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Study on the Wear Characteristics of Angular Contact Ball Bearings

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Abstract: For the wear of rolling bearings, this paper establishes a wear model of angular contact ball bearings based on the proposed static mechanics of rolling bearings, kinematics of rolling bearings and Archard's wear theory, studies the wear of bearings, and analyses the effects of rotational speed, load and structural parameters on the wear of bearings. The results show that: the inner ring of the bearing is uniformly worn and the depth of wear is larger than the outer ring; the depth of wear of the inner ring of the bearing increases with the increase of rotational speed, the load has a certain effect on the depth of wear, the depth of wear increases with the increase of axial load; the structural parameters of the bearings have a certain effect on the wear, the depth of wear of the inner ring decreases with the increase of the radius of curvature of the internal grooves, the radius of curvature of the internal grooves has a small effect on the outer ring wear, and the selection of appropriate structural parameters can effectively reduce the wear of the bearings, the wear of the bearings can be reduced. Selection of appropriate structural parameters can effectively attenuate the wear.

Keywords: Proposed statics; Rolling bearings; Bearing wear; Archard model.

1. Introduction

Bearings as an important part of mechanical equipment, once the failure, will inevitably have a great impact on the equipment, therefore, the research on bearing failure is particularly important.

Lixin Xu et al.[1] investigated the effect of deep groove ball bearings with ripple degree defects on the dynamic response of the system in a multi-body system, and the influence law of local defect excitation on the dynamic performance of planar multibody systems is investigated[2]; Tiago H.Machado et al. [3] investigated raceway wear in fluid lubricated bearings and analysed the effect of wear on the dynamic response of the rotor bearing system.Tdriss EI-Thalji et al. [4]developed a model to simulate the evolution of wear and the results obtained are in good agreement with the experimental results. Athanasios C.Chasalevris et al. [5] investigated the effect of bearing wear on the rotor system using the Dufrane wear model.

Through the above research results, it can be seen that scholars have achieved numerous valuable results in bearing wear, which provide important theoretical guidance for bearing design, maintenance guarantee and life evaluation[6]. In order to study the wear of angular contact ball bearings, this paper firstly establishes the proposed static mechanical model of rolling bearings, and based on the Hertz contact theory and Archard wear theory, establishes the wear model of angular contact ball bearings considering the dynamic wear coefficient. The wear model established in this paper is programmed to be solved, and the results obtained are analysed and discussed to obtain some conclusions.

2. Proposed Hydrostatic Modelling of Bearings

2.1. Geometric Relation

Under the action of high speed, the bearing due to the role of centrifugal force will make the rolling body and the inner and outer rings of the contact angle changes, which leads to the bearing inner and outer rings of the load borne by different[7]. In order to clarify the distribution of the internal load of the bearing in such a state, the displacement relationship of the first rolling element in any angular position is analysed, as shown in Figure 1.

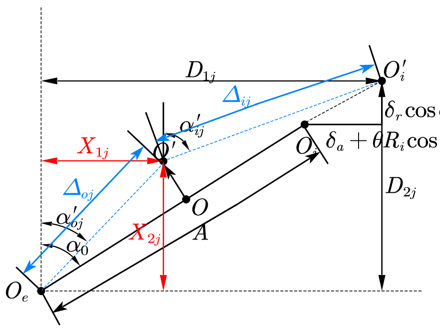


Figure 1. Position of the rolling element in relation to the centres of curvature of the inner and outer grooves[8]

The equation can be obtained

$$\begin{aligned}(D_{1j}-X_{1j})^2+(D_{2j}-X_{2j})^2-\Delta_{ij}^2=0\\ X_{1j}^2+X_{2j}^2-\Delta_{oj}^2=0\end{aligned} \tag{1}$$

Where O_e is the centre of curvature of the outer ring, O is the centre of the rolling element, and O_i is the centre of curvature of the inner ring.

2.2. Rolling Body Force Analisis

The rolling body forces include the normal contact force acting on the rolling body by the raceway, the tangential friction force, the centrifugal force of the rolling body, and the gyroscopic moment, as shown in Figure 2.

