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Original Article

Effect of hydromagnetic squeeze film between non-porous rough triangular plates

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Abstract

The current investigation analyse the impact of hydromagnetic squeeze film between non-porous rough triangular plates. The bearing surface are viewed transversely rough. The Christensen and Tonder model is embraced for transverse roughness. The concerned Reynolds type equations are solved with appropriate boundary conditions to get pressure distribution, which is used to get load carrying capacity. The outcomes are indicated graphically. The outcomes demonstrate that the magnetization parameter and conductivity increase load carrying capacity, while standard deviation decreases load carrying capacity. Further, the negative mean expands the load carrying capacity. So, appropriate values of magnetization parameter and conductivity improves the performance of bearing system by enhancing load carrying capacity. It is fascinating to take note of that qualities of bearing can be improved for non-porous squeeze film compare to porous squeeze film.

Keywords: hydromagnetic squeeze film, triangular plates, conductivity, Reynolds equation, roughness, load carrying capacity

1. Introduction

The principle of hydromagnetic lubrication theory from the mathematical point of view is the assessment of modified Navier stokes equations updated by Maxwell's conditions and Ohms law. Christensen and Tonder (1971, 1972, 1973) analyzed the discretion of the surface roughness utilized a stochastic way to deal with a mathematical roughness model of the bearing surface. The investigation of transverse and longitudinal roughness was explored. Bhat and Hingu (1978) considered the hydromagnetic squeeze film behaviour between two rectangular plates. It was examined that the modified action of the squeeze film due to applied magnetic field was more huge as compare to non-homogeneity of the porous facing. Patel and Gupta (1979) examined the impact of transverse magnetic field on the behaviour of squeeze film between porous plates of different geometry. The governing equation for the pressure distribution in the film region can be uncoupled and imparted as a Poisson distribution by utilizing an estimation, which in any case does not have any huge impact on the bearing qualities. Vadher, Deheri, and Patel (2008a) examined the impact of transverse roughness on the performance of hydro magnetic squeeze film porous triangular plates. It was talked about that the negative effect due to porosity and standard deviation could be limited by thinking about the positive effect of magnetization parameter and conductivity. Vadher, Deheri, and Patel (2008b) examined the performance of hydromagnetic squeeze film between rough porous infinitely long rectangular plates having effect of transverse magnetic field. It was inferred that the bearing with magnetic field support a load even in the absence of flow. Nanduvinamani, Fathima, and Jamal (2010) considered the joined effect of unidirectional surface roughness and magnetic on the performance characteristics between porous rectangular plates. It was seen that the pressure, load carrying capacity and squeeze film time expanded because of the impact of surface roughness. Shukla and Deheri (2017) talked about the impact of hydromagnetic squeeze film in transversely rough narrow width journal bearing. It was analysed that for better performance of bearing system, slip had to be considered minimum. Muhammad, Hayat, Alsaedi, and Qayyum (2017)

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considered time dependent squeezing flow of magneto hydrodynamic Jeffrey fluid between two parallel walls. It was examined that the increase in the squeezing parameter S_q increased in the velocity profile both suction and blowing cases. Hanumagowda, Siddangouda, Nagarajappa, and Kumar (2018) examined a magneto hydrodynamic squeeze lubrication of parallel stepped plates with a transverse magnetic field. The outcomes indicated that it increased the load carrying capacity and delayed in time of approach. Patel, Deheri, and Vadher (2019) examined the performance of a hydromagnetic squeeze film for rough porous annular plates by considering the impact of slip velocity when lower plate rotates. It was examined that the negative effect of porosity and roughness could be minimized by the positive effect of aspect ratio and conductivity. Tolani, Daliri, and Javani (2020) investigated a couple stress ferrofluid lubricant effects on the performance of squeeze film when external magnetic field was applied. The outcomes presumed that couple stress ferrofluid lubricant in the presence of the magnetic field increased performance of the squeeze film.

Here, it is important to examine the effect of hydromagnetic squeeze film between non-porous rough triangular plates.

