

# Bearing Capacity and Temperature Rise Characteristics Analysis of Herringbone Groove Hydrodynamic Lubricating Bearing

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**Abstract.**In this paper, numerical analysis of the high speed and small herringbone groove hydrodynamic lubricating bearing's bearing capacity,rotational speed effected on the bearing's eccentricity ratio and temperature rise, film thickness,oil film pressure distribution was solving by Reynolds equation under the Reynolds boundary condition, temperature rise was solving by Reynolds equation. The results shown that the temperature of bearing decreased first, then increased with eccentricity increasing, eccentricity ratio increased with bearing's load increasing but decreased with journal's rotational speed increasing, compared to normal sliding bearing, herringbone groove hydrodynamic lubricating bearings had higher stability and bearing capacity.

## 1. Introduction

Herringbone groove hydrodynamic lubricating bearing had higher stable, well anti-vibration,high load-capacity etc. advantages which was widely used in high-speed and precision situations[1,2]. Herringbone grooved bearing's journal opened herringbone grooves, in the process of high-speed rotating bearing generated pump suction phenomenon, lubricating oil flowed to the center through herringbone grooves, forming pressure peaks which distributed along the journal improved stiffness and stability. According to the narrow groove theory[3], the number of grooves was infinite, made pressure distribute along the journal smooth changing which ignored the pressure fluctuations, with the decrease of eccentricity ratio[4,5]that improved bearing stiffness coefficient. Analyzed film lubrication of Herringbone grooves by two-dimensional that ignored the narrow groove theory shown that light-load herringbone groove lubricating bearings had better stable. The research on herringbone groove lubricating bearing's parameters effected on the characteristics of lubrication and rotor dynamic, shown that pressure distributed widely along the circumference and the rotor had higher stable[6,7]. This paper numerical analysis[8] of herringbone groove hydrodynamic lubricating bearing based on Reynolds equation[9], obtained the high speed and small herringbone groove hydrodynamic lubricating bearing's relationship between load, rotational speed and eccentricity, temperature rise which provided evidences for application.

## 2.Basic Equation

### 2.1 Static load Reynolds equation

Hydrodynamic Lubricating's pressure distribution of bearing's clearance was obtained by solving Reynolds Equation. Bearing's pressure distribution effected the performance of bearing. In this paper has studied on high-speed small bearing's according to static load Reynolds equation (1).

$$\frac{\partial}{\partial x} \left( h^3 \frac{\partial p}{\partial x} \right) + R^2 \frac{\partial}{\partial y} \left( h^3 \frac{\partial p}{\partial y} \right) = 6\eta R^2 \omega \frac{dh}{dx} \quad (1)$$

where:  $x$  circular cardinality(m) ,  $y$  axial coordination(m),  $\eta$  dynamic viscosity of oil (Pa·s),  $p$  lubricant pressure(Pa),  $h$  oil film thickness(m),  $y$  radial coordinate(m),  $\omega$  journal angular velocity(rad/s),  $R$  journal radius(m)

Formula (1) obtained dimensionless equations (2);

$$\frac{\partial}{\partial \varphi} \left( H^3 \frac{\partial P}{\partial \varphi} \right) + \theta \frac{\partial}{\partial Y} \left( H^3 \frac{\partial P}{\partial Y} \right) = \frac{dH}{d\varphi} \quad (2)$$

Where:  $y = \frac{YL}{2}$  ,  $\theta = \left( \frac{2R}{L} \right)^2$  ,  $h = c(1 + \varepsilon \cos \varphi) = Hc$  ,  $p = P \frac{6U\eta R}{c^2}$  ,  $U = R\omega$  ,  $R$  journal radius(m),  $L$  bearing length(m),  $c$  radius clearance(m),  $H$  dimensionless oil film thickness.

Following boundary conditions(1) axial direction, at the edges  $Y=1$ ,  $\frac{\partial P}{\partial Y} = 0$  ,(2) In the circumferential direction, lubricant pressure of end-point equal start-point,  $P|_{\varphi_0=0} = P|_{\varphi_0=2\pi}$

## 2.2 The equations of temperature

High-speed rotation of lubricating bearing's shaft produced frictional heat which made lubricating oil temperature rise high, analyzed the thermal properties of lubricating bearing to make sure temperature within a reasonable range, temperature rise was consisted of the heat generated by friction bearing, the heat taken away by hydraulic oil, the heat taken away by bearing dissipated. The temperature rise equation(3)[10];

$$\Delta t = \frac{\frac{f}{\phi} p}{c\rho \left( \frac{Q_L}{\phi UBd} \right) + \frac{\pi \alpha_s}{\phi U}} \quad (3)$$

Where:  $\frac{Q_L}{\phi UBd}$  fuel consumption dimensionalized coefficient,  $Q_L$  leakage( $m^3 \cdot s^{-1}$ ),  $f$  friction coefficient,  $f = \frac{\pi \eta \omega}{\psi} + 0.55 \psi \xi$  ,  $\rho$  hydraulic oil density( $Kg \cdot m^{-3}$ ),  $\xi$  width-radius ratio coefficient,  $p$  bearing average pressure  $p = \frac{\omega}{LD}$  (Pa),

## 3. Numerical Examples and Analysis

### 3.1 Basic parameters of bearing

Numerical analysis of the herringbone groove hydrodynamic lubricating bearing obtained the bearing characteristic and temperature rise characteristic of herringbone groove bearing, the Basic parameter bearing shown in table(1), the bearing's journal was 3.98mm, inner diameter was 4mm.

