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THERMAL EFFECTS AND VISCOSITY VARIATION IN FINITE JOURNAL BEARING WITH TWO LAYER FLUID: REASON-NARANG RAPID TECHNIQUE

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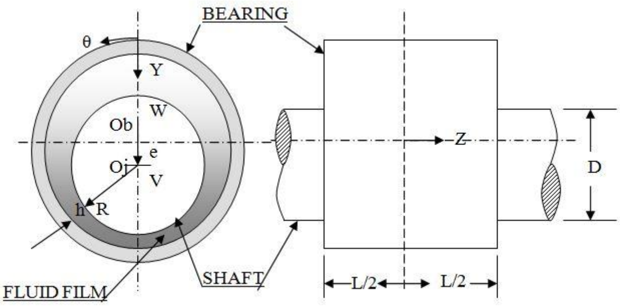
ABSTRACT: In this paper the generalized Reynolds equations are derived earlier is applied to study the squeeze film lubrication of Finite journal bearing considering thermal effect and viscosity variation, using Reason-Narang Rapid technique. Expressions for Load capacity in short and long journal bearings of squeeze film lubrication are obtained. Reason-Narang Rapid technique is applied for load capacity and analyzed numerically for viscosity variation and thermal effects. Graphs are plotted for various parameters.

KEY WORDS: Viscosity, Peripheral layer thickness, Eccentricity, Thermal effect, Load capacity

I. INTRODUCTION

The phenomenon of two lubricated surfaces approaching each other with a normal velocity is known as squeeze film lubrication. The time required to squeeze out the lubricant depends upon surface configuration, fluid properties and the load applied. In recent years a great deal of work has been done by tribologists to increase the efficiency of lubricants. It has been observed that the addition of small amount of long-chain polymer solutions to Newtonian fluids gives the most suitable lubricants owing to stabilization of the flow properties of the lubricants. The use of additives minimizes the sensitivity of lubricants to charges the shear rate. In particular to improve the characteristics of the base oil the additives can be used as rust inhibiters (Amine Phosphates), corrosion inhibiters (sulphurised olefins), and fire resistant (Halogenated hydrocarbons). There are several experimental reports in which it is pointed out. The additives added to the base oil reduces friction, wear and supports greater load capacities which results in a longer bearing life. In particular it has been noted that in the lubrication of rollers, there has been considerable increase of thickness when additives are added to the base lubricant. The squeeze film characteristics of long partial journal bearing lubricated with couple stress fluid byLin [11], the generalized Reynolds equation for bearing under dynamics conditions with varying loads was investigated numerically by Xiao-Li Wang et al. The elastohydrodynamic analysis was derived for journal bearing in isothermal condition by Lahmar: whereas, the steady state and dynamic analysis were investigated for ball bearings by Sarangi et al. The analysis of load carrying capacity using Rapid Narang technique Jayachandra reddy and Eswar Reddy [8]. The generalized Reynolds equations are derived earlier is applied to study the squeeze film lubrication of Finite journal bearing considering thermal effect and viscosity variation, using Reason-Narang Rapid technique. Expressions for Load capacity in short and long journal bearings of squeeze film lubrication are obtained. Reason-Narang Rapid technique is applied for load capacity and analyzed numerically for viscosity variation and thermal effects. Graphs are plotted for various parameters eccentricity, film thickness and viscosity variation.



R = Radius of the Shaft. L = Length of the Bearing.
W = Load on the Shaft. V = Approach Velocity of the Shaft.
Ob = Center of the Bearing Oj= Center of the Shaft.
e = Eccentricity. h = Fluid Film Thickness.

