Bearing roller smearing testing machine and its simulation analysis

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Abstract. Rolling bearings are the most common rotating mechanical parts in actual work, with the rapid development of industrial technology, the performance requirements of rolling bearings in actual work are getting widely used, but under the actual working conditions, some large bearings with low speed and heavy load are easy to be smeared and lead to the extension of bearing life. In order to study the effect of early surface smearing on the fatigue life of rolling bearings, a self-designed bearing roller early smearing tester was designed, the test machine can simulate the movement process of roller in the bearing and make different degree of smearing on the surface of roller. According to the function, the smearing testing machine is divided into four parts: driving system, loading system, signal acquisition system and test system. The smearing testing machine can set the test conditions according to relevant theories to fabricate different degree of early smearing on the bearing roller surface, the transient dynamics simulation can simulate the smearing test of the testing machine, by comparing the results of the simulation analysis with the actual experimental circumstances, the stability and reliability of the testing machine can be proved, and it can also be testified that the test results of the testing machine are researchable.

1. Introduction

Early bearing smearing may cause secondary fatigue failure, which seriously affects the service life and operation performance of the bearing, due to the complexity of rolling element movement and the randomness of instantaneous contact, the occurrence of smearing is inevitable, the early surface smearing of large roller bearings will shorten the life of the bearings. The early surface scratches of large roller bearings will shorten the life of the bearing. It is necessary to stop the machine and replace the new bearing, which will cause a lot of economic losses.

As for the research on the smearing, in the early stage of the world, the research mainly focused on the mechanism and dynamics of the smearing. On the basis of the Elastohydrodynamic lubrication theory, Harris of SKF proposed an analysis method to predict the slip of high-speed cylindrical roller bearing to verify the occurrence of the smearing[1]. Domestic research on smearing is mainly focused on smearing experiments and dynamic simulation research, in the early stage, for example, Professor Zheng Linqing of Tsinghua University[2] and Professor Zhan Mingxue of 606 Institute[3] made pioneering work in the aspects of smearing dynamics analysis, lubrication calculation and experimental test respectively. Smearing is an early failure form of bearings, in large-scale roller bearings, compared with other bearing failures, there is less research on smearing. To study the early smearing on fatigue life of rolling bearings, scraped from the Angle of the smearing, designed bearing roller early smearing testing machine, the
machine can simulate the movement process of roller in the bearing, make different degree of smearing in the surface of roller, the contact fatigue life test of the tested roller is carried out to explore the influence mechanism of the smearing on the fatigue life of the bearing.

2. Design of testing machine

The smearing of rolling bearing is affected by many factors. While the theoretical research is carried out, the experimental research is also the focus of the research on the smearing. In Figure 1, the bearing is divided into different speed zones, the rollers will pass through different zones during rotation, the research shows that the speed of roller will change in different regions during the process of rotation, as shown in Figure 2[4-5]. When the roller is in the non-load-bearing area, it will decelerate, or even the speed will be zero, when it enters the load-bearing area, there is a large Hertz contact stress at the contact with the raceway under the action of radial force, and the roller is rubbing accelerate under the action of force, and there is relative sliding motion with the raceway[6-7]. At this time, the temperature rises, when it reaches a certain level, it will cause the lubricant film to fail, and the roller will directly contact the raceway and cause smearing.

Figure 1 Radial bearing speed zone

Based on the above theory, the design idea of the testing machine is to design a disc to be in radial contact with a roller with a certain speed, and to apply a radial load to the roller through the disc to simulate the force of the roller in the working bearing. Considering the actual movement of the roller in the bearing, the testing machine is divided into driving system, loading system, signal acquisition system and test roller clamping system. The structure of the smearing testing machine is shown in Figure 3.

Figure 3 Positive triaxial measurement of the testing machine
2.1. Driving system
The driving system selects a DC motor and is equipped with a driver, the motor power is 1.5KW and the maximum speed is 4500 rpm, stepless speed regulation can be achieved by connecting the driver and the potentiometer. As shown in Figure 4, the motor and the main shaft are connected by an elastic diaphragm coupling, and the main shaft is supported by the bearing in the bearing seat, the bearing selects the angular contact bearing of type 7304 as shown in Figure 4. One end of the main shaft is machined with a groove for the roller clamping to ensure that the rotation speed of the roller and the main shaft are consistent.

![Figure 4 Exploded view of drive system and angular contact bearing](image)

2.2. Loading system
As shown in Figure 5, the pneumatic system is used to load the test roller, the cylinder is connected with the spoke-type pressure sensor to push the test disc bearing seat to load the roller, the bearing seat is equipped with a linear guide slider system to achieve the front and back sliding of the disc bearing seat. A magnetic powder brake is installed in the bearing seat, relying on the magnetic powder brake, when the rotation speed of the test disc tends to be stable, the upper computer can adjust the braking torque to brake the rotation speed of the test disc to zero, and then enter the next acceleration period. The cylinder is equipped with pneumatic system accessories such as pressure regulating valve, overflow valve and reversing valve to adjust the value of air pressure to achieve the variability of output force.