2. Analysis

The geometry of the bearing system is represented as follows:

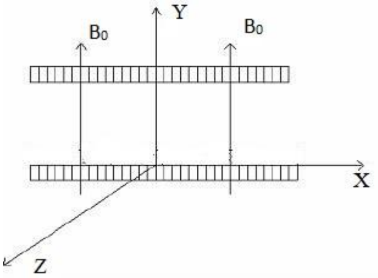

Figure 1. Configuration of the bearing system

The thickness h(x) is considered as

$$h(x) = \bar{h}(x) + h_s \tag{1}$$

Where $\bar{h}$ is the mean film thickness and h_s is the difference from the mean film thickness representing the random roughness of the bearing roughness. Here h_s is presumed to be stochastic in nature and given by the probability density function $f(h_s)$, represented as

$$f(h_s) = \begin{cases} \dfrac{32}{35b}\left(1 - \dfrac{h_s^2}{b^2}\right)^3 & -b \le h_s \le b \\ 0 & elsewhere \end{cases} \tag{2}$$

The mean α, the standard deviation σ and the parameter ε, which is the measure of symmetry associated with the random variable, h_s are determined by the relations

$$\alpha = E(h_s) \tag{3}$$

$$\sigma^2 = E\left[(h_s - \alpha)^2\right] \tag{4}$$

and

$$\varepsilon = E\left[(h_s - \alpha)^3\right] \tag{5}$$

Where E denotes the expected value defined by

$$E(R) = \int_{-c}^{c} R f(h_s)\, dh_s \tag{6}$$

The characterization of the roughness aspects can be acquired from Christensen and Tonder (1971, 1972, 1973). From Vadher, Deheri, and Patel (2008a) the hydromagnetic lubrication the modified Reynolds equation is

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial z^2} = \frac{{dh}/{dt}}{\left[\dfrac{2g(h)}{\mu M^3}\left(\tanh\dfrac{M}{2} - \dfrac{M}{2}\right)\right]} \times \frac{\phi_0 + \phi_1 + \dfrac{\tanh\left({M}/{2}\right)}{\left({M}/{2}\right)}}{\phi_0 + \phi_1 + 1} \tag{7}$$

Where $g(h) = h^3 + 3h^2\alpha + 3h\alpha^2 + 3h\sigma^2 + 3\sigma^2\alpha + \alpha^3 + \varepsilon$. Solving the equations with appropriate boundary conditions $p(x_1, z_1) = 0$ gives the expression for the pressure distribution in dimensionless form is given by

$$P = \frac{-ph^3}{\mu\, {dh}/{dt}\, 3\sqrt{3}a^2}$$

$$= \frac{\dfrac{1}{9\sqrt{3}} \cdot \left[(1 - x^*)\left(1 - \dfrac{\sqrt{3}}{2}z^* + \dfrac{1}{2}x^*\right)\left(1 + \dfrac{\sqrt{3}}{2}z^* + \dfrac{1}{2}x^*\right)\right]}{2\pi\left[\dfrac{2G}{M^3}\left(\tanh\dfrac{M}{2} - \dfrac{M}{2}\right)\right]} \times \frac{\phi_0 + \phi_1 + \dfrac{\tanh\left({M}/{2}\right)}{\left({M}/{2}\right)}}{\phi_0 + \phi_1 + 1} \tag{8}$$

Where $G = 1 + 3\alpha^* + 3\alpha^{*2} + 3\sigma^{*2} + 3\sigma^{*2}\alpha^* + \alpha^{*3} + \varepsilon^*$

and

$$\sigma^* = \frac{\sigma}{h},\ \alpha^* = \frac{\alpha}{h},\ z^* = \frac{z}{a},\ \varepsilon^* = \frac{\varepsilon}{h^3},\ x^* = \frac{x}{a}$$

Then the load carrying capacity given by

$$w = \int_{x=-2a}^{x=a} \int_{z=-(x+2a)/\sqrt{3}}^{z=(x+2a)/\sqrt{3}} p\, dx\, dz \tag{9}$$

is obtained in dimensionless form as

$$W = -\frac{wh^3}{27\mu\, {dh}/{dt}\, a^4}$$

$$= \frac{\dfrac{1}{20\sqrt{3}}}{\left[\dfrac{2G}{M^3}\left(\tanh\dfrac{M}{2} - \dfrac{M}{2}\right)\right]} \times \frac{\phi_0 + \phi_1 + \dfrac{\tanh\left({M}/{2}\right)}{\left({M}/{2}\right)}}{\phi_0 + \phi_1 + 1} \tag{10}$$