Fig (1.1): Geometry of a Squeeze Film journal Bearing

1.2 BASIC EQUATION

Consider the flow of the lubricant as two layer fluid in journal bearing as shown in fig (1.1). The equation governing to the fluid flow in the bearing is given by equation

$$\frac{\partial}{\partial x}\left[\frac{h^3}{12\mu}F\frac{\partial p}{\partial x}\right]+\frac{\partial}{\partial z}\left[\frac{h^3}{12\mu}F\frac{\partial p}{\partial z}\right]=U\frac{dh}{dt} \quad (1)$$

Here $F=\dfrac{(1-\frac{a}{h})^3(k-1)+1}{k}$ (2)

Here h is the film thickness is given by

$$h=c(1+\varepsilon\cos\theta)$$

$$\frac{\partial h}{\partial t} = c\frac{d\varepsilon}{dt}\cos\theta \quad (3)$$

Where c = r-R is the clearance width and $\varepsilon = \frac{e}{c}$ is the eccentricity ratio as shown fig (1.1)
By substituting eq (3)in (4), we get the modified Reynolds equation is

$$\frac{\partial}{\partial x}\left[\frac{h^3}{12\mu}F\frac{\partial p}{\partial x}\right] + \frac{\partial}{\partial z}\left[\frac{h^3}{12\mu}F\frac{\partial p}{\partial z}\right] = Uc\frac{d\varepsilon}{dt}\cos\theta$$
(4)

Where $F = \frac{(1-\frac{a}{h})^3(k-1)+1}{k}$ and $\mu = \mu_0(\frac{h}{h_0})^q$
Then

$$\frac{\partial}{\partial x}\left[\frac{h^3}{12\mu_0(\frac{h}{h_0})^q}F\frac{\partial p}{\partial x}\right] + \frac{\partial}{\partial z}\left[\frac{h^3}{12\mu_0(\frac{h}{h_0})^q}F\frac{\partial p}{\partial z}\right] = Uc\frac{d\varepsilon}{dt}\cos\theta$$
(5)

Now non-dimensional parameters are
x=Rθ, dx=Rdθ, $\bar{a} = \frac{a}{c}$, $\bar{h} = \frac{h}{c}$, $\lambda = \frac{L}{2R}$, (6)

The modified Reynolds equation in a non-dimensional form can be written as

$$\frac{\partial}{\partial\theta}\left[\bar{h}^3 h^{-q}\bar{F}\frac{\partial p}{\partial\theta}\right] + \frac{1}{4\lambda^2}\frac{\partial}{\partial\bar{z}}\left[\bar{h}^3 h^{-q}\bar{F}\frac{\partial p}{\partial\bar{z}}\right] = 12\frac{\mu_0 R^2 U}{c^2}\frac{d\varepsilon}{dt}\cos\theta \quad (7)$$

The non-dimensionless pressure is given by

$$\bar{p} = \frac{pc^2}{U\mu_0 R^2\frac{d\varepsilon}{dt}} \quad (8)$$

By substituting (8) in (7), it becomes

$$\frac{\partial}{\partial\theta}\left[\bar{h}^{(3-q)}\bar{F}\frac{\partial\bar{p}}{\partial\theta}\right] + \frac{1}{4\lambda^2}\frac{\partial}{\partial\bar{z}}\left[\bar{h}^{(3-q)}\bar{F}\frac{\partial\bar{p}}{\partial\bar{z}}\right] = 12\cos\theta \quad (9)$$

Where $\bar{F} = \frac{(1-\frac{a}{h})^3(k-1)+1}{k}$

The boundary conditions for the equation (8) are

$$\bar{p} = 0, \ at \ \theta = \frac{\pi}{2}, \ \frac{3\pi}{2} \quad (10)$$

$\bar{p} = 0$ at $\bar{z} = \pm\frac{1}{2}$

$$\frac{\partial\bar{p}}{\partial\bar{z}} = 0 \ \ at \ \ \bar{z} = 0$$

Where θ the circumferential angle, z is bearing axis parallel to the shaft axis

II. SHORT BEARING ANALYSIS

If λ≤ 0.5 it is called short bearing or narrow bearing. Neglecting pressure variation in x
Direction, the modified Reynolds equation reduces to

$$\frac{\partial}{\partial\bar{z}}\left[\bar{h}^{(3-q)}\bar{F}\frac{\partial\bar{p}}{\partial\bar{z}}\right] = 48\lambda^2\cos\theta \quad (11)$$

Integrating the above equation (11) twice, the equation becomes

$$\bar{p} = \frac{48\lambda^2\cos\theta\bar{z}^2}{2\bar{h}^{(3-q)}\bar{F}} + \frac{c_1}{\bar{F}\bar{h}^{(3-q)}}\bar{z} + c_2 \quad (12)$$

