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COMPREHENSIVE ANALYSIS OF LOAD CAPACITY IN SPHERICAL BEARINGS CONSIDERING SURFACE ROUGHNESS AND THERMAL EFFECTS

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Abstract: This study investigates the behavior of squeeze film lubrication in spherical bearings, accounting for variations in viscosity and the influence of heat. Graphical representations are constructed, and analytical expressions for load capacity and squeezing time are derived and systematically analyzed. The findings illustrate that the presence of a high viscous layer near the periphery contributes to an increase in load capacity and squeezing time, while a low viscous layer results in a decrease in both parameters. To assess the thermal impact on load capacity and squeezing time in spherical bearings, a parameter denoted as "q" is introduced and scrutinized across different values.
Key Words: squeeze film, viscosity, eccentricity, thermal effect, film thickness, squeezing time etc.,

INTRODUCTION

This paper explores the phenomenon of squeeze film lubrication, which occurs when two lubricated surfaces approach each other with a normal velocity. The thin layer of lubricant between these surfaces serves as a cushion, preventing direct contact. The duration needed for the lubricant to be displaced depends on factors such as surface configuration, fluid properties, and applied load. Typically, squeeze film analysis focuses on understanding the relationship between load carrying capacity and the rate of approach.

Spherical bearings, designed to allow angular rotation about a central point in two orthogonal directions, find widespread application in scenarios requiring rotational motion adjustment. These bearings accommodate changes in alignment of the rotation axis, making them essential in various fields.

This paper specifically investigates the squeeze film lubrication of spherical bearings, considering the influence of viscosity variation and thermal effects. It derives expressions for load capacity and squeezing time, which are then subjected to numerical analysis. Graphical representations are employed to provide insights into the behavior of the system under study.

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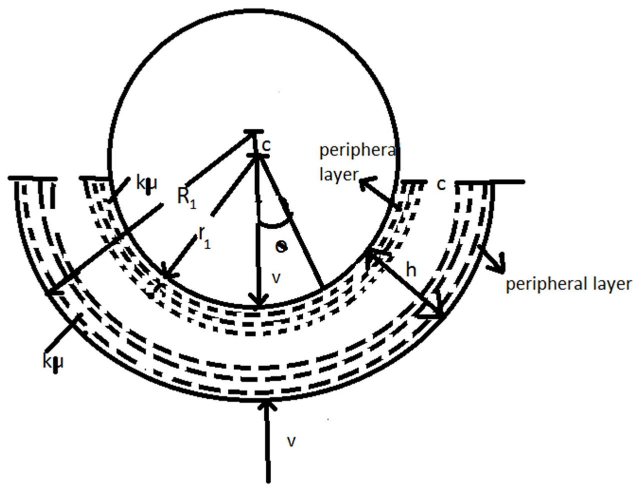

Fig (1.1): SQUEEZE FILM IN SPHERICAL BEARING

SQUEEZE FILM LUBRICATION IN SPHERICAL BEARING:

Consider squeezing between two eccentric spherical surfaces of radii r_i and R_i which are approaching each other with a normal velocity V as shown in Fig (1.1).

The film thickness h is given by h = c (1- εcosθ) where c = R_1-r_1 is the clearance width and $\varepsilon = \frac{e}{c}$ is the eccentricity ratio

The flow flux can be derived as

$$Q = \left[\frac{F}{r}\frac{dp}{d\theta} 2\pi r_1 \sin\theta\right] \quad (1.1)$$

The flux Q obtained from the equation of continuity is

$$Q = 2\pi r_1 V \sin^2\theta \quad (1.2)$$

Where $F = \frac{(1-\frac{a}{h})^3(k-1)+1}{k}$ (1.3)

From (1.1) and (1.2) $\frac{dp}{d\theta} = \frac{r_1 V \sin\theta}{F}$ (1.4)

Integrating (1.4) equation using the boundary condition

$p = 0 at \theta = \frac{\pi}{2}$ We get the expression for pressure distribution as

$$p(\theta) = \int_0^\theta \left[\frac{r_1 V \sin\theta}{F}\right] d\theta \quad (1.5)$$

