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Effect Of Roughness On Performance Of a Finite Journal Bearing

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Abstract

Efforts have been made to analyze the performance characteristics of a finite rough journal bearing. The bearing surfaces are transversely rough. The roughness of the surfaces is charcterised by employing the Christensen-Tonder model. The associated stochastically averaged Reynold's type equation is solved with appropriate boundary condition to obtain the pressure distribution in turn, which gives the expression for Load Carrying Capacity (LCC). The results presented in graphical form establish that the transverse roughness induces an adverse effect on the bearing system. However, the situation remains comparatively better in the case of negatively skewed roughness, when negative variance is in place.

Key Words: *Journal Bearing Load Carrying Capacity (LCC), roughness, skewness.*

1. Introduction

The theory of journal bearing has been extensively discussed by Majumdar, B.C and Hemrock, B.J, [1].Wu et.al. [2], proposed a design idea based on quadratic programming algorithm for an infinite journal bearing with optimized sleep zone on the wearing sleep surface. Lau et.al.[3],carried out an experimented study on positioning control of a smart journal bearing based on GMM (Gaint Magnetostrictive Material) actuators. Sahu et.al [4] launched a thermodynamic analysis for a journal bearing through a numerical investigation for application point of view. The study of the effect of surface roughness on the hydrodynamic lubrication of bearing system has attracted many researchers in this area. Patir and Cheng [5] proposed an average flow model for deriving the Reynolds type equation which is applicable to any general surface roughness structure. Christensen [6] suggested a new stochastic averaging approach for the study of the effect of roughness on the hydrodynamic lubrication of bearings. Christensen and Tonder [7,8] proposed a general analysis for transverse and longitudinal of one dimensional surface roughness patterns based on the general probability density function. Tzeng and Seibel [9] studied the effect of roughness. Deheri and Andharia [10] have analyzed the effect of surface roughness on the performance characteristics of one dimensional slider bearing with a general probability density function for the random variable characterizing the surface roughness. Lin et.al. [11] investigated surface roughness effects on the oscillating squeeze film behavior of long partial journal bearing. Rusma et.al. 2011 [12] considered lubrication of journal bearing considering the combined effect of couple stress and reughness. Here, it was proved that the couple stresses increased the Load Carrying Capacity (LCC) while the roughness effects depended on the pattern. Ighil et.al. 2011 [13] made use of textured surfaces with different shapes of Micro-cavities and at different locations to improve the performance of a hydrodynamic journal bearing.The results carried out in the study are presented in graphical form. It is noticed that the transverse roughness induces an adverse effect on the bearing system. If the roughness parameters are equal to zero, then the present study reduces to the study of long bearing. The effect of skewness indicates that the load carrying capacity decreases as positive skewness increases. Here, it has been sought to analyze the effect of transverse roughness on the performance of a finite journal bearing.

2. Analysis

The configuration of the bearing system is shown below where in the film thickness h is constant over two regions.

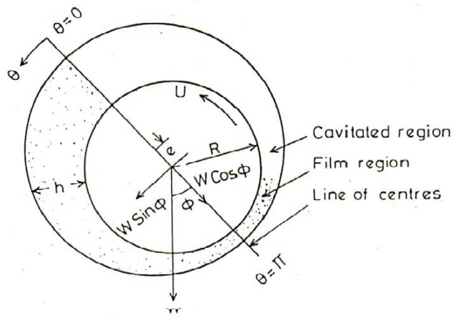


Figure :1 Configuration of bearing system.

Boegli,C.P.(1947),[15] had given approximate solution based on two assumption, (i) the pressure functions along the length and width of the bearing are independent and (ii) the pressure function along the bearing in the direction of motion is the same as that of an infinitely long bearing solution. This solution is in between the idealized bearing approximation and the full solution. The method of solution given here is for finite slider bearing. But it can be easily applied to a finite journal bearing.The governing differential equation for a finite bearing using incompressible lubricant of constant viscosity is given by

$$\frac{\partial}{\partial x}\left(h^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial z}\left(h^3\frac{\partial p}{\partial z}\right)=6\eta U\frac{dh}{dx} \quad ....(1)$$

where η is a viscosity of lubricant.

