about the same temperature as the surface of the bearing with due regard to the size of the bearing. Practically, the temperatures of the bearing in somewhere were almost same and appeared 1~3°C difference. The thermocouples for the measurement of the temperature were used with one for the room temperature and the others for the surface of the bearing. The test environment is closed using the transparent sealed box.

Measurement of wear volume of the bearing

The material and geometry of the bearing for wear test appear in Table 2. To wear the bearing, the contact between the shaft and the sleeve must occur. For the contact, the radial load was imposed on the bearing with the top position, as shown in Fig. 1 The critical value of the load had been determined to 3 N by the preliminary examination. At the load, the wear test was

Table 2. Bearing geometry for wear tests

Bearing Number	Material	Clearance	Groove depth
#1	Phosphor Bronze	7 μm	6 μm
#2	Brass	7 μm	6 μm
#3	Brass	7 μm	3 μm
#4	Brass	7 μm	3 μm

Table 3. Temperature variation of the bearing surface at room temperature (RT)

Room Temperature	Temperature	
	5 μm	7 μm
8cSt	29~51°C (+22)	29~47°C (+18)
12cSt	29~53°C (+24)	29~49°C (+20)

Table 4. Temperature variation of the bearing surface at high temperature (HT)

High Temperature	Temperature	
	5 μm	7 μm
8cSt	40~69°C (+29)	40~68°C (+28)
12cSt	40~70°C (+30)	40~69°C (+29)

Table 5. Friction forces due to load variation at 28,000 rpm

Radial Clearance	Friction force, N			
	5 μm		7 μm	
Viscosity	RT1	HT2	RT3	HT4
8cSt	0.165	0.083	0.107	0.04
	0.178	0.083	0.125	0.058
	0.197	0.1	0.146	0.078
	0.209	0.107	0.166	0.088
12cSt	0.181	0.078	0.146	0.066
	0.199	0.079	0.147	0.072
	0.199	0.117	0.152	0.073
	0.207	0.154	0.165	0.096

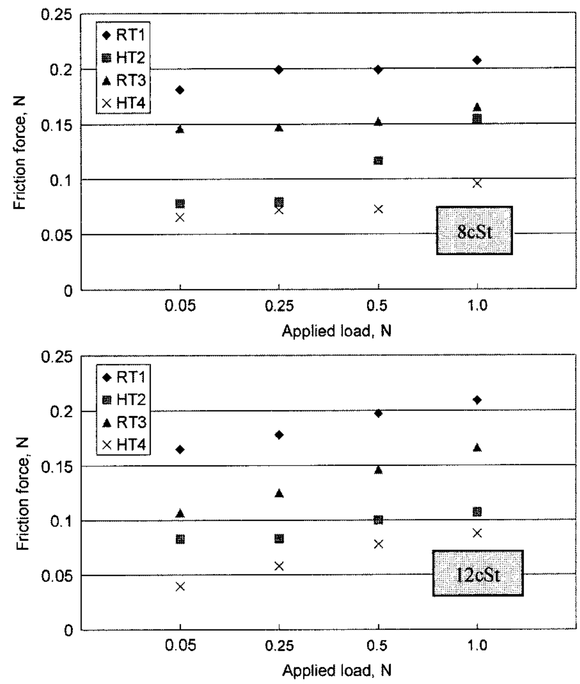
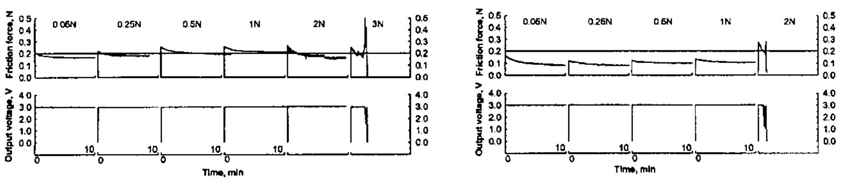
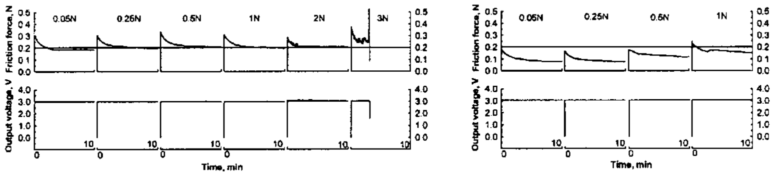