Where c_1 and c_2 are constants of integration and evaluated using boundary conditions given in equation(10), we get

$$c_1 = 0 \ c_2 = \frac{48\lambda^2\cos\theta}{\bar{h}^{(3-q)}\bar{F}}\left(\frac{1}{8}\right)$$
(13)

Substituting equation(13) in (12), the pressure for a short bearing becomes

$$\bar{p} = \frac{24\lambda^2\cos\theta}{\bar{h}^{(3-q)}\bar{F}}\left(\bar{z}^2 + \frac{1}{4}\right)$$
(14)

Pressure at the centre line of the bearing is, i.e., $\bar{z}$ =0 then

$$\bar{p} = \frac{6\lambda^2\cos\theta}{\bar{h}^{(3-q)}\bar{F}}$$
(15)

Therefore the non-dimensional pressure for short bearing is

$$\bar{p}_s = \frac{6\lambda^2\cos\theta}{\bar{h}^{(3-q)}\bar{F}}$$
(16)

The load carrying capacity is

$$W_s = 2\int_{\frac{\pi}{2}}^{\frac{3\pi}{2}}.\int_0^{\frac{L}{2}} PR\text{Cos}\,\theta dz$$
(17)

$$W_s = 2\frac{\mu_0 UR^3\frac{d\varepsilon}{dt}L}{h_0 c^2}\int_0^{\frac{3\pi}{2}}\frac{6\lambda^2 Cos^2\theta}{\bar{h}^{(3-q)}\bar{F}}d\theta$$
(18)

And the dimensionless load carrying capacity is given by

$$\overline{W}_s = \frac{h_0 W_s c^2}{\mu_0 U R^3 \frac{d\varepsilon}{dt} L} = 6\lambda^2 \int_{\frac{\pi}{2}}^{\frac{3\pi}{2}} \frac{Cos^2\theta}{\overline{h}^{(3-q)}\overline{F}} d\theta \quad (19)$$

Where $\overline{F} = \frac{(1-\frac{a}{h})^3(k-1)+1}{k}$

III. LONG BEARING ANALYSIS

If λ > 2, it is called long bearing. That is the bearing is infinitely long in axial direction and the pressure is constant in that direction. Thus neglecting the

$\frac{\partial p}{\partial z}$, the modified Reynolds equation reduces to

$$\frac{\partial}{\partial\theta}\left[\overline{h}^{(3-q)}\overline{F}\frac{\partial\overline{p}}{\partial\theta}\right] = 12\cos\theta \quad (20)$$

Integrating (1.20) with respect to θ,

We get $\overline{h}^{(3-q)}\overline{F}\frac{\partial\overline{p}}{\partial\theta} = 12\sin\theta + B$ (21)

Where B is the integral constant

Applying the boundary condition in (21)

$$\frac{\partial\overline{p}}{\partial\theta} = 0 \ at \ \ \theta = \pi$$

Then the constant B=0 then

$$\frac{\partial\overline{p}}{\partial\theta} = \frac{12\sin\theta}{\overline{h}^{(3-q)}\overline{F}}$$

(22)

Again integrating (21) and applying the boundary conditions

$\overline{p} = 0, at\theta = \frac{\pi}{2}, \frac{3\pi}{2}$, $\overline{p} = 0$ at $\overline{z} = \overline{+}\frac{1}{2}$, $\frac{\partial\overline{p}}{\partial\overline{z}} = 0 at$ $\overline{z} = 0$

Then we get dimensionless pressure as

$$\overline{p}_l = 12\int_0^{\frac{\pi}{2}} \frac{\sin\theta}{\overline{h}^{(3-q)}\overline{F}} d\theta \quad (23)$$

Load capacity W_l for the long bearing is

$$W_l = 2L\int_0^{\pi} PR\sin\theta d\theta$$

$$W_l = \frac{\mu_0 U R^3 \frac{d\varepsilon}{dt} L}{h_0 c^2} \int_0^{\pi} \frac{24 \ \sin^2\theta}{\overline{h}^{(3-q)}\overline{F}} d\theta$$

