Diagnostic method and application of low speed sliding bearing wear fault

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Abstract. The static thermal and dynamic characteristics of the oil film affect the motion stability of the rotor system and directly determine whether the entire equipment can operate safely and stably. In this paper, the characteristics of sliding bearing oil film are studied by theoretical analysis, and the bearing wear fault diagnosis model is proposed. The model is verified by the actual production. The results show that the proposed diagnostic model can quickly locate the cause of the fault and ensure the safe and stable operation of the equipment.

1. Introduction

Sliding bearings have the advantages of high bearing capacity, long service life, convenient processing and maintenance, etc., and thus are widely used in rotating machinery, especially in rotating machinery of thermal power plants [1]. In China, the support of medium and low-speed rotating equipment such as circulating water pumps and condensate pumps in active units is based on sliding bearings. The stability of these equipments will be severely tested when the rotating machinery or the bearings themselves deviate from normal operation. Research on the characteristics of sliding bearings and the establishment of fault diagnosis models for sliding bearings are of great significance for the stable operation of these equipments.

The static and dynamic characteristics of the sliding bearing oil film are one of the key factors affecting the bearing capacity and stability of the system [2]. Therefore, the study of the static and dynamic characteristics of the oil film of the sliding bearing is of great significance in the analysis of the characteristics of the bearing rotor system. According to the theory of sliding bearing oil film dynamic pressure, the fluid dynamic pressure bearing is carried out. When analyzing the characteristics of the rotor system, it is found that there are many characteristic parameters that affect its characteristics. Including the bearing structure such as the bearing's aspect ratio, bearing clearance, physical properties of the medium, as well as operating conditions such as external load and speed, etc., will affect the performance of the bearing rotor system. In this regard, many relevant scholars at home and abroad have carried out extensive and in-depth research. In 1982, based on experience, the analytic solution of the oil film pressure of a finite-length sliding bearing was obtained based on the analytic function of the infinite-length and infinite-short bearing oil film pressure. However, since the analytical solution is based on the steady-state solution, it is not suitable for Transient oil film pressure study [3]. In 1986, Capone proposed a method for calculating the oil film force of a symmetrical supported sliding bearing
In 1991, the nonlinear oil film force model under the assumption of short bearing theory was proposed. Because of the good precision and convergence of the model, it is widely used [5]. In 2002, Kraiko proposed a bearing optimization approximation method for the lubrication of incompressible fluids based on Elrod-Burgdorfer boundary conditions [6]. At present, domestic and foreign scholars' research on fault diagnosis of sliding bearings is mostly limited to theoretical research and simulation and simulation. The established analytical model also requires a large amount of detailed measurement data support. At present, the vibration signal of the low-speed sliding bearing is difficult to accurately measure, and most of the currently obtained diagnostic models relying on detailed measurement data are not available. It is necessary to study the fault diagnosis model of sliding bearing based on the actual operation of the site.

2. Sliding bearing lubrication principle

The friction surface of two mutually moving objects, the viscous fluid film generated by the action of the pump oil when the shaft diameter itself rotates completely separates the two friction surfaces, and the pressure generated by the fluid film balances the external load, which is called hydrodynamic lubrication. There are three elements of the fluid-generating dynamic pressure lubricating film: 1. There are two solid surfaces which can form a wedge-shaped gap with each other. The wedge-shaped gap formed is filled with a fluid having a certain viscosity, and the relative relationship between the two solid surfaces. The motion causes the viscous fluid filled therein to move from the large end of the gap to the small end of the gap to generate supporting pressure. The structure of the radial sliding bearing and its working form just make it necessary to form the dynamic pressure lubricating film.

![Figure 1. Schematic diagram of sliding bearing lubrication principle](image)

Under the action of the external force load $F$, in order to reach the equilibrium state, the shaft center $O_1$ needs to be at an eccentric position with respect to the bearing center $O$. Where $e$ is the eccentricity and $\theta$ is the deviation angle. On the extension line of the continuous heart line $OO_1$, one end is the maximum oil film thickness $h_{\text{max}}=R-r+e$, and the other end is the minimum oil film thickness $h_{\text{min}}=Re$; the shaft diameter is clockwise rotation direction, in the semicircle of $h_{\text{max}}$ to $h_{\text{min}}$, the gap From the large to the small convergent wedge gap, this is the most important set of conditions for the lubricating oil film to generate the lifting pressure to withstand the load $F$. In the semicircle from $h_{\text{min}}$ to $h_{\text{max}}$, the wedge-
If lubricating oil is used as the lubricant, it is usually after $h_{min}$. At a small distance, the oil film breaks due to the inability to withstand too much negative pressure, forming a void area. This creates a complete pressure distribution in a gap slightly larger than 180°.