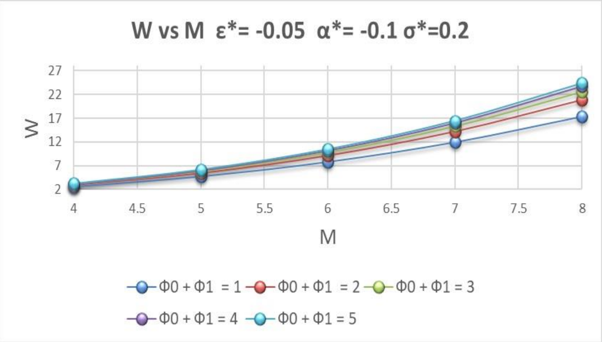

Figure 2. W versus M for different values of $\phi_0 + \phi_1$

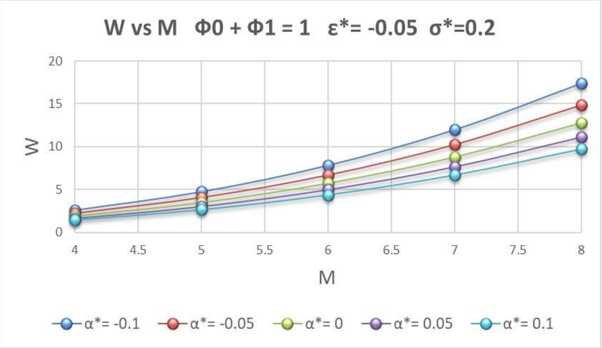

Figure 3. W versus M for different values of α*

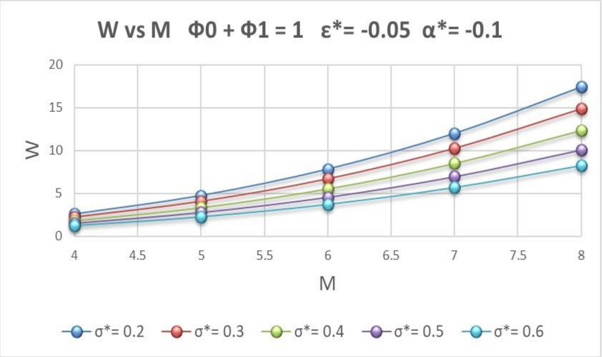

Figure 4. W versus M for different values of σ*

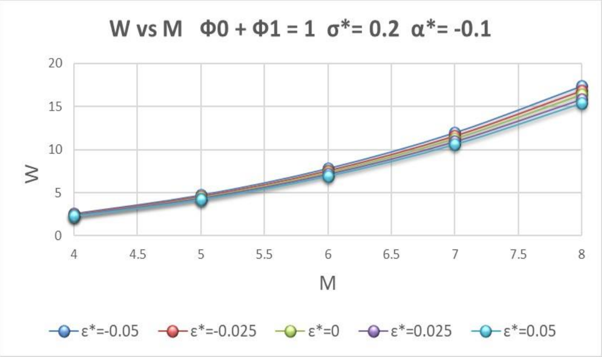

Figure 5. W versus M for different values of ε*

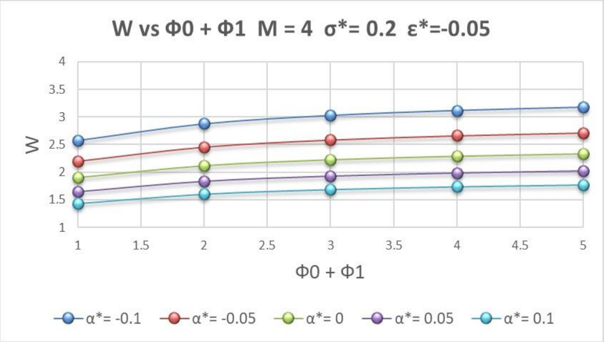

Figure 6. W versus $\phi_0 + \phi_1$ for different values of α*

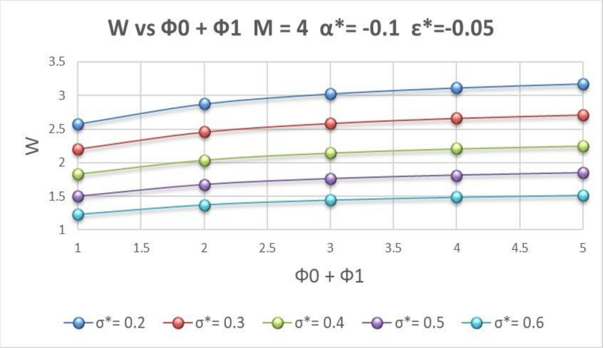

Figure 7. W versus $\phi_0 + \phi_1$ for different values of σ*

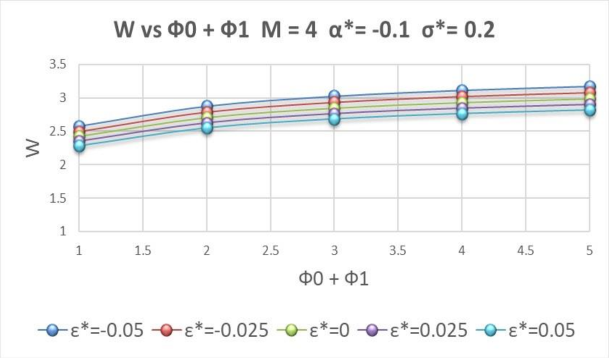

Figure 8. W versus $\phi_0 + \phi_1$ for different values of ε*

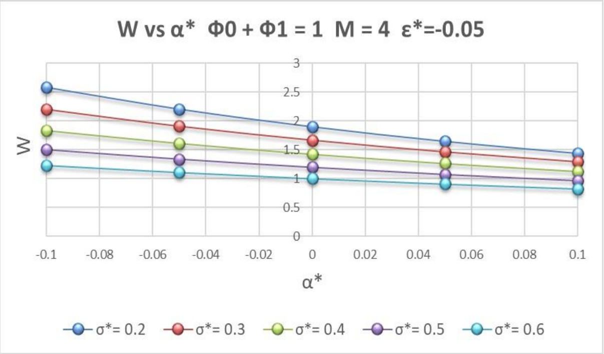

Figure 9. W versus α* for different values of σ*

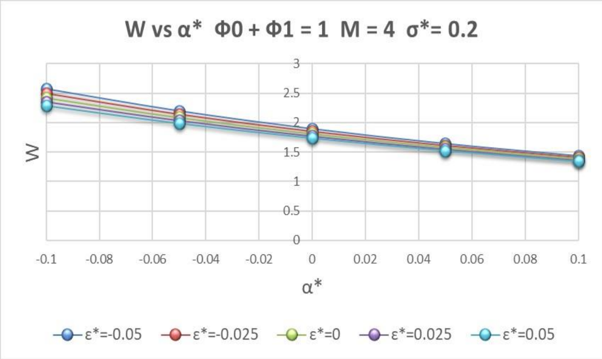

Figure 10. W versus α* for different values of ε*

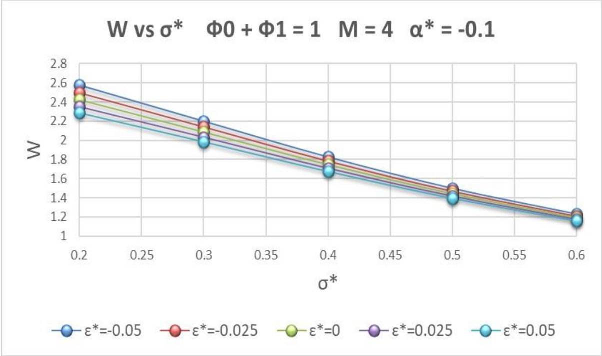

Figure 11. W versus σ* for different values of ε*.

3. Results and Discussion

Equation (8) represents dimensionless pressure while equation (10) gives dimensionless load carrying capacity. The results for rough porous surface bearings are reduced to Vadher, Deheri, and Patel (2008a). It can be seen that the pressure and load carrying capacity depends M, $\phi_0 + \phi_1$, α*, σ*and ε*.Moreover the impact of conductivity on load carrying capacity is from

