Analysis of Steady State Characteristics for Single-axial Groove Sleeve Bearing

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Abstract: The finite difference method is used to solve the Reynolds equation and the steady state characteristics of single-axial groove bearings are obtained theoretically. It is assumed that the groove is located in four different positions on the top, the bottom, the left and the right of the bearings. The pressure distribution curves and bearing capacity of groove at four different positions are analyzed under the predefined boundary conditions. It has been shown that the oil film pressure distribution and bearing capacity remain unchanged with the common sleeve bearing when the groove is located in the divergence area of oil film; when the groove is located in the convergence area of oil film, the oil film pressure distribution will change greatly. Compared to the sleeve bearing with groove located in the divergence area, the bearing capacity of the sleeve bearing with groove located in the convergence area will decrease to a certain extent, the amplitude of the decrease will change with the different positions of groove in the convergence area of oil film. When oil groove is in the convergence area, though the carrying capacity and pressure decreases, the pressure forms the two pressure strips and the stable performance of sleeve bearing is improved.

1. Introduction

Sleeve bearing is widely used in various fields, due to its higher bearing capacity, higher turning accuracy, higher impact resistance, smaller noise and vibration. For larger size and higher bearing capacity requirements, the sleeve bearings with oil groove have better lubrication performance and heat dissipation effect.

Axially grooved journal bearing is widely used in industry with its better stability and better lubrication performance. Wang [1] analyzed the influence of groove depth on oil film pressure and bearing capacity of single-axial journal bearing. Roy et al. [2-3] studied the steady state and dynamic characteristics of single-axial journal bearing. Brito et al. [4] compared the performance of a journal bearing with a single and a twin axial groove configuration. Through the experimental study of two-axial oil groove journal bearing, the influence of rotated speed and load on the oil film pressure of two-axial oil groove journal bearing is analyzed by Chatterton et al. [5]. Yu et al. [6] analyzed double oil grooved round sliding bearing performance with disturbance. The linear and nonlinear transient motion of a 2-lobe geometrically imperfect hybrid journal bearing system compensated with constant flow valve restrictor is analyzed by Jain and Sharma [7]. Majumdar et al. [8] studied the state and dynamic characteristics of journal bearing with three axial grooves. Mallya et al. [9] analyzed the static characteristics of misaligned three-axial water-lubricated journal bearing in the turbulent regime. On the basis of previous studies, the influence of eccentricity and groove location on the oil film...
pressure and bearing capacity of single-axial groove sleeve bearing is studied

2. Theory Model

2.1. Reynolds equation

The two-dimensional Reynolds equation of incompressible fluid lubrication and finite long bearing can be expressed as:

$$\frac{\partial}{\partial x} \left( h^3 \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial y} \left( h^3 \frac{\partial p}{\partial y} \right) = 6U\eta \frac{\partial h}{\partial x}$$  \hspace{1cm} (1)

where $h$ is the oil film thickness, $p$ is the oil film pressure, $U$ is the rotation speed of the sleeve, $\eta$ is lubricating oil dynamic viscosity, $x$ is the circumferential coordinate, $y$ is the axial coordinate.

Geometry of single-axial groove bearing is shown in Figure 1, bearing has one groove along the axial direction, and the axial groove angle of the sleeve bearing is 36°. As shown in Figure 1, it is assumed that the groove is located in the position of A, B, C and D of the bearing. The oil film thickness without oil groove: $h = c[1 + \varepsilon \cos(\varphi - \theta)]$, and the oil film thickness with oil groove: $h = c[1 + \varepsilon \cos(\varphi - \theta)] + h_g$, $c$ is the radius clearance, $\varepsilon$ is the eccentricity, $\theta$ is the attitude angle, $h_g$ is the depth of the oil groove, $\varphi$ is circumferential coordinate.

Under steady state condition, equation (1) can be reduced to

$$\frac{\partial}{\partial \varphi} \left( H^3 \frac{\partial p}{\partial \varphi} \right) + \left( \frac{\varepsilon}{l} \right)^2 \frac{\partial}{\partial \lambda} \left( H^3 \frac{\partial p}{\partial \lambda} \right) = 3 \frac{\partial p}{\partial \varphi}$$  \hspace{1cm} (2)

where $H$ is the non-dimensional oil film thickness: $H = \frac{h}{c}$, $P$ is the non-dimensional oil film pressure, $P = \frac{pc^2}{2U\eta}$, $d$ is the width of bearing, $l$ is the length of bearing, $\lambda$ is axial coordinate, $\lambda = \frac{y}{l/2}$.

