ROUGHNESS EFFECT IN SHORT BEARING.

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ABSTRACT

This paper aims to investigate the performance of a magnetic fluid based transversely rough short bearing. A magnetic fluid is taken as the lubricant. A stochastic random variable with non-zero mean, variance and skewness characterizes the roughness. The fluid film pressure then is obtained by solving the stochastically average Reynold's equation with appropriate boundary conditions. This results in the calculation of the load carrying capacity. It is observed that the magnetization introduces a sharp increase in the load carrying capacity while the load carrying capacity decreases(although negligibly).A comparison of this study with the conventional lubricant establishes that at least there is 2.58 times increase in the load carrying capacity here. Besides this investigation offers an additional degree of freedom in terms of the form of the magnitude of the magnetic field from design point of view.

KEYWORDS Short Bearing , Magnetic Fluid ,Rough Surface , Load Carrying Capacity.

INTRODUCTION

The hydrodynamic lubrication of slider bearing has been investigated by several investigators (Pinkus and Sternlitcht[1], Cameron[2], Archibald[3], Lord Rayleigh[4], Prakash and Vij[5],Patel and Gupta[6]).

However, bearing surfaces could be roughened through the manufacturing process, the wear and the impulsive damage. In order to account for the effect of surface roughness Tzeng and Seibel[7],Christensen Tonder[8,9].Utilized a stochastic concept and introduced an averaging film model to lubricated surfaces. Significant contributions for the roughness spectra came from Christensen and Tonder[10,11,12], Guha[13], Taranga et.al.[14], Christensen and Tonder[15], Andharia et. al.[15].

In all the above studies conventional lubricants were used. The use of magnetic fluid as a lubricant modifying the performance of the bearing has been very well recognized. For the details regarding the magnetic fluid and properties one can turn to Bhat[16].

Agrawal[18] considered the configuration of Prakash and Vij[5] in the presence of a magnetic fluid lubricant and found its performance better than the one with conventional lubricant. Bhat and Deheri[19] modified the analysis of Agrawal[18] by investigating a magnetic fluid based porous composite slider bearing with its slider consisting of an inclined pad and a flat pad. Magnetic fluid increased the load carrying capacity and unaltered the friction and shifted the centre of pressure towards the inlet.

Here it has been sought to investigate the performance of a transversely rough short bearing in the presence of a magnetic fluid lubricant, where in the effect of standard deviation is predominant.

ANALYSIS

Figure.1 describes the geometrical configuration of the bearing system which is infinitely short. The slider moves in the X-direction with the uniform velocity u. The length of the bearing is L and breadth B is in Z-direction where B<<L. The dimension
B being very small, the pressure gradient \( \frac{\partial p}{\partial z} \) is much larger than the pressure gradient \( \frac{\partial p}{\partial x} \) and hence the latter can be neglected.

Fig. 1 Configuration of the bearing system.

The lubricant film is considered to be isoviscous and incompressible and the flow is laminar. The magnetic field is oblique to the stator as in Agrawal[18]. Following the discussions carried out by Prajapati[20] regarding the effect of various forms of magnitude of the magnetic field, here the magnitude of the magnetic field is expressed as

\[
M^2 = KB^2 \sin(4\pi \frac{z^2}{B^2}) \quad \ldots (1)
\]

where \( K \) is a suitably chosen constant from dimensionless point of view [Bhat and Deheri[21]]

The bearing surfaces are assumed to be transversely rough. Following the discussion regarding the modeling of roughness by Christensen and Tonder [10,11,12], the thickness \( h(x) \) of the lubricant film is taken as

\[
h(x) = \bar{h}(x) + h_s
\]

where \( \bar{h}(x) \) is the mean film thickness and \( h_s \) is the deviation from the mean film thickness characterizing the random roughness of the bearing surfaces. \( h_s \) is considered to be stochastic in nature and governed by the probability density function

\[
f(h_s) = \begin{cases} 
\frac{35}{32} \left( 1 - \frac{h_s^3}{c^3} \right)^3, & -c \leq h_s \leq c \\
0, & \text{elsewhere}
\end{cases} \quad \ldots (2)
\]

where \( c \) is the maximum deviation from the mean film thickness. The mean \( \mu \), the standard deviation \( \sigma \) and the parameter \( \varepsilon \) which is the measure of symmetry of the random variable \( h_s \), are defined by the relationships

\[
\alpha = E(h_s),
\]

\[
\sigma^2 = E((h_s - \alpha)^2)
\]

and

\[
\varepsilon = E((h_s - \alpha)^3)
\]

where \( E \) denotes the expected value defined by

\[
E(R) = \int Rf(h_s) dh_s \quad \ldots (3)
\]

It is well-established that in this type of bearing system the standard deviation plays a central role as compared to the other two parameters. Hence under the usual assumptions of hydromagnetic lubrication and neglecting the effect of variance and skewness the governing Reynolds equations [Bhat[16], Prajapati[20], Deheri, Andharia and Patel[22]] comes out to be

\[
\frac{d^2}{dz^2} \left( p - \frac{\mu_0 \mu M^2}{2} \right) = \frac{6 \mu u}{g(h)} \frac{dh}{dx} \quad \ldots (4)
\]

where

\[
g(h) = h^3 + 3\sigma^2 h
\]

while, \( \mu_0 \) is the magnetic susceptibility, \( \mu \) is the free space permeability, and \( \mu \) is the lubricant viscosity.

