An Improvement on Traction Measurement System

Yan MA, Bing SU and Yue-yang LIU

School of Mechatronics Engineering, Henan University of Science and Technology, Luoyang, 471003, China

Keywords: Elastohydrodynamic lubrication, Traction, Sensor bracket.

Abstract. In our previous traction measurement system of the ball-disc Elastohydrodynamic Lubrication (EHL) test, the transfer of friction force during measurement was complicated and there existed some error, in the meanwhile the system can only test the single direction friction torque. In order to solve these problem, a new sensor component was specially designed and configured with a new-style sensor, then the more accurate measurement results were obtained.

Introduction

Bearing is one of the most widely used components in the equipment manufacturing industry. Its working principle is simple, but the mechanism of the friction and wear of bearing is very complex. Lubrication is an effective way to reduce friction and wear. Therefore, many scholars have studied the antifriction properties of the lubricant under complex conditions[1-3]. In order to study the point-contact elastohydrodynamic lubrication, Henan University of Science and Technology developed a ball-disc test rig(the details about the test rig and the method to measure the traction coefficients can be referred to the literature[4]). The elastohydrodynamic friction characteristics of many domestic high-speed lubricants were tested on this test rig, and some research results in this field were obtained [5-6]. However, the transfer process of friction force in the previous traction measurement system was very complicated, and it would generate some error, which would affect the accuracy of the measurement. In the meanwhile it can only test the torque of single direction, so it limits the simulation some conditions of the experiment. Furthermore, because the sensor can only bear the pressure amplified by rigid lever structure in previous component, its service life will be shortened.

In view of these problems, the traction force measurement system was improved to obtain more accurate measurement results and promote the service life of the sensor.

The diagram of the test rig as figure 1.

Figure 1. Diagram of EHL traction test rig.
1-electric spindle I ;2-disc specimen; 3-ball specimen; 4-electric spindle II; 5-friction force sensor; 6-hydrostatic spindle; 7-hydrostatic bearing ; 8-load sensor
Organization of the Text

The Introduction of the Previous Friction Testing System

The previous friction force measuring system used in the test rig adopts a quartz resonant sensor and a rigid sensor component with a frictionless hinge as shown in figure 2. The sensor bracket is mainly divided into a part of force-transferring lever and a positioning part of the sensor, these two parts are connected by a frictionless hinge. When testing, the force process of the sensor is as follows: the torque of electric spindle II constrict the pole(indicia 3 in figure 2), then the force in the pole is transferred to the sensor through rigid lever(indicia 4 in figure 2). In the system, the rigid lever and the sensor clamp holds the steel ball.

![Figure 2. Previous friction measurement system: 1-electric spindle II bracket; 2-hydrostatic bearing base; 3-pole for transmitting traction force; 4-rigid lever; 5-resonant sensor; 6-signal extraction line; 7-frictionless hinge.](image)

Improved Friction Force Measurement System

The sensor used in the new friction force measurement system is made by Kistler Instrumente AG, the model number is 9323A, as shown in figure 3.

![Figure 3. Schematic of 9323A sensor.](image)

The sensor 9323A is based on the principle of piezoelectric measurement, its sensitive element is made of quartz material. Quartz material will produce charge on its surface when it is forced, and then the charge output by the amplifier, the quantity of electricity treated is linearly related with the force of the sensor. The structure of 9323A type piezoelectric sensor is handy and easy to install. The sensor has the advantages of high sensitivity, broad frequency base band and anti-interference. Its main performance indicators are as follows:
Table 1. 9323A sensor.