(24)

And the dimensionless load capacity is

$$\overline{W}_l = \frac{h_0 W_l c^2}{\mu_0 U R^3 \frac{d\varepsilon}{dt} L} = 24\int_0^{\pi} \frac{\sin^2\theta}{\overline{h}^{(3-q)}\overline{F}} d\theta \quad (25)$$

Where $F = \frac{(1-\frac{a}{h})^3(k-1)+1}{k}$

IV. FINITE BEARING ANALYSIS

For finite bearings, the two dimensional Reynolds equation is solved using Rapid-Narang technique. If p, p_s and p_l are the pressure in finite, narrow and long bearings respectively, then the relationship between them is

$$\frac{1}{p} = \frac{1}{p_s} + \frac{1}{p_l}$$

(26)

The finite bearing pressure is

$$p = \frac{p_s p_l}{p_s + p_l}$$

(27)

LOAD CARRYING CAPACITY

As the load is proportional to the pressure, the load carrying capacity for the finite bearing is $\frac{1}{W_f} = \frac{1}{W_s} + \frac{1}{W_l}$

$$W_f = \frac{W_s W_l}{W_s + W_l} \quad (28)$$

By substituting the short and long bearing load equations(19) and (25) in the above equation(28) the finite bearing load carrying capacity in non-dimensional form is

$$\overline{W} = \frac{W_f c^2}{\mu U R^3 \frac{d\varepsilon}{dt} L} = \frac{W_s W_l}{W_s + W_l} \quad (29)$$

Equation(29) is solved numerically and graphs have been plotted for different values of various parameters.

V. RESULTS AND DISCUSSION

In fig (1.2) the load carrying capacity is plotted with $'a'$, for different values of 'k'. As the parameter $'a'$ increases the load capacity decreases with the decrease values of k<1 and the load capacity increases with increase values of k>1.

In fig (1.3) the load carrying capacity is plotted with 'a', for different values of eccentricity ratio 'epc'. As the parameter 'a'increases the load capacity increases with the increase values of eccentricity 'epc'.

In fig (1.4) the load carrying capacity is plotted with 'q' for different values of 'a'. As the parameter 'q'increases the load capacity decreases with the increase of'a'.

In fig (1.5) the load carrying capacity is plotted with 'q' for different values of'k'. As the parameter 'q'increases the load capacity decreases with increase values of 'k'.

In fig (1.6) the load carrying capacity is plotted with 'q' for different values of eccentricity 'ε'. As the parameter 'q'increases the load capacity decreases with the increase of eccentricity 'ε'.

1.4 GRAPHS

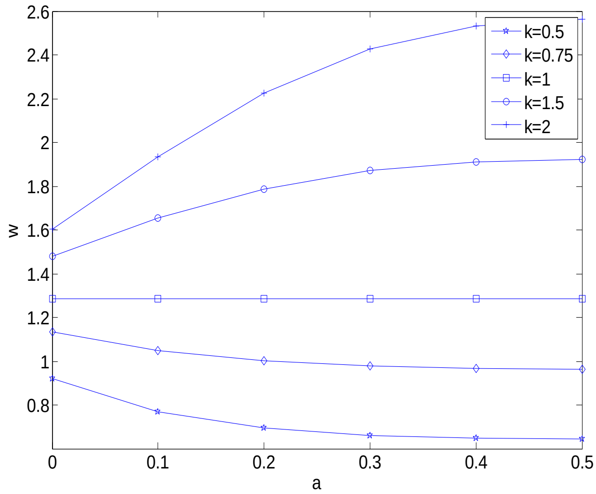


Fig (1.2): Dimensionless load Vsperipheral thicknessa for various k at q=0.1,epc=0.4,λ=0.2