Table 1 Basic parameters of bearing

variable name	value	variable name	value
Journal d (mm)	3.97	G/R	1
bearing inner D (mm)	4	groove depth $\mu$ (mm)	0.005
length-diameter ratio L/D	1	groove angle $\beta$ (°)	30
groove number	10		

The Fig.1 shown that the herringbone groove hydrodynamic lubricating bearing's groove angle was  $30^\circ$ , groove number was 10, groove depth was 0.005mm.  $\lambda = y/L$  was dimensionless parameter Ridg divided Groove was 1.

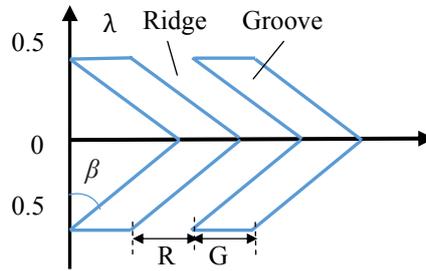
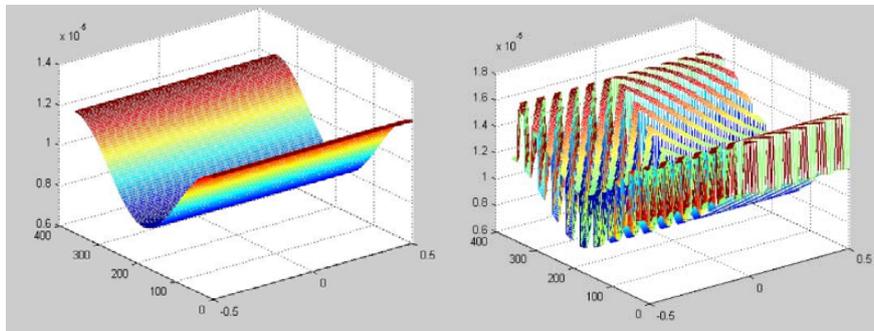


Fig.1 Sketch map of the herringbone groove hydrodynamic lubricating bearing

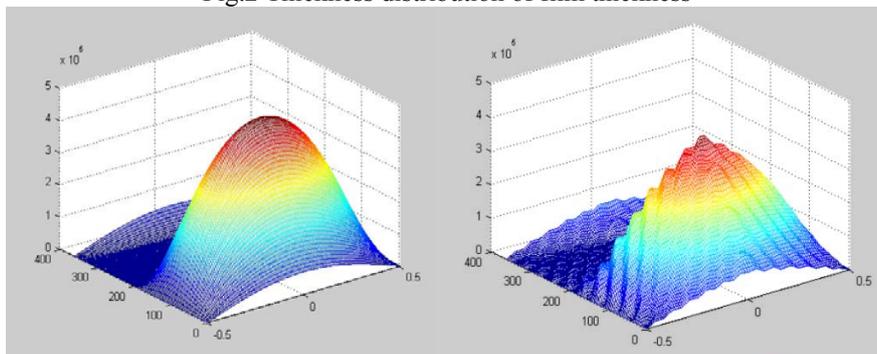
### 3.2 Numerical Analysis of the bearing

Comparing bearings and herringbone groove bearings which in the same geometry and load obtained film thickness and pressure distribution shown in Fig.2 and Fig.3 which spread out in circumferential direction.



(a) Film thickness distribution of sliding bearing (b) Film thickness distribution of herringbone grooved bearing

Fig.2 Thickness distribution of film thickness



(a) Pressure distribution of sliding bearing (b) Oil film pressure distribution of herringbone grooved bearing

Fig.3 Pressure distribution of bearing's film

Fig.2 and Fig.3 shown that lubricating oil in the herringbone grooved bearing flown to tip that lead to film become thicken, and the pressure distributed along the circumference of herringbone grooved bearing was wider, peak pressure in each grooves superimposed which improved bearing capacity, peak pressure distributed along the journal could improve bearing's stability.

According to characteristics of herringbone grooved bearing, analyzed the bearing's rotational speed  $n$  (r/min), load  $F$  (N) effected on temperature rise  $\Delta t$  ( $^\circ$ ) and eccentricity ratio  $\epsilon$

Fig.4 shown that eccentricity ratio of herringbone grooved bearing increased with the bearing capacity increasing. Eccentricity ratio increasing trend becomes larger when bearing capacity more than 25N, eccentricity ratio became lager wasn't conducive to form hydrodynamic lubricant film. In practical application, the force should be chose in reasonable range.