$$\frac{\phi_0 + \phi_1 + \dfrac{\tanh\left(M/2\right)}{\left(M/2\right)}}{\phi_0 + \phi_1 + 1}$$

Otherwise, for large value of M, the term goes to $\dfrac{\phi_0 + \phi_1}{\phi_0 + \phi_1 + 1}$, as tanh $M \sim 1$ and $(2/M) \sim 0$, As both functions are increasing functions of $\phi_0 + \phi_1$, so from mathematical analysis, one can observe that the pressure and load carrying capacity increases as the value of conductivity $\phi_0 + \phi_1$ increased. Figures (2-5) show the variation of load carrying capacity with respect to M for different values of $\phi_0 + \phi_1$, α*, σ*and ε*.The results suggest that due to magnetization parameter, the load carrying capacity increases. The effect of skewness on load carrying capacity with respect to magnetization parameter is negligible. The variation of load carrying capacity with respect to conductivity for different values of α*, σ*and ε* can be seen from figures (6-8). The statistics shows that the efficiency of bearing improves as load carrying capacity increases with $\phi_0 + \phi_1$. The negative mean increases load can be seen from the figures (9 -10). In particular, from figure (10) one can see that the effect of skewness on load with respect to mean is marginal. Figure (11) suggests that the impact of skewness on load is negligible when σ* exceeds 0.5.

