Study on Lubrication and Friction Performance of Grease Lubricated Sliding Bearings

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Abstract. In order to study the friction performance of grease lubricated sliding bearings of construction machinery under long-term radial heavy load, a bearing testing machine was developed to measure the changes of friction force, friction coefficient and temperature rise of such bearings. The testing machine can not only simulate the operation process of bearings under low speed and heavy load conditions, but also evaluate the operation state of grease during grease lubrication. Through durability tests on bearings designed and produced by three different manufacturers, the friction coefficient between bearings and pin shafts can be accurately obtained, the current lubrication and wear conditions of bearings can be detected, the advantages and disadvantages of bearing performance can be judged, and at the same time, reference can be provided for designers to estimate bearing life and optimize design.

1. Introduction
In recent years, with the application and development of tribology in the fields of industry and science and technology, more and more attention has been paid to the research on the friction characteristics of various sliding bearings in key industries, and the development of corresponding experimental equipment has also received the attention of friction scholars in various countries. In 1981, p k Gupta [1] and others simplified the experimental data into a simple rheological model by studying MIL-L-23699, MIL-L-7808 and other specifications, and calculated appropriate coefficients for application in computer programs. DOWSON D [2] and others published elastic hydrodynamic lubrication in 1982. Wikstrom v [3] and others conducted experimental research on the friction torque of roller bearings by examining different temperatures, loads, base oil viscosity, etc. However, due to the complex factors affecting the friction torque of bearings, it is not only related to the material composition and lubricating medium of the two contact surfaces, but also has many relationships with the working state and working environment of the friction pair, so far there is no precise theoretical calculation formula to accurately calculate it.

The research object of this paper is grease lubricated sliding bearings commonly used in construction machinery. This kind of bearings work under radial heavy load for a long time, and the working load is large. It is impossible to use rolling bearings with friction coefficient 1~2 orders of magnitude smaller than sliding bearings to carry out radial loading to solve the interference problem
when friction torque is collected. Secondly, the action relationship between these bearings and pin shafts is more the swing motion form of pin shaft fixed bearings, which brings difficulties to the collection of friction force. Moreover, the swing frequency of such bearings is generally low (≤0.5Hz) when working. In addition, due to space and structure limitations, grease is usually used for lubrication, and the damage caused by friction and wear is more common and serious.

In order to study the friction and wear performance of this type of sliding bearing, aiming at the above problems, the author developed a bearing testing machine which can simulate the whole process of friction and wear of this type of bearing to the greatest extent, and can measure various performance parameters such as load force, working temperature, friction coefficient and wear amount during the bearing wear test.

2. Structure of Testing Machine

Figure 1 is a schematic diagram of grease lubricated sliding bearing test, and figure 2 is a layout diagram of the main machine of the testing machine. The radial loading system uses an electric servo control system to provide load force for the test and is fixed at the bottom of the frame. The swing system uses a crank swing rod mechanism to output reciprocating swing. The fixture system fixes the test bearing (as shown in figure 3) on the test system according to the test requirements. The basic specifications of the test bearing are: inner diameter 60mm, outer diameter 75mm, width 60 mm. The measurement and control system are based on PLC and cooperates with a special control and detection system to complete data acquisition and control of the testing machine, and displays and stores the data at the same time. The testing machine is equipped with load sensors, torque sensors, displacement sensors, angle sensors and temperature sensors to detect the load, friction coefficient, wear amount, swing angle and test temperature during the experiment.

The testing machine can realize a radial constant load of 0-300 kN, and the loading period and loading amount can be adjusted by the upper computer detection software; The output swing angle is 45; Swing frequency ≤0.5Hz and adjustable. The measurement functions that can be realized mainly include: the radial force loading is realized through an electric servo loading system, and the loading is designed into two control modes of manual mode and automatic mode. The manual mode can
manually adjust the pressure head position according to the user's needs, which is convenient for disassembling and assembling the test piece. In the automatic mode, the user only needs to set the load, and the system automatically loads to the set value to maintain the set load. The swing system drives the rocker to swing through the connecting rod, the swing angle of the swing rod is 90 degrees, and the swing frequency of the swing rod is the same as the rotation frequency of the motor. The fixture system is fixed on the worktable by screws, and a spherical pair is arranged between the spherical fixture and the loading plate and has two degrees of freedom, so that the loading force can follow the axis of the loading system. The thermal resistance installed axially on the outer sleeve of the test bearing measures the temperature change in the working process of the bearing. An eddy current displacement sensor fixed below the test bearing measures the displacement of the test bearing in the vertical direction to calculate the wear amount of the test bearing; In addition, the friction moment and friction coefficient between the bearing and the pin shaft are measured by other means. These signals are displayed in real time and plotted on the upper computer testing and monitoring software. At the same time, an upper limit alarm value is set for each test parameter according to the design requirements. When one or more of the parameters exceeds the alarm value, the computer controls automatic shutdown and the data is automatically saved in the database. After the cause of the problem is found and solved, the new test can be restarted.