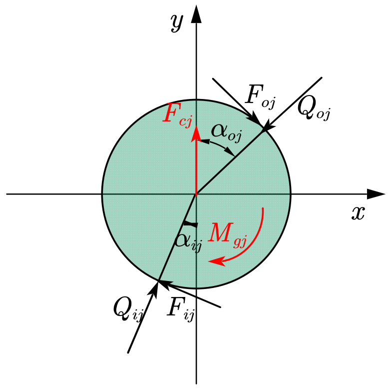


Figure 2. Forces on the rolling body in contact with the raceway

The equilibrium equation for a rolling body is

$$\begin{aligned} Q_{ij}\sin\alpha_{ij}^{'} - Q_{oj}\sin\alpha_{oj}^{'} - F_1 = 0 \\ Q_{ij}\cos\alpha_{ij}^{'} + F_{cj} - Q_{oj}\cos\alpha_{oj}^{'} - F_2 = 0 \end{aligned} \tag{2}$$

which

$$\begin{aligned} F_1 = \frac{M_{gj}}{D_b}\left(\lambda_{ij}\cos\alpha_{ij}^{'} - \lambda_{oj}\cos\alpha_{oj}^{'}\right) \\ F_2 = \frac{M_{gj}}{D_b}\left(\lambda_{ij}\sin\alpha_{ij}^{'} - \lambda_{oj}\sin\alpha_{oj}^{'}\right) \end{aligned} \tag{3}$$

where F_{cj} is the centrifugal force on the rolling body, M_{gj} is the gyroscopic moment on the rolling body.

2.3. Inner Ring Force Analysis

Considering that the bearing is subjected to external loads, based on the hydrostatic equilibrium relationship, the external load applied to the bearing and the load acting on the inner raceway of the rolling element constitute a balanced force system[9], therefore, the force balance equation of the inner raceway under the operating conditions of the bearing can be expressed as follows

$$\begin{aligned} F_a = \sum_{j=1}^{Z}\left(Q_{ij}\sin\alpha_{ij} - \frac{\lambda_{ij}M_{gj}}{D}\cos\alpha_{ij}\right) \\ F_r = \sum_{j=1}^{Z}\left(Q_{ij}\cos\alpha_{ij} + \frac{\lambda_{ij}M_{gj}}{D}\sin\alpha_{ij}\right)\cos\varphi_j \\ M = \sum_{j=1}^{Z}\left(Q_{ij}\sin\alpha_{ij} - \frac{\lambda_{ij}M_{gj}}{D}\cos\alpha_{ij}\right)R_i\cos\varphi_j \end{aligned} \tag{4}$$

3. Archrad Wear Models

The Archard model is most widely used in the field of wear studies of rolling contact parts. The formula is

$$dV = kdQdL \tag{5}$$

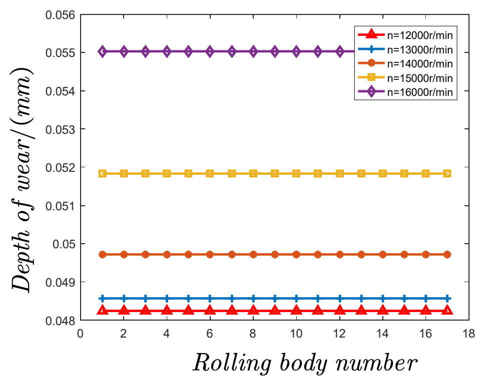
Where, dV is the wear volume, divided by the wear area of the raceway to get the wear depth, k is the wear coefficient, closely related to the oil film parameters, dQ is the contact surface normal force, dL is the relative sliding displacement.

