Math. J. Interdiscip. Sci.Vol. 7, No. 2, March 2019, pp.93–101

CHITKARA

Mathematical Journal of Interdisciplinary Sciences

Journal homepage: https://mjis.chitkara.edu.in/

Influence of Ferrofluid Lubrication on Longitudinally Rough Truncated Conical Plates with Slip Velocity

M M Munshi[1*], A R Patel[2] and G M Deheri[3]

[1]*Alpha College of Engineering and Technology, Gujarat Technological University, Kalol, 382 721, Gujarat, India*

[2]*Vishwakarma Government Engineering College, Gujarat Technological University, Ahmedabad, 382 424, Gujarat, India*

[3]*Sardar Patel University, Vallabh Vidhyanagar, Anand, 388 120, Gujarat, India*

[*]Email: raiyan.munshi@gmail.com

ARTICLE INFORMATION

Received: 01 November, 2018
Revised: 13 January, 2019
Accepted: 21 February, 2019

Published online: March 6, 2019

Keywords:
Slip velocity, Ferrofluid, longitudinal roughness

DOI: https://doi.org/1015415/mjis.2019.72012

ABSTRACT

The study focuses on analyzing the effect of slip velocity in the case of a Ferrofluid squeeze film when the surface of truncated cone-shaped plates has a longitudinal roughness. Each oblique to the bottom plate was utilized by the external magnetic field. The bearing surface has a roughness that is designed with the help of a random stochastic variable having a nonzero mean, skewness and variance. The load carrying ability of a bearing system's surface is determined by calculating the dispersal of pressure in the system, which is calculated by using the associated stochastically average Reynolds' equation. The graphs obtained from the study shows that there is a correlation between the longitudinal surface roughness and the bearing system performance. The magnetic fluid lubrication has a positive impact on a system's bearing capacity. However, the load bearing capacity declines as a result of the effect of slip. A high negative skewness of the surface roughness also has a positive impact on a bearing's load carrying capacity. One interesting finding shows that contrasting to the results of transverse roughness, standard deviation positively impacts the load bearing capacity. This investigation suggests despite the im-portance of aspect ratio and semi vertical angle is significant for performance enhancement, it is also essential to maintain the slip at the lowest level.

1. Introduction

Various industrial applications including aerospace and aeronautical industries, nuclear and civil engineering, modern construction engineering amongst others make use of conical plates as crucial constitutional elements. The dynamic response of these conical plates is significantly impacted by various fluids (stationary or flowing) that they work with. That is why, it is crucial to study the behavior generated by different load types in order to ensure safe functioning in applications. A number of experimental and analytical studies have come forward recently that study the fluid effects on plates and shells. Flat and curved plates and circular cylindrical shells have been the major concern for most of them. While there hasn't been much work on the fluid effects on conical plates. Thin walled conical plates are used in many different engineering domains. From aircrafts and satellites in aerospace to submarines, waterborne ballistic missiles and torpedoes in ocean engineering and containment vessels in civil, conical shells have a lot of different applications.

Different researchers have come up with a number of ways to study the impact of surface roughness on bearing performance. (Christensen and Tonder 1969a, 1969b, 1970) utilized the concept of stochastic averaging and created a model with lubricated films having longitudinal and transverse roughness. (Burton 1963), (Berthe and Godet 1974) and (Gadelmawla *et. al.* 2002) used this model and came up with a different geometric configurations to understand the impact of surface roughness. When two distinct lubricating surfaces generate positive pressure by approaching each other in normal direction and supports a load, this phenomenon called the squeeze film. A squeeze film has a lot of different applications in automobile and domestic appliances. That is why, researchers like (Bhat and Deheri 1991, Lin *et. al.* 2013, Prakash and Vij 1973, Ting 1975) worked on studying the impact of a squeeze film bearing. (Neuringer and Rosensweig 1964) designed a basic model of flow to analyze the behavior of Ferrofluid with different external magnetic fields. A lot of papers have been written that study various bearing systems under the Neuringer and Rosensweig model, for example circular plates by (Bhat and Deheri 1992), (Patel *et. al.* 2012) in journal bearing and (Patel and Deheri 2011) in plane inclined slider bearing.