Considering thermal effect and viscosity, μ can be taken as $\mu = \mu_0 (\frac{h}{h_0})^q$ (1.6)

Where q is thermal factor

Then $F = \frac{1}{12\mu_0 (\frac{h}{h_0})^q} \frac{[(1-\frac{a}{h})^3(k-1)+1]}{k}$ (1.7)

The load capacity W is given by

$$W = 2\pi r_1^2 \int_0^{\frac{\pi}{2}} p \sin\theta \cos\theta \, d\theta \qquad (1.8)$$

Using (1.5) in (1.8) we get the load capacity, W as

$$W = 2\pi r_1^3 V \int_0^{\frac{\pi}{2}} \left[\frac{\sin^2\theta \cos\theta}{F}\right] d\theta \qquad (1.9)$$

Where $F = \frac{h_0{}^{q} h^{-q}}{\mu_0 \, 12} \frac{[(1-\frac{a}{h})^3(k-1)+1]}{k}$ (1.10)

And squeeze time 't' for the surfaces to approach from the initial eccentric position (ε= 0) to a final eccentric position ($\varepsilon = \varepsilon_1$) we get

$$t = \int_0^{\varepsilon_1} I_1 \, d\varepsilon \qquad (1.11)$$

Where $I_1 = \int_0^{\frac{\pi}{2}} \left[\frac{\sin^2\theta \cos\theta}{F}\right] d\theta$ (1.11)

Equations (1.9) and (1.11) are solved numerically and graphs are plotted.

RESULTS AND DISCUSSION:

Graphical Figures from (1.2) to (1.7) are plotted for the load capacity and the squeezing time with 'a', 'q' for various parameters 'ε',' k'.

Fig (1.2) is plotted for the load capacity with 'a' for different 'k'. From this figure we can see that the load capacity increases with the increase of 'a' for k>1and the load capacity decreases for k<1. When k=1 in the case of single layer the load capacity has no effect as 'a' increase.

Fig (1.3) is plotted for the load capacity with 'q' for different 'ε'. From this figure we can see that the load capacity decreases with increasing 'q' and the load capacity decreases for increasing values of eccentricity 'ε'.

Fig (1.4) is plotted for the load capacity with 'q' for different 'k'. From this figure we can see that the load capacity decreases with increasing 'q' and the load capacity increases for increasing values of 'k'

Fig (1.5) is plotted for the load capacity with 'q'or different 'a'. From this figure we can see that the load capacity decreases with the increasing 'q' and the load capacity increases for increasing values of 'a' at k>1.

Fig (1.6) is plotted for the squeezing time with 'a' for different 'k'. From this figure we can see that the squeezing time increases with the increasing 'a' for k>1 and the squeezing time decreases for k<1.

Fig (1.7) is plotted for the squeezing time with 'q' for different 'k'. From this figure we can see that the squeezing time decreases with the increasing 'q' and the squeezing time increases for increasing 'k' values.

GRAPHS:

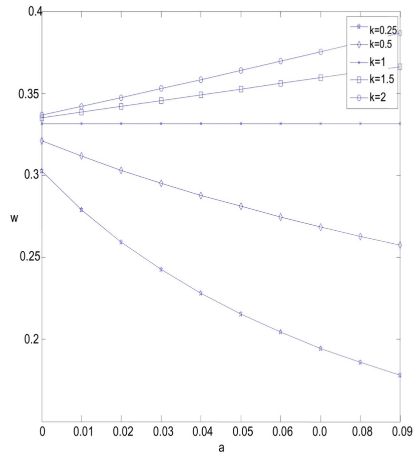

Fig (1.2): The load carrying capacity with ‘a’ capacity with ‘q’ for various ‘k’, ε=0.1,q=0.1

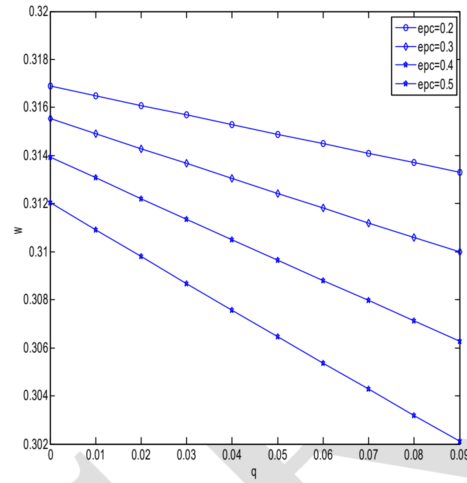

Fig (1.3): The load carrying for various ‘ε’, at k=0.4 and a=0.