4. Conclusions

An investigation suggests that the negative effect due to standard deviation associated with roughness can be minimized by considering positive effect of magnetization parameter and conductivity parameter. It is advised that the roughness parameter must be considered while framing bearing. It is concluded that the bearing performance can be improved by considering non-porous squeeze film as compare to porous squeeze film. Proper values of magnetization parameter, conductivity parameter and for non porosity, bearing performance can be improved and will be utilized in industry to minimize maintenance. For future scope, the same discussion can be done for longitudinal roughness.

Nomenclature

α: Variance (m)
σ: Standard deviation (m)
ε: Skewness (m^3)
α*: Dimensionless variance
σ*: Dimensionless standard deviation
ε*: Dimensionless skewness
p: Lubricant Pressure (N/mm^2)
P: Dimensionless Pressure
w: Load carrying capacity (N)
W: Dimensionless load carrying capacity
μ: Viscosity (N-s/m^2)
$\phi_0 + \phi_1$: Conductivity
M: Magnetization parameter
h_0: Surface width of the lower plate (m)
h_1: Surface width of the upper plate (m)

References

Bhat, M. V., & Hingu, J. V. (1978). A study of the hydromagnetic squeeze film between two-layered porous rectangular plates. *Wear, 50*(1), 1-10.

Christensen, H., & Tonder, K. (1971). The hydrodynamic lubrication of rough bearing surfaces of finite width. *Journal of Tribology, 93*(3), 324-329.

Christensen, H., & Tonder, K. (1973).The hydrodynamic lubrication of rough journal Bearings. *Journal of Tribology, 95*(2), 166-172.

Hanumagowda, B. N., Siddangouda, A., Nagarajappa, C. S., & Kumar, J. S. (2018). Hydromagnetic squeeze film lubrication between parallel stepped plates. *International Journal of Research in Engineering, IT and Social Sciences, 8*(06), 258-266.

Muhammad, T., Hayat, T., Alsaedi, A., & Qayyum, A. (2017). Hydromagnetic unsteady squeezing flow of Jeffrey fluid between two parallel plates. *Chinese Journal of Physics, 55*(4), 1511-1522.

Naduvinamani, N. B., Fathima, S. T., & Jamal, S. (2010). Effect of roughness on hydromagnetic squeeze films between porous rectangular plates. *Tribology International, 43*(11), 2145-2151.

Patel, K. C., & Gupta, J. L. (1979). Behaviour of a hydromagnetic squeeze film between porous plates. *Wear, 56*(2), 327-339.

Patel, R. M., Deheri, G., & Vadher, P. A. (2019). Effect of slip velocity on the performance of hydromagnetic squeeze film between conducting rough porous annular plates with the lower plate rotating, *6*(8), 1-9.

Shukla, S., & Deheri, G. (2017). Hydromagnetic squeeze film in rough porous narrow journal bearing: A study of slip effect. *Tribology Online, 12*(4), 177-186.

Toloian, A., Daliri, M., & Javani, N. (2020). The performance of squeeze film between parallel triangular plates with a ferro-fluid couple stress lubricant. *Advances in Tribology, 2020*(3), 1-8.

Tønder, K., & Christensen, H. (1972). Waviness and roughness in hydrodynamic lubrication. *Proceedings of the Institution of Mechanical Engineers, 186*(1), 807-812.

Vadher, P. A., Deheri, G. M., & Patel, R. M. (2008a). Effect of surface roughness on the performance of hydromagnetic squeeze film between conducting porous infinitely long rectangular plates. *International Journal of Applied Mechanics and Engineering, 13*(2), 473-498.

Vadher, P. A., Deheri, G. M., & Patel, R. M. (2008b). Hydromagnetic squeeze film between conducting porous transversely rough triangular plates. *Journal of Engineering Annals of faculty of Engineering Hunedoara, 6*, 155-168.