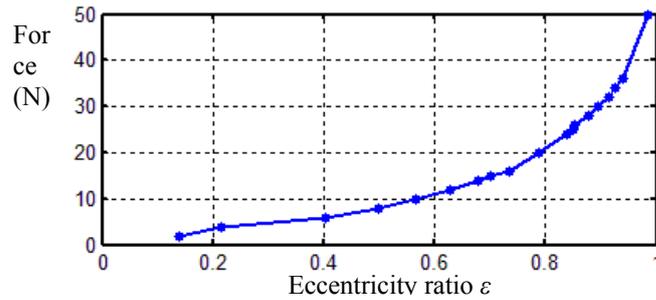


Fig.4 Variation of load capacity with eccentricity ratio

Fig.5 shown that the temperature of bearing decreased first, then increased with eccentricity ratio increasing. there was an optimal value between eccentricity ratio and bearing temperature rise that's inflection point bearing temperature curve.

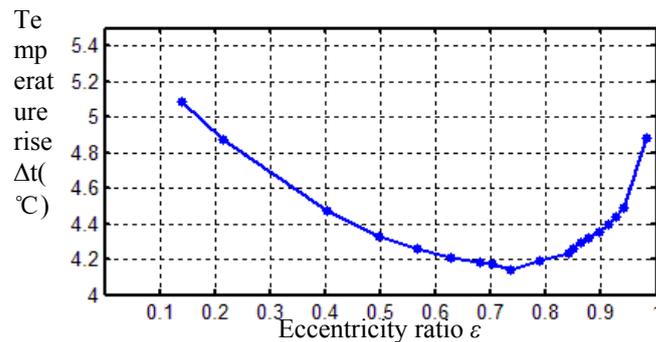


Fig.5 Variation of eccentricity ratio with temperature rise

Fig.6 shown that the eccentricity of bearing decreased with rotating speed increasing. Film thickness increasing with eccentricity ratio decreased which would improve bearing's stable, but rotational speed was too high would lead to temperature rise of bearing increased that led to the lubricating oil viscosity reduction, which was not beneficial to film thickness.

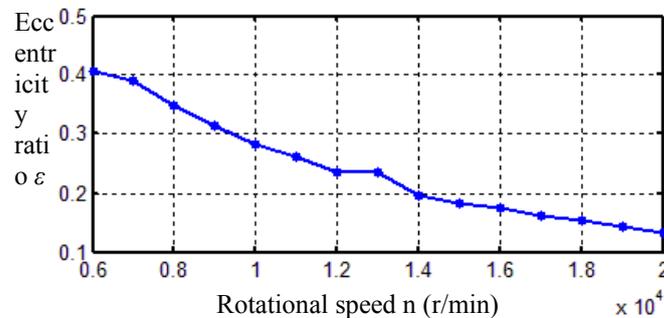


Fig.6 Variation of eccentricity ratio with rotational speed

Fig.7 shown that temperature of bearing increased with the journal rotat speed increasing. Temperature of bearing was too high might lead to hydrodynamic lubricant film broken, lubrication failure, which made bearing wear.

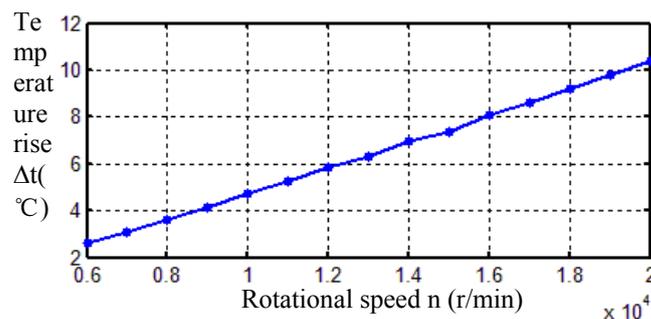


Fig.7 Variation of temperature rise with Rotational speed

#### 4. Conclusion

Herringbone groove's oil formed pressure peaks which distributes along the journal would improve the herringbone grooved bearing stiffness and stability. Numerical analysis bearing capacity, rotational speed of herringbone groove hydrodynamic lubricating bearing which effected on the bearing's eccentricity and temperature rise, the results shown that;

1. Herringbone groove bearing's eccentricity ratio increasing with the load increased, Eccentricity ratio increasing trend was slowly when the load within a reasonable range, eccentricity ratio increasing trend becomes large when load exceed a certain value. Eccentricity ratio was not beneficial to form hydrodynamic lubricant film. In practical application load should be in a reasonable range to make sure herringbone groove bearing stability.

2. Eccentricity ratio decreasing with the journal rotational speed increased which increased the film thickness that's beneficial to improve herringbone groove bearing stability, but herringbone groove bearing temperature rising with the journal rotational speed increased might lead to hydrodynamic lubricant film broken, lubrication failure. In practical applications should set rotating speed according to requirements.

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