The dimensionless oil film thickness without oil groove: $H = 1 + \varepsilon \cos(\varphi - \theta)$, the dimensionless oil film thickness with oil groove: $H = 1 + \varepsilon \cos(\varphi - \theta) + H_g$, $H_g = h_g/c$.

2.2. Boundary conditions

For axially grooved sleeve bearings, the Reynolds boundary condition is used.

Pressure at both edges of the bearing is zero.

$$P(\varphi, \pm 1) = 0$$  \hspace{1cm} (3)

Pressure distribution is symmetric about the mid plane along axial direction.

$$\left( \frac{\partial p}{\partial \lambda} \right)_{\lambda=0} = 0$$  \hspace{1cm} (4)

Pressure is set equal to 0 when the pressure falls below zero.

2.3. Loading capacity

For single-axial groove sleeve bearing, the non-dimensional loading capacity components along the line of centers and its perpendicular direction are as following:

$$\bar{W}_t = -\int_0^{2\pi} \left( J_0 \frac{1}{Pd\lambda} \right) \sin(\varphi - \theta) d\varphi$$  \hspace{1cm} (5)

$$\bar{W}_n = -\int_0^{2\pi} \left( J_0 \frac{1}{Pd\lambda} \right) \cos(\varphi - \theta) d\varphi$$  \hspace{1cm} (6)
where $\bar{W}_x$ is the non-dimensional loading capacity components along the line of centers, $\bar{W}_\theta$ is the non-dimensional loading capacity which is perpendicular to the line of centers.

The non-dimensional loading capacity and attitude angle are as following:

$$\bar{W} = (\bar{W}_x + \bar{W}_\theta)^{1/2}$$

$$\theta = \tan^{-1}\left(\frac{\bar{W}_x}{\bar{W}_\theta}\right)$$

![Figure 1. Geometry of single-axial groove bearing](image)

### 3. Results and discussion

The Reynolds equation with different locations of groove A, B, C and D is solved, and the non-dimensional oil film pressure and bearing capacity are obtained in Figure 2(a), (b), (c), (d), Figure 3(a), (b) and Figure 4.

(a) Position A  
(b) Position B
It can be seen from Figure 2(a), (b), (c), (d), Figure 3(a), (b) and Figure 4 that the non-dimensional oil film pressure distribution and non-dimensional bearing capacity of position A and B are obviously different with common sleeve bearing, and the non-dimensional oil film pressure distribution and non-dimensional bearing capacity of position C and D are basically the same with the common sleeve bearing. According to the location of each groove in Figure 1, the non-dimensional oil film pressure distribution and non-dimensional bearing capacity remain unchanged when the groove C, D are located in the divergence area of oil film; when the groove A, B are located in the convergence area.
of oil film, the non-dimensional oil film pressure distribution will change greatly. Compared to the sleeve bearing with groove located in the divergence area, the non-dimensional bearing capacity of the sleeve bearing with groove located in the convergence area will decrease to a certain extent, the amplitude of the decrease will change with the different position of groove in the convergence area of oil film. As shown in Position A of Figure 3(a) and (b), because the location of groove is near to the oil film start position, the non-dimensional oil film pressure is close to zero. However, when the location of groove has a certain distance from the oil film start position, as shown in Position B of Figure 3(a) and (b), the oil film forms two distinct pressure regions. So when oil groove is in the convergence area, though the carrying capacity and pressure decreases, the pressure forms the two pressure strips and the stable performance of sleeve bearing is improved. In the future study, the structure of single-axial groove bearing should be optimized to get the optimal groove position.

4. Conclusions
The steady state characteristics of bearing are affected by the location of groove when the oil groove is located in the convergence area of oil film. The bearing capacity of the sleeve bearing with groove located in the convergence area will decrease to a certain extent, the amplitude of the decrease will change with the different position of groove in the convergence area of oil film. When the location of groove is a certain distance from the oil film start position, the oil film forms two distinct pressure regions, which is helpful to improve the dynamic characteristics of sleeve bearing.

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