<table>
<thead>
<tr>
<th>Main Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0[N]~1000[N]</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>[PC/N], -3.9</td>
</tr>
<tr>
<td>Linearity</td>
<td>≤±0.5%</td>
</tr>
<tr>
<td>Lag Error</td>
<td>0.5%</td>
</tr>
<tr>
<td>Maximum Torque</td>
<td>5[N·m]</td>
</tr>
<tr>
<td>Maximum Shearing Force (F=0)</td>
<td>0.62[KN]</td>
</tr>
<tr>
<td>Natural Frequency</td>
<td>&gt;72[kHz]</td>
</tr>
<tr>
<td>Rated Temperature</td>
<td>-40[°C] to +120[°C]</td>
</tr>
</tbody>
</table>

In order to realize the test of the friction measurement system from negative slide-roll ratio to positive slide-roll ratio (in this process, the sensor is affected by pressure firstly and then affected by pulling force), a new sensor component was specially designed and manufactured, as figure 4.

Figure 4. New friction force measurement system: 1-strong magnet base; 2-strong magnet; 3-the ball head screw; 4-9323A sensor; 5-linear bearing guide; 6-linear bearing cover; 7-connecting seat I; 8-straight line bearing cover bracket I; 9-linear bearing guide rail bracket II; 10-connecting seat II; 11-hydrostatic spindle base; 12-electric spindle II bracket.

The sensor component consists of linear bearing gland bracket I and linear bearing guide rail bracket II, the surface of the bracket have phosphating treatment to ensure greater stiffness. The specific implementation methods of the system are as follows. The base with the strong magnet is fixed on the bracket I by bolts, the linear bearing guide rail is fixed on the bracket II by bolts. The flange at one end of the sensor is fixed with the connecting seat I by bolts, the flange at the other end is fixed with the connecting seat II by bolts, then take the sensor together with connecting seat I and connecting seat II fixed on the linear bearing cover by bolts. Finally, the ball head screw is arranged on the connecting seat II, and adjusting its elongation at the same time to ensure that the rotation axis of the two electric spindle is in the same plane after the ball head and the strong magnet stick tightly, to avoid sideslip (The strong magnet and electric spindle II bracket swing surround hydrostatic spindle axis lightly). Locking the ball head screw and connecting seat II by the nut after the adjustment is completed. Such structure not only can determine the indirect connection of the sensor and the electric spindle II bracket but also reduce the deviation of the friction measuring system in the installation process.

In the experiment, when the hydraulic station was opened, the sensor will rise together with the electric spindle II because of the supporting function of the bracket I. Under the condition of negative slide-roll ratio, electric spindle II will do counterclockwise deflection around the axis of hydrostatic spindle. Meanwhile the ball head screw will press the friction sensor, the data acquisition system will measure the friction value of the negative slide-roll ratio in real time. With the increase of the slide-roll ratio in the negative range(realized by adjusting the speed of the ball disk drive motor), the
pressure on the sensor will be reduced. After the slide-roll ratio increases to a critical value (near zero slide-roll ratio), electric spindle II will do clockwise deflection around the axis of hydrostatic spindle. At this moment, the ball head screw will stretching the friction force sensor under the impact of magnet absorption. With the constantly increasing of the slide-roll ratio in the positive range, the pulling force on the sensor is also gradually increased, the data acquisition system can measure the value of the friction under the condition of positive slide-roll ratio in real time. The friction sensor will come down together with the electric spindle II after the hydraulic station is close. When the test ended, take the sensor with the ball head screw and linear bearing cover together and rotate 450 around linear bearing guide rail, separate the sensor from strong magnet by the limiting bolt.

**Summary**

Traction measurement system was improved to obtain more accurate measurement data. With the cooperation of Schaeffler Company, the new measuring device was used and obtained good results[7]. Figure 5 shows three curves of EHL test which used the same lubricating oil and under the condition of U=20m/s, T=60°C, W=69N. There into, U is entrainment velocity, T is test temperature, W is nominal load. The curve 2 shows the experimental data obtained from the test system with improvement, while the curve 3 shows the data in the same condition but without improvement. Compared with the reference data shown in the cuvre 1, the data of curve 2 are obviously more close to them.

![Figure 5. Comparison of experimental data](image)

**References**