Using the following non-dimensional quantities

$$\bar{h}=h\,|\,h_2,\ \bar{x}=x\,|\,B,\ \bar{z}=z\,|\,L,$$

$$\bar{p}=\frac{ph_2{}^2}{6\eta UB'}$$

in Eq. (1), one obtains

$$\frac{\partial}{\partial \bar{x}}\left(\bar{h}^3\frac{\partial \bar{p}}{d\bar{x}}\right)\left(\frac{B}{L}\right)^2\frac{\partial}{d\bar{z}}\left(\bar{h}^3\frac{\partial \bar{p}}{d\bar{z}}\right)=\frac{d\bar{h}}{d\bar{x}} \quad .... (2)$$

Here h_2 is the minimum film thickness and L and B are length and width of the rectangular slider. Let $\bar{p}=f(\bar{x})f(\bar{z})$ and substituting this into Eq. (2) and noting assumption (i), we get

$$\frac{\partial}{\partial \bar{x}}\left(\bar{h}^3 f(\bar{z})\frac{df(\bar{x})}{d\bar{x}}\right)+\left(\frac{B}{L}\right)^2\bar{h}^3 f(\bar{x})\frac{d^2f(\bar{z})}{d\bar{z}^2}=\frac{d\bar{h}}{d\bar{x}}$$

……………………(3)

In Eq. (3), $\bar{h}$ is assumed to be function of *x* only.

Eq. (3) is solved at the point where the pressure is maximum. i.e., where $\frac{df(\bar{x})}{d\bar{x}}=0.$

This leads to the following equation

$$\frac{f(\bar{z})}{\left(\frac{B}{L}\right)^2 f(\bar{x})}\frac{d^2f(\bar{x})}{d\bar{x}^2}+\frac{d^2f(\bar{z})}{d\bar{z}^2}=\frac{d\bar{h}/d\bar{x}}{\left(\frac{B}{L}\right)^2\bar{h}^3 f(\bar{x})}$$

………………………………….…..... (4)

Using assumption (ii), we can write

$$3\bar{h}^2\frac{d\,f(\bar{x})}{d\,\bar{x}}\frac{d\,\bar{x}}{d\,\bar{x}}+\bar{h}^2\frac{d^2f(\bar{x})}{d\,\bar{x}^2}=\frac{d\,\bar{h}}{d\,\bar{x}} \quad ..... (5)$$

At the point of maximum pressure

$$\frac{d\,f(\bar{x})}{d\,\bar{x}}=0 \ \text{ and so } \ \frac{d^2f(\bar{x})}{d\,\bar{x}^2}=\frac{d\,\bar{h}\,|\,d\,\bar{x}}{\bar{h}^3}$$

………………………………………….….... (6)

Following the stochastical modeling of Christensen-Tonder, we get

$$\frac{d^2f(\bar{z})}{d\,\bar{z}^2}+\frac{f(\bar{z})}{\left(\frac{B}{L}\right)^2}\cdot\frac{d\bar{h}/d\,\bar{x}}{G(1)\,f(\bar{x})}=\frac{d\,\bar{h}\,|\,d\,\bar{x}}{\left(\frac{B}{L}\right)^2 G(1)\,f(\bar{x})}$$

……………………………….... (7)

Where,

$$G(1)=1+3\alpha+3\alpha^2+3\sigma^2+3\sigma^2\alpha+\alpha^3+\varepsilon$$

Note that, $\frac{d\,\bar{h}/d\,\bar{x}}{f(\bar{x})}$ is a negligible quantity

So, let $C=\frac{d\,\bar{h}/d\,\bar{x}}{f(\bar{x})}$

∴ Eq. (7) can be written as

$$\frac{d^2f(\bar{z})}{d\,\bar{z}^2}+\frac{f(\bar{z})}{\left(\frac{B}{L}\right)^2}\cdot\frac{C}{G(1)}=\frac{C}{\left(\frac{B}{L}\right)^2 G(1)} \quad .... (8)$$

Putting $k=\frac{C}{G(1)\left(\frac{B}{L}\right)^2}$ in equation (8)

One gets, $\frac{d^2f(\bar{z})}{d\,\bar{z}^2}+k\,f(\bar{z})=k$ ………… (9)

The solution of Eq. (9) is given by

$$f(\bar{z})=-\left(\frac{e^k-1}{e^k-e^{-k}}\right)(e^{k\bar{z}}+e^{-k(1-\bar{z})}) \quad .....(10)$$

The value of k can be evaluated at $\bar{h}=\bar{h}_m$ and $\bar{p}=\bar{p}_{\max}$.

The ratio of W/W_∞ can be calculated from the foregoing study. As $f(\bar{x})$ is $\bar{p}_\infty$, the pressure function of the infinite bearing, the ratio W/W_∞ is simply the integral of $f(\overline{z})$ of Eq. (10).