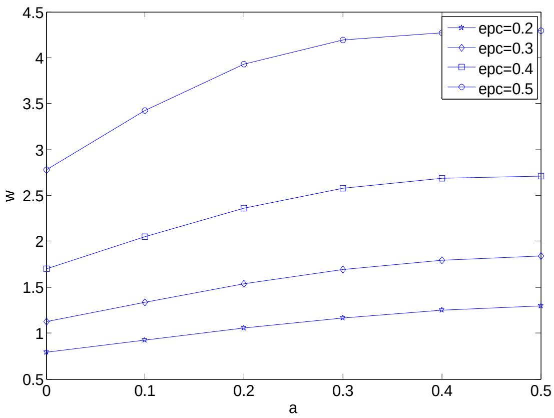


Fig (1.3): Dimensionless load Vsperipheral thickness a for various 'epc'at k=2,q=0.1,λ=0.2

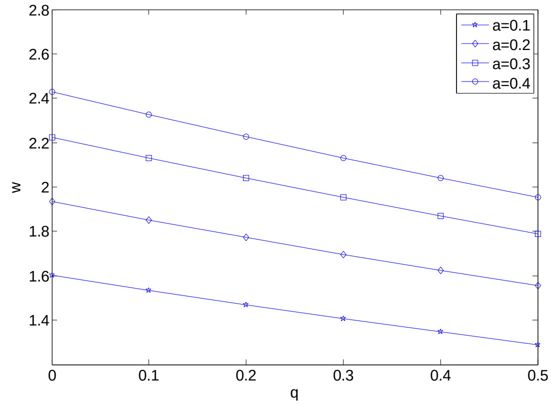


Fig (1.4): Dimensionless load Vsthermal effect for various a at k=2,epc=0.4,λ=0.2

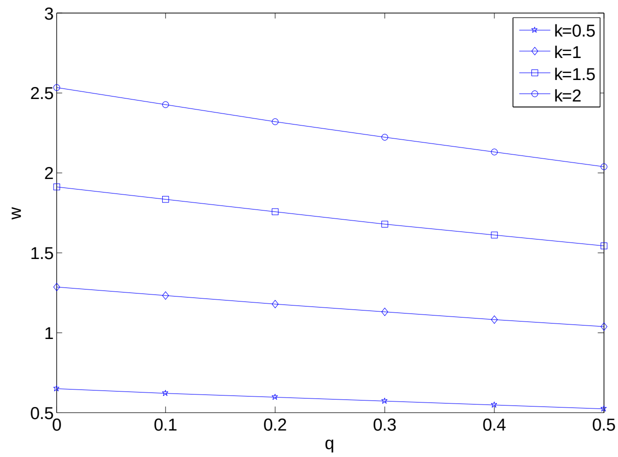


Fig (1.5): Dimensionless load Vsthermal effect for various k at a=0.5,epc=0.4,λ=0.2

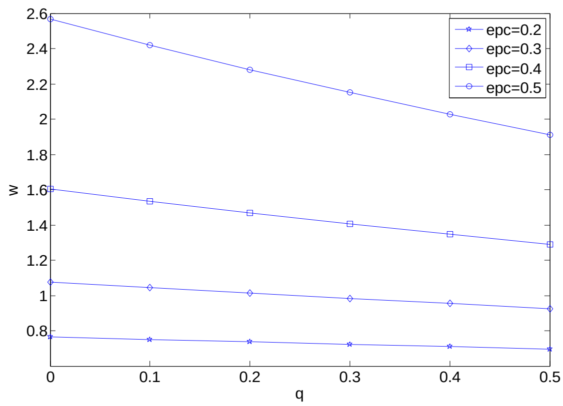


Fig (1.6): Dimensionless load Vsthermal effect for various 'epc' at k=2,a=0.1,λ=0.2

SUMMARY

The cases of short and long journal bearing are analyzed and are applied to study the load capacity with various parameters numerically and graphs are plotted. It is shown that the load capacity increases due to high viscous layer near periphery and decreases due to low viscous layer.

VI. NOMEMCLATURE

a The mean height of surface asperities in the symmetric roughness case
h Film thickness
c Radial clearance
e Eccentricity
ε Eccentricity ratio
μ Viscosity of the base lubricant
p Hydrodynamic pressure
W Load carrying capacity
R Radius of the shaft
R Radius of the bearing
k Ratio of the viscosities near the surface to the purely hydrodynamic zone

U Velocity of the surfaces in the case of one-dimensional form
x,*y*,*z* Cartesian coordinates
μ Viscosity of the base lubricant
q Thermal factor

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