3. Test conditions and test methods
The bearing with an inner diameter of 60mm shown in figure 3 is selected for testing, and the pin shaft matched with the bearing has a diameter of 60mm and a length of 750 mm. Run for 10min at no load, and confirm whether the testing machine runs normally; Set the test force during the loading and grinding period, start the swing system (5r/min, swing angle 45), run for 50h, and inject grease automatically every 8 hours. Load the test force to the requirements of test conditions and start the test. The experimental test data are displayed in real time [4-5] and the test time, loading force, friction coefficient, friction force, bearing outer ring temperature and other data in the test process are recorded. When abnormal noise occurs or exceeds the set limit, the system will automatically stop. After completing the test, unload the test force and disassemble the test bearing.

The test process is carried out according to the following steps: 1 Detect the installation position of the temperature sensor probe and confirm that it can contact the bearing surface; 2 Before the start of the experiment, run the testing machine with no load to ensure normal operation; 3 Turn on the testing software of the bearing testing machine, set the system parameters, select the “automatic” working mode, load the testing force and apply swing at the same time; 4 After the test, save the test data in the upper computer monitoring system; 5 Analyze the data offline, and judge the service state of the bearing through the change of data trend.

4. Experimental treatment
Wear tests were carried out on three kinds of bearings with 60mm inner diameter from different manufacturers on a testing machine. Test conditions: constant radial loading force 80MPa, swing frequency 5r/min, swing angle 45. After the test starts, grease the loaded bearing and the support bearing regularly. The test bearing is greased only once before the test starts and every 8 hours during the process. The test starts AM 9:30 am on February 20, 2018 and ends at 18:30 pm on October 21, 2018. During the test, real-time detection is carried out on the performance parameters such as friction coefficient, wear amount, temperature rise, etc. See Table 1 for the variation curves of friction coefficient and bearing temperature during the test of each bearing.
Table 1. Variation Trend Diagram of Friction Coefficient and Temperature of Bearings from Three Manufacturers

| Sample | Friction coefficient | Bearing temperature | Bearing |
|--------|----------------------|----------------------|---------|
| 1#     | ![Graph](image1.png) | ![Graph](image2.png) | ![Image](image3.png) |
| 2#     | ![Graph](image4.png) | ![Graph](image5.png) | ![Image](image6.png) |
| 3#     | ![Graph](image7.png) | ![Graph](image8.png) | ![Image](image9.png) |

From the test results, it can be seen that the endurance time of 1# bearing and 2# bearing is 50h and 51h respectively, i.e. the friction coefficient is too high to stop shortly after loading 80MPa. The friction coefficient of 2# bearing suddenly changes within 15h, and its performance is the worst. The endurance time of 3# bearing reaches the upper limit of 300h, the friction coefficient remains stable during the test, and it can still be used continuously. After observing the appearance of the bearing, its friction surface is smooth and its wear resistance is obviously better than that of 1# and 2# bearings.

From the bearing temperature, it can be seen that the temperature of 1# and 3# bearings changes smoothly during the test, and the temperature rise of 2# bearings fluctuates greatly, which also reflects that the performance of 2# bearings is worse than that of 1# and 3# bearings. 3# bearing has the best performance among the 3 kinds of bearings, and is recommended to be used or used as a reference for independent design.

Bench test by sliding bearing tester can not only evaluate the difference of bearing durability, but also study the performance of its grease injection cycle. However, the existing design can only meet the needs of the laboratory, and cannot more truly reflect the actual operating conditions of the equipment. The next step is to design a more real and visual reflection of the operating conditions of the equipment, such as heightening the low temperature, water drenching device, silt mixing device, etc. on the testing machine to inspect the service life of bearings and grease.

5. Conclusion

1) A testing machine has been developed to measure the friction and lubrication characteristics of grease lubricated sliding bearings, and various operating parameters and wear performance parameters of the bearings in the test can be accurately tested by the developed upper computer software.
2) By observing the change trend of friction coefficient curve obtained from monitoring test, the wear and lubrication condition of bearings can be monitored in real time, which plays an important role in engineering application.
3) Provide technical support for bearing selection and bearing design by testing the performance of bearings designed and produced by different manufacturers.

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