Thus, $$\frac{W}{W_\infty} = 1 - \frac{2(1-e^{-k})^2}{k(1-e^{-2k})} \quad \text{.......................(11)}$$

Knowing the load capacity of an infinitely long bearing, the actual load capacity can be computed from Eq. (11)

3. Results and Discursion:

It is seen that $\frac{W}{W_\infty} = 1 - \frac{2(1-e^{-k})^2}{k(1-e^{-2k})}$ .The expression involved ,is dependent on various parameters such as ε, α, σ, C and $\frac{B}{L}$. Setting the roughness parameters to be zero, this analysis reduces to the study of a long bearing as out lined in Basu et.al. [16]

Figure: 2 Variation of Load carrying capacity with respect to ε for various values of α.

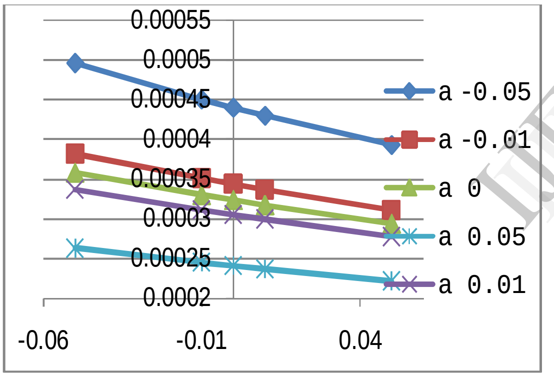


Figure: 3 Variation of Load carrying capacity with respect to ε for various values of σ.

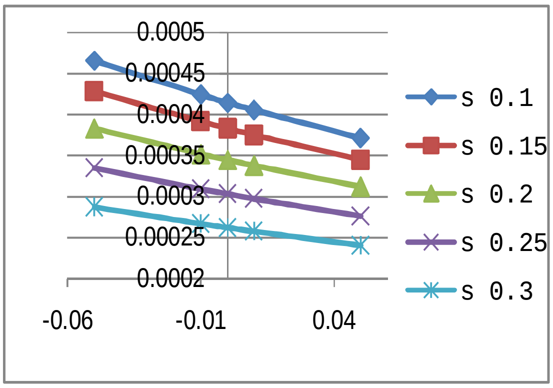


Figure: 4 Variation of Load carrying capacity with respect to ε for various values of C.

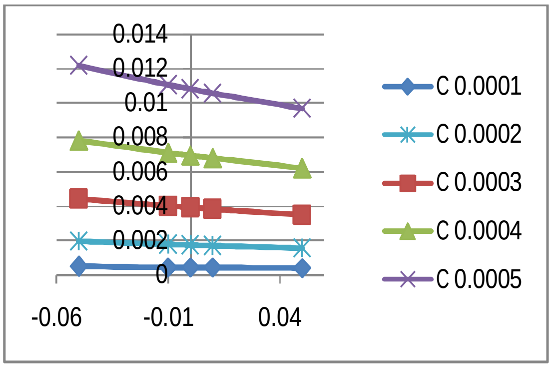
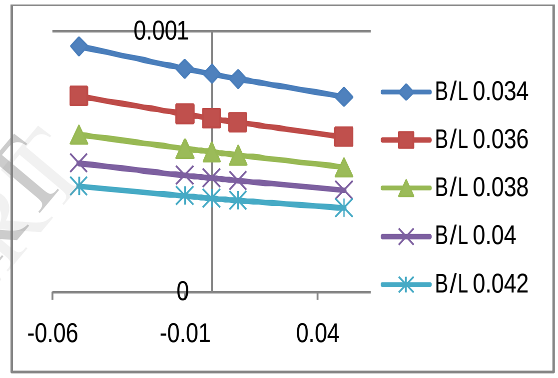


Figure: 5 Variation of Load carrying capacity with respect to ε for various values of B/L.



The effect of skewness presented in figures (2) to (5) indicate that the load carrying capacity decreases as positive skewness increases while negatively skewed roughness increases the load carrying capacity, The positive effect of the negatively skewed roughness is relatively more in the case of standard deviation, while there is a nominal adverse effect registered by standard deviation.

Figure: 6 Variation of Load carrying capacity with respect to α for various values of σ.

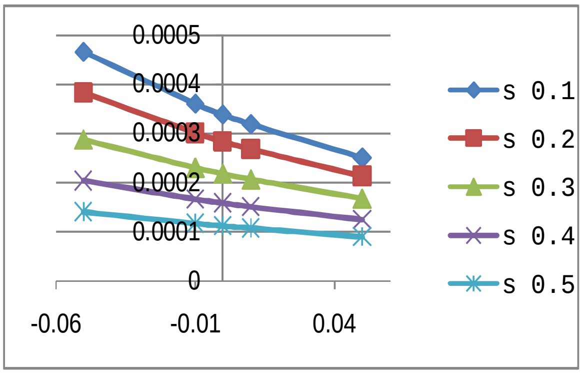


Figure: 7 Variation of Load carrying capacity with respect to α for various values of C.