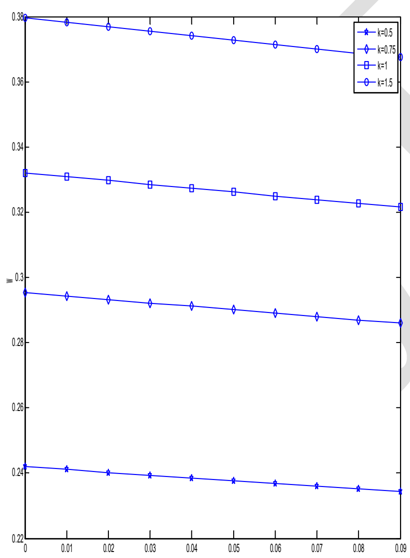

Fig (2.4): The load carrying capacity with ‘q’ with‘q’for various ‘k’, a=0.01 and ε=0.5

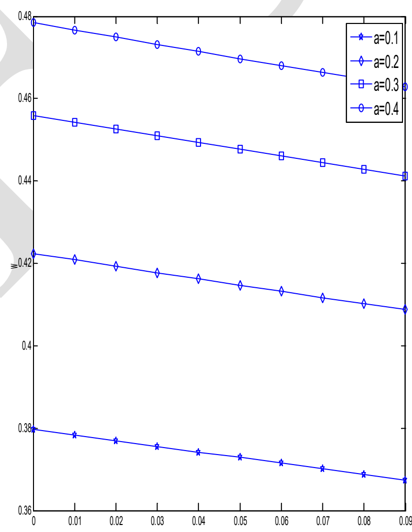

Fig (2.5): The load carrying capacity for various ‘a’, k=1.5 and ε=0.5

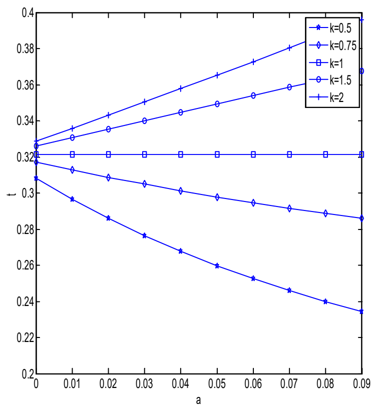

Fig (2.6): The squeezing time with 'a' for various 'k', ε=0.2 to 0.3 and q=0.1

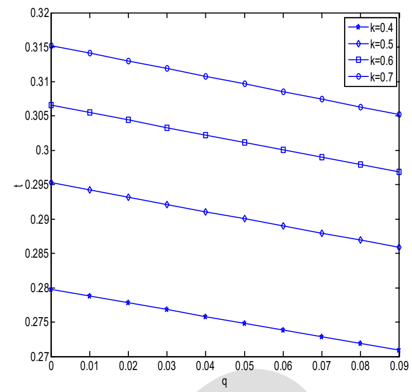

Fig (2.7): The squeezing time with 'q' for various 'k', a=0.03 and ε=0.2 to 0.3

CONCLUSION

- In this paper the squeeze film lubrication of spherical bearing considering viscosity variation and thermal effects are analyzed.
- A parameter 'q' is introduced to see the thermal effect
- From the graphs

It is observed that the load capacity decreases as thermal factor increases.
It is observed that the time of squeezing is decreasing as thermal factor increases.
It is shown that the load capacity and the time of squeezing increase due to high viscous layer near the periphery,
decreases due to low viscous layer.

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