In order to apply the Archard wear model to the analysis of bearing raceway wear, the Archard wear model was rewritten to be able to establish the relationship between the bearing raceway wear depth and the contact pressure distribution, sliding speed, and wear time, with the equation:

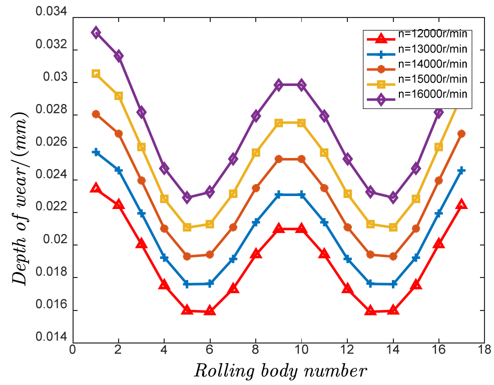
$$h = \frac{1}{s}\iint kpvdsdt \tag{6}$$

4. Analysis of Results

For the proposed hydrostatic model of the bearing, the Newton-Raphson iterative method is used for the solution[10]. In order to discuss the effect of rotational speed on bearing wear, take the bearing rolling element and surface roughness are $0.18\mu m$, external load $F_a = 2000N$, $F_r = 1000N$, $M = 0$,respectively, set the rotational speed to $6000r/min, 7000r/min, 8000r/min, 9000r/min, 10000r/min$, to solve for it, and the results are obtained as shown in the figure 3.



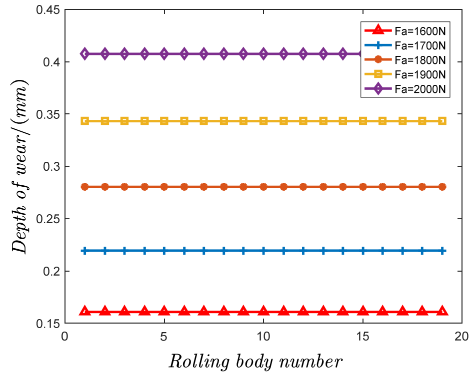
(a) Inner circle



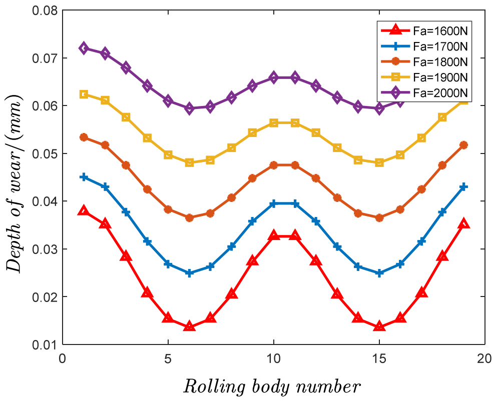
(b) Outer ring

Figure 3. Bearing wear depth at different speeds

From the figure, it can be seen that the wear of the inner ring of the bearing is uniform wear, with the increase of rotational speed, although the wear coefficient decreases and the increase of rotational speed will make the centrifugal force of the rolling body increase, which will make the contact pressure of the inner ring decrease, but the increase of rotational speed makes the sliding speed between the rolling body of the bearing and the bearing raceway increase, and the speed of the impact on the wear is larger than the contact force, so the depth of wear of the bearing increases.



(a) Inner circle



(b) Outer ring

Figure 4. Bearing wear depth under different loads

Figure 4 shows the variation of wear depth of the inner ring of the bearing with axial load when the bearing speed is equal to $8000r/min$. It can be seen from the figure: with the increase of initial preload, the wear depth of the bearing will increase accordingly. The reason is: with the increase of initial preload, the contact stress of rolling element and raceway contact area will increase accordingly, resulting in the increase of raceway wear depth.

5. Conclude

In this paper, for the angular contact ball bearings used in rotating equipments in mechanical industry, based on the bearing proposed static model and Archard wear model, the proposed static analysis and wear characteristic analysis are carried out, and the law of bearing wear depth change with rotational speed and load is calculated, and the law of change is analysed. Based on the results obtained, the following conclusions can be summarised:

(1) In bearing operation, the wear of the inner raceway of the bearing is uniform, and the wear of the inner raceway is greater than that of the outer raceway.

(2) The speed and load of the bearing have a significant effect on the depth of wear of the bearing; the higher the speed, the more likely the bearing is to wear out. The wear depth will increase with the increase of axial load.

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