The concerned boundary conditions are

\[
p = 0 ; \quad z = \pm \frac{B}{2}.
\]

\[
\frac{dp}{dz} = 0 ; \quad z = 0 \quad \ldots (5)
\]

Introducing the dimensionless quantities,

\[
m = \frac{h_1 - h_2}{h_2}, \quad Z = \frac{z}{B}, \quad P = \frac{h_2^3}{\mu u B^2} P,
\]

\[
\mu^* = \frac{h_2^3 K \mu_0 \mu}{\mu u}, \quad X = \frac{x}{L}
\]

one obtains the pressure distribution in dimensionless form as
The load carrying capacity then is determined by

\[ P = \frac{\mu^*}{2} \sin(4\pi Z^2) + \frac{3m h_2}{L} \left( \frac{1}{4} - Z^2 \right) \]

\[ \frac{1}{1 + m(1 - X)} \frac{1}{(1 + m(1 - X))^2 + \frac{3\sigma^2}{h_2^2}} \ldots (6) \]

The load carrying capacity then is determined by

\[ w = \int_{-h_2}^{h_2} \int_{0}^{1} p(x, z) dx dz \]

Thus, the dimensionless load carrying capacity is obtained from

\[ W = \frac{h_2^2}{\mu B^*} w \ldots (7) \]

and hence one finds that

\[ W = \mu^* \frac{\pi}{6} \frac{L h_2}{h_2 B} \]

\[ + \frac{1}{12} \frac{h_2^2}{\sigma^2} \frac{h_2}{B} \ln \left( \frac{1 + \frac{3\sigma^2}{h_2^2}}{(1 + m)^2 + \frac{3\sigma^2}{h_2^2}} \right) \ldots (8) \]

RESULTS AND DISCUSSION

It is evident that the pressure distribution is determined by Equation-6 while Equation-8 presents the expression for the dimensionless load carrying capacity. These performance characteristics depend on several parameters such as \( \mu^*, \frac{L}{h_2}, \frac{h_2}{B}, \frac{n}{h_2}, \frac{\sigma}{h_2} \) and \( m \). In the absence of magnetization this study reduces to the discussion carried out in Basu et. al.(2005).

The variation of load carrying capacity with respect the magnetization presented in Figures 2-5 for various values of \( \frac{L}{h_2}, \frac{n}{h_2}, \frac{\sigma}{h_2} \) and \( m \) respectively, makes it clear that the load carrying capacity increases sharply with increase in magnetization parameter. However, the effect of \( \frac{\sigma}{h_2} \) with respect to \( \mu^* \) tends to be neglected as can be seen from figure-5.
Figure 6-8 profile the distribution of the load carrying capacity with respect to the ratio \( \frac{L}{h_2} \) for different values of \( \frac{B}{h_2} \), \( m \) and \( \frac{\sigma}{h_2} \) respectively. It is clearly seen that the load carrying capacity increases significantly with the increases in \( \frac{L}{h_2} \). However, the effect of the standard deviation \( \frac{\sigma}{h_2} \) with respect to \( \frac{L}{h_2} \) is negligible (Figure-7).
The effect of $\frac{\mu}{h_2}$ on the load carrying capacity is given in Figure 9 and 10. It is observed that the already decreased load carrying capacity due to $\frac{\mu}{h_2}$ gets further decreased by the standard deviation. Of course, the effect of $\frac{\mu}{h_2}$ with respect to $\frac{\sigma}{h_2}$ is not that significant. Also observed is the fact that higher values of the aspect ratio $m$ cause sharp increase in load carrying capacity.

Lastly, Figure-11 underlines that the standard deviation induces a nominal decrease in the load carrying capacity. Thus, the negative effect of standard deviation can be minimized by the positive effect of the magnetization by suitably choosing the aspect ratio. A comparison of this study with the conventional lubricant suggests that at least there is 2.58 times increase in the load carrying capacity here.

CONCLUSION

Even if a suitable magnetic field is chosen, from bearing life period of view the
roughness must be accorded top priority while designing the bearing system.

REFERENCE