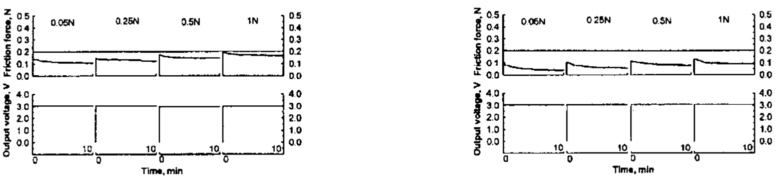
Fig. 3. Friction forces at various conditions.



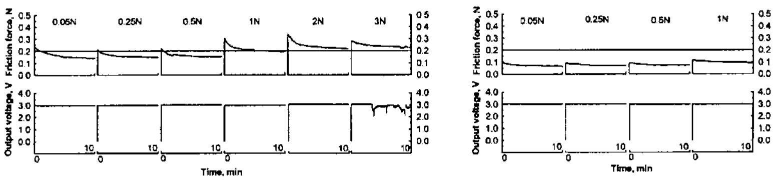
(a) Radial clearance 5㎛, Viscosity 8cSt



(b) Radial clearance 5㎛, Viscosity 12cSt

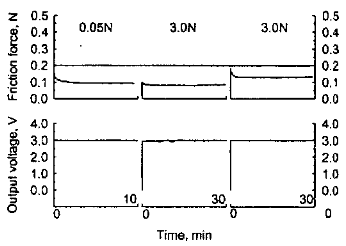


(c) Radial clearance 7㎛, Viscosity 8cSt

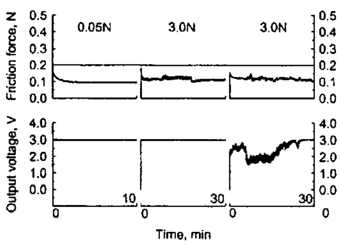


(d) Radial clearance 7㎛, Viscosity 12cSt

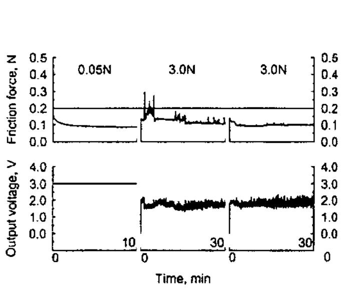
Fig. 4. Friction forces and output voltage of electric contacts due to load variation at 28,000 rpm (left: room temperature, right: high temperature).



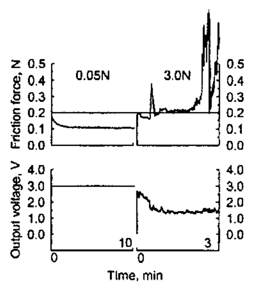
#1 bearing (35,000rpm, 8cSt)



#2 bearing (35,000rpm, 8cSt)



#3 bearing (35,000rpm, 8cSt)



#4 bearing (35,000rpm, 12cSt)

Fig. 5. Friction forces and output voltage of electric contacts due to load variation at 3 N.

conducted for 1hour. Roundness tester that can appear the profile of circle measured the wear volume before and after the test instead of measuring the wear weight because the quantity was too little.

Results

Temperature variation tests

Table 3 shows the temperature variation of the bearing surface

Table 6. Wear quantity of the bearing

Bearing Number	Wear (10^{-7}g)	
	Top	Bottom
#1	3.4	2.6
#2	8.5	7.6
#3	16.3	9.1
#4	8.2	4.4