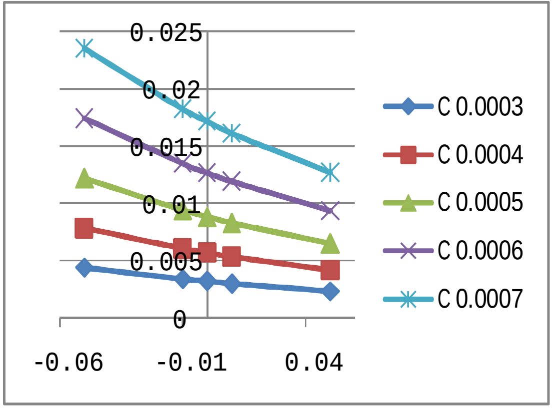
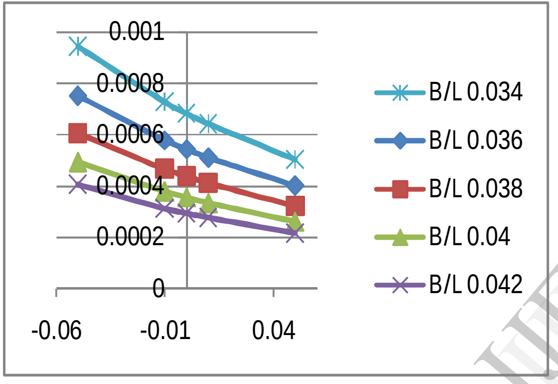


Figure: 8 Variation of Load carrying capacity with respect to α for various values of B/L.



The effect of variance on LCC in given in figures (6) to (8). It is interesting to note that variance follows the path of the skewness so for as the LCC is concerned. Accordingly the positive effect of negative variance gets enhanced by negatively skewed roughness.

Figure: 9 Variation of Load carrying capacity with respect to σ for various values of B/L.

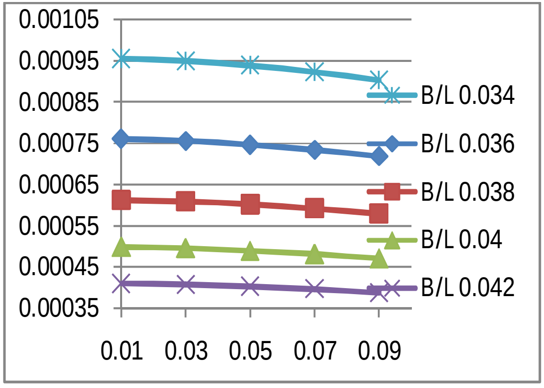
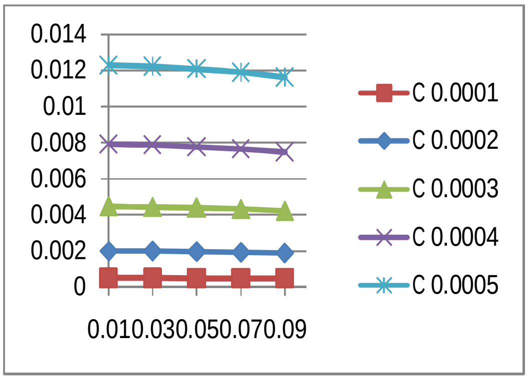
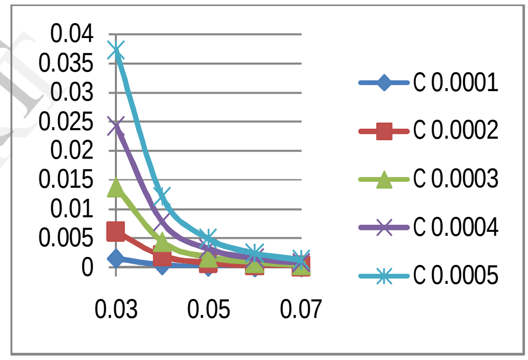


Figure: 10 Variation of Load carrying capacity with respect to σ for various values of C.



The fact that the standard deviation has a moderately adverse effect in depicted in figures (9) and (10)

Figure: 11 Variation of Load carrying capacity with respect to B/L **for various values of** C.



Lastly from Figure (11), it is observed that the adverse effect of C is comparatively more for small values of the ratio $\frac{B}{L}$.

4. Conclusion :

Although, The effect of transverse roughness is adverse in general, there exist some scopes for a relatively better performance in the case of negatively skewed roughness particularly when negative variance is involved. This investigation make sure that the effect of C is important, equally for enhancing the bearing performance characteristics. Lastly, this article makes it clear that the roughness must be given due consideration while designing this type of leering systems. This is all the more crucial from bearings life period point of view.

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