![Figure 5 explosion diagram of loading system](image)
2.3. Signal acquisition system
The signal acquisition system is mainly divided into lubricating oil temperature, test disk speed and load acquisition system. The thermal resistance temperature sensor and temperature transmitter are used to measure the temperature of the heated lubricating oil, the test needs to monitor the speed of the test disc in real time, so the non-contact speed measurement method is adopted, and the Hall sensor and AC current speed transmitter are selected for data communication with the computer to transmit data. The load measurement adopts the spoke type force sensor, the measurement signal is transmitted to the display device through the transmitter, and the thrust is converted and displayed.

2.4. Test roller clamping system
The test roller clamping part is an important part. It is necessary to ensure that the speed of the roller and the motor are consistent, but also to ensure the neutrality of the roller during high-speed rotation and the stability during the contact between the roller and the test disc. The purpose of ensuring the neutrality of the test roller is to reduce the vibration of the testing machine during operation. Considering that the roller has to make contact and friction with the test disc in the radial direction, in-line grooves are opened at the left and right ends of the roller, and the center lines of the grooves are perpendicular to each other. The fixed roller is shown in Figure 6, one end of the test roller is connected with the supporting main shaft, and the other end is connected with the rotating center on the tailstock of the engraving machine.

![Figure 6(a) Test roller clamping](image1)

![Figure 6(b) 3D drawing of test roller](image2)

2.5 Test machine assembly
The drive system of the smearing testing machine is fixed on an integral flat plate, in order to ensure the alignment between the motor and the spindle, the experimental roller and the tailstock of the engraving machine, a groove is machined on the integral flat plate, and the boss embedded with the groove is processed at the bottom plate of the motor, the bottom of the angular contact bearing seat and the bottom of the tailstock, at the same time, the screw connection is used for auxiliary fixation to ensure the neutral alignment. The assembly drawing of the smearing testing machine is shown in Figure 7.

![Figure 7 Assembly drawing of testing machine](image3)
3. Transient dynamics simulation of disc and roller

Transient dynamic analysis is a time domain analysis process, which is the dynamic response process of the model structure under the time-varying load. The input is the load as a function of time, and the output is the time-varying displacement, stress, strain and other variables. Transient dynamic analysis includes linear dynamic analysis and nonlinear dynamic analysis. The transient dynamic analysis of the experimental part of the testing machine can analyze and study the force of the roller and the change of the rotating speed of the disc at the moment of contact between the test disc and the roller, and judge whether the structure of the testing machine meets the requirements of the experiment and whether it has sufficient stability.

3.1. Build an analysis model

UG 3D modeling software are used to draw the analysis model, and then imported into the ANSYS Workbench, the analysis model is shown in Figure 8. Cut out the roller and test disc in the assembly drawing and add constraints according to the actual situation. The roller only has the degree of freedom of circumferential rotation, while the test disk has the degree of freedom of circumferential rotation and radial movement of roller. The load is applied in the radial direction of the roller through the disc.

![Figure 8 Roller disc analysis model](image)

3.2. Meshing

Meshing is one of the most important tasks of finite element analysis, it is not only related to the efficiency of analysis, but also directly affects the accuracy of the results, the meshing method adopts the hexahedral main body method. The hexahedral main body method is generally used to control the surface of the geometric body to generate a hexahedral mesh. Compared with other meshing methods, it is more suitable for geometric models with slightly complicated surfaces with curvature. The finite element mesh of the geometric model is shown in Figure 9.

![Figure 9 Finite element meshing](image)

3.3. Analysis of calculation results

The main results of the analysis are total deformation and directional deformation, the analysis results of total deformation and directional deformation are shown in Figure 10 and 11, it can be seen from the analysis results that the maximum stress is the outer side of the contact between the test disc and the roller, which is in line with the theoretical calculation prediction of the testing machine. Observing the maximum stress in the figure, it is found that the stress generated by the test disc and roller during the experiment is within the range that the testing machine can withstand, and the test disc and roller are not deformed.
3.4. conclusion

The smearing testing machine can realize the predetermined function. During the experiment, the maximum speed of the DC motor is 4500rpm, and the test can be carried out at high speed, low speed and medium speed. The output force range is 0 ~ 560N, in the analysis of ANSYS, the applied load is 3000N, which is far greater than the rated 560N. In the case of 3000N, the testing machine has no deformation, so it can fully meet the experimental conditions and ensure the smooth progress of the test.

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