### 3. Diagnostic model

When the rotating shaft starts to start, the journal depends on the frictional force and crawls upward along the inner surface of the bearing. After reaching a certain position, the frictional force can not support the weight of the rotor and begins to slip. At this time, it is semi-liquid friction. As the rotational speed continues to increase, the journal brings the viscous lubricating oil into the wedge-shaped gap (oil wedge) between the bearing, because the wedge-shaped gap is convergent, and its inlet section is larger than the outlet section, so a certain oil pressure is generated in the oil wedge, and the journal is pushed by the pressure of the oil to the other side.

If the flow of lubricating oil introduced into the wedge gap is continuous, the oil pressure in the oil will increase, causing the average flow rate at the inlet to decrease and the average flow rate at the outlet to increase. The oil layer accumulated in the gap is called an oil film, and the oil film pressure can lift the rotor journal. When the oil film pressure is balanced with the external load, the journal operates stably without contact with the inner surface of the bearing.

According to the conditions established by the oil film, for low-speed sliding bearings, there are three main problems that may cause oil film damage: 1. The bearing lubrication system is insufficiently supplied with oil. 2. Mechanical vibration exists in the shaft or bearing bush. 3. The bearing load is too large. The manifestations and hazards of the three types of problems are shown in Table 1:

| Fault type          | Manifestations                                                                 | harm                                |
|---------------------|-------------------------------------------------------------------------------|------------------------------------|
| Lack of oil supply  | Lubricating oil temperature rises rapidly and oil return decreases             | Insufficient lubrication damage    |
| Mechanical vibration| Lubricating oil temperature rises, equipment parameters are abnormal          | bearing bush                       |
| Excessive load      | The temperature of the lubricating oil rises and returns to normal after the  | Worn bushing, damaged equipment    |
|                     | output of the equipment drops.                                                |                                    |

According to Table 1, the bearing wear accidents encountered in the actual production can be analyzed. The production parameters and operating conditions can basically locate the cause of the accident and solve it.

### 4. Case analysis

The circulating water pump of #4 unit of a power plant adopts G48SH-19 horizontal pump with YD1250/780-12/14/1730 motor. After the overhaul, the temperature of the motor bearing bush has been high, and the tungsten gold phenomenon has been worn. After the power plant technicians adjusted and replaced the bearing bush several times, the wear phenomenon still exists.
Based on the diagnostic model given in Section 3, we made the following diagnosis:

a. In-situ inspection of the wear of the bearing bushings, according to the wear characteristics of the black gold, the wear caused by poor lubrication is judged.

b. Look for the cause of poor lubrication of the bearing bush. Due to the low motor speed (495r/min), the bearing lubrication requirements are low, and it is judged that there is an external force to cause the rotor to rotate irregularly. It is recommended to start the test, observe the actual operation and contact the vibration expert to try to test the vibration.

c. During the trial operation, the temperature of the lubricating oil at the driving end bearing bush is raised from 34 °C to 70 °C within 15 min, and the inspection is stopped. It is found that the phenomenon of black gold wear occurs. During the trial operation, it was found that the oil ring was severely beaten.

d. Through trial operation, it is preliminarily determined that the bearing bush wears due to insufficient oil supply due to severe oil slamming at the drive end bushing. The cause of the oil ring vibration is suspected to be the following: the roundness of the shaft is poor; the shaft sway is too large at the oil ring; the oil ring size does not match and cannot work normally; the motor force is unbalanced, causing abnormal vibration.

Disposal: Check the roundness of the shaft of the motor rotor oil ring; measure the oil slinger and connect the wheel sway (should be no more than 50µm); check that the oil ring specifications and models match the original design; contact the motor manufacturer to try the test The rotor at the oil ring vibrates.

The motor was disassembled by the motor manufacturer, and the following problems were found:

a. The shaft extension is beating 0.14-0.16;

b. The iron core file beats 0.18-0.24;

c. the bearing profiles at both ends are different from each other;

d. the bearing pad babies alloy grinding;

e. The rotor imbalance is distorted and the data deviation is large.

According to the above situation, the technical analysis believes that the motor shaft is deformed and the coaxiality is extremely poor, resulting in poor stability during the operation of the motor, increased temperature, and large vibration, resulting in damage to the bearing bush. The result is consistent with model analysis results.
5. Conclusion
In this paper, the characteristics of sliding bearing oil film are studied by theoretical analysis, and the bearing wear fault diagnosis model is proposed, which outlines the manifestations and hazards of the three main types of failures. The model is verified by the actual production. The results show that the proposed diagnostic model can quickly locate the cause of the fault and ensure the safe and stable operation of the equipment.

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