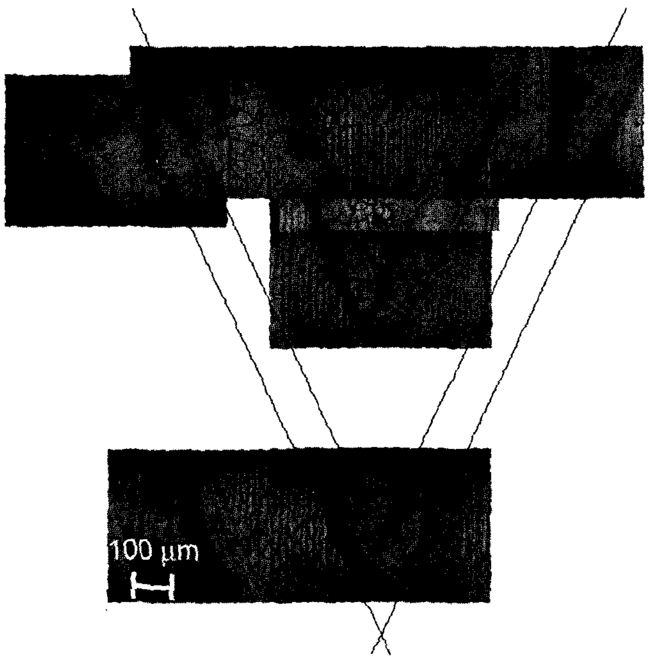


Fig. 6. Cavitation of the bearing surface.

at room temperature, 28,000 rpm for 10 min. The temperature reaches steady state in 4 min. As the clearance of the bearing decreases and the viscosity of the lubricant increases, the temperature increases much more. Table 4 shows the temperature variation of the bearing surface at high temperature. The variation was little and the trends of the variation were the same at room and high temperature. The maximum temperature of the bearing arrived at 70°C. Therefore the temperature of the lubricant comes to the same value. Considering above tests, the friction force at high temperature decreased remarkably comparing with that at room temperature as shown Table 5. This is caused by the decrease of the viscosity of the lubricant due to the increase of the temperature. Fig. 3 compares the friction forces of the bearing at room temperature with that at high temperature. Fig. 4 (left) shows the friction force and contact voltage of the bearing due to load variation at room temperature 29 and 28,000 rpm. Fig. 4 (right) except at high temperature 60 shows in like manner. The friction forces and contact voltages were very stable until the load of 1N and the bearing shows better characteristics at room temperature.

Wear tests

Table 6 shows the wear weight of the bearing computed by multiplying the wear volume by the density. Fig. 5 shows the friction force and output voltage of electric contacts of fluid bearing due to load variation at the load of 3N. The bearings #1 and #2 with stable contact voltage had small wear weight relatively. Because the load was imposed on the top of the bearing, the wear weights of the top and the bottom appeared differently. The contact voltage of the bearings #3 and #4 varied distinctly below 3V by not generating sufficient hydrodynamic pressure due to relatively shallow groove depth. Especially, The #4 bearing with 12 cSt appeared severely high friction force and instability of the contact voltage resulting in the seizure as shown Fig. 5 (d). Fig. 6 shows the cavitation of bearing surface due to pressure fluctuation. Because the position of the load is the top of the bearing, the bearing is tilted and shows cavitation only on the left of the herringbone.

Conclusions

(1) The bearings have sufficient stiffness and load carrying capacity at high temperature.
(2) The friction force between the sleeve and shaft was reduced to a half because of the decrease of the viscosity due to the increase of the temperature.
(3) The bearing has wear resistance characteristics with the order of minus 7.

References

1. Kinouchi, K. and Tanaka, K., 1990, Performance Characteristics of Herringbone-grooved Journal Bearings Using a Finite Element Method, *Proc. Japan International Tribology Conference*, Nagoya, Japan, pp. 935-940
2. Bootsma, J. and Tielemans, L. P. M., 1977, Conditions of Leakage-free Operation of Herringbone-grooved Journal Bearings, *Journal of Lubrication Technology*, Vol. 99, pp.215-223.
3. Tanaka, K. and Muraki, H., 1991, Performance of Air-lubricated Hydrodynamic Bearing Spindles for Laser Scanners, *Journal of Tribology*, Vol. 113, pp. 609-614.
4. Kucinschi, B., Fillon, M., 1999, An Experimental Study of Transient Thermal Effects in a Plain Journal Bearing, *Journal of Tribology*, Vol. 121, pp. 327-332.