ISSN No.: 2278-9561 (Print) ISSN No.: 2278-957X(Online) Registration No. : CHAENG/2013/49583 Periodicity: Bi-Annually

(Patel and Deheri 2007) focused their study on analyzing the impact of magnetic fluid on bearing performance of porous truncated conical plates. (Deheri *et. al.* 2007) took their work further and focused on transverse roughness. They concluded that negative variance and negative skewness are crucial with appropriate semi vertical angle. (Andharia and Deheri 2011) further worked on this aspect by taking into account the longitudinal roughness. (Shimpi and Deheri 2014) took into account the slip velocity and deformation impact to extend the study of (Deheri *et. al.* 2007). (Shimpi and Deheri 2016) also studied truncated conical plates by taking into account longitudinal roughness, slip velocity and deformation. (Vadher *et. al.* 2011) worked on the study by using hydromagnetic bearing instead of hydrodynamic bearing. The squeeze films with a magnetic fluid base had an impact on conical plates which has been studied by a lot of researchers using a number of different parameters. For example, (Patel and Deheri 2007) used porosity, (Patel and Deheri 2013) studied the model using transverse roughness and porosity, (Andharia and Deheri 2010) worked on longitudinal roughness, (Patel and Deheri 2016) studied it by taking into account longitudinal roughness with slip velocity and (Patel *et. al.* 2017) worked with longitudinal roughness as well as deformation effect. The design of a structure from porous as well as fluid layer is derived by (Beavers and Joseph 1967). They considered slip boundary condition at the interface. Many researchers have worked with slip velocity; (Munshi *et. al.* 2017) used circular plates, (Shukla and Deheri 2013) worked on Rayleigh step bearing and (Shah and Bhat 2002) studied inclined slider bearing. From these studies, it can be concluded that slip place a crucial part in changing the bearing capacity of any system. This study aims to change and clearly define the findings (Andharia and Deheri 2011) to find the correlation between slip velocity and Ferrofluid squeeze film in truncated conical plates with roughness pattern of longitudinal.

2. Analysis

The system has two plates in the shape of truncated cones. The upper plate is in motion towards the lower plate.
The $h(x)$ is considered as

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

using the works of (Christensen and Tonder 1970, 1969a,b). Also, the study uses h_s using the probability density function

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

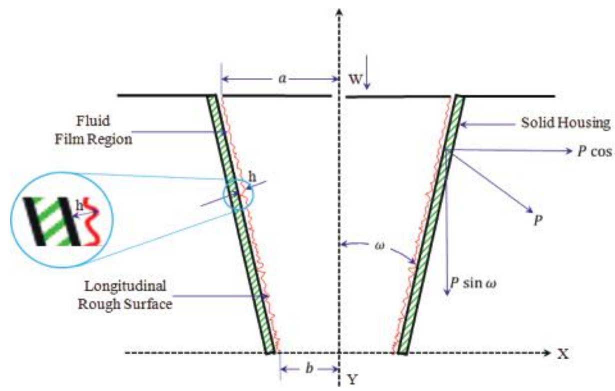


Figure 1. Configuration of truncated conical plates (Andharia and Deheri 2011)

In this case, c is the highest possible deviation from the average width of the film. α, σ and ε are considered in view of relationships

$$\alpha = E(h_s),\ \sigma^2 = E(h_s - \alpha)^2,\ \varepsilon = E(h_s - \alpha)^3 \tag{3}$$

In this equation, $E(\bullet)$ represents the expectancy operator which can be calculated by

$$E(\bullet) = \int_{-c}^{c} (\bullet) f(h_s)\, dh_s \tag{4}$$

Further, the magnetic field's magnitude is represented by (Andharia and Deheri 2011)

$$M^2 = k(a\,\mathrm{cosec}\omega - x)(x - b\,\mathrm{cosec}\omega),\ b < x < a \tag{5}$$

In the equation, k is the suitable constant. If we assume that the magnetic field existing external has developed as a result of a potential function, $\phi = \phi(x,z)$ making the equation

$$\cot\phi\frac{\partial\phi}{\partial x} + \frac{\partial\phi}{\partial z} = \frac{2x - a\,\mathrm{cosec}\omega - b\,\mathrm{cosec}\omega}{2(a\,\mathrm{cosec}\omega - x)(x - b\,\mathrm{cosec}\omega)} \tag{6}$$

The general hydrodynamic lubrication assumption modified Reynolds' (Andharia and Deheri 2011, Shimpi and Deheri 2014) equation as follows:

$$\frac{1}{x}\frac{d}{dx}\left[xh^3\frac{d}{dx}\left(\bar{p} - \frac{1}{2}\mu_0\bar{\mu}M^2\right)\right] = \frac{12\mu\dot{h}_0}{\sin^2\omega} \tag{7}$$

The averaging process of stochastic suggested by (Andharia and Deheri 2011), equation (7) takes the form

$$\frac{1}{x}\frac{d}{dx}\left[x\frac{1}{E(\bar{h}+h_s)^{-3}}\frac{d}{dx}\left(\bar{p} - \frac{1}{2}\mu_0\bar{\mu}M^2\right)\right] = \frac{12\mu\dot{h}_0}{\sin^2\omega}$$
$$\frac{1}{x}\frac{d}{dx}\left[x\frac{1}{m(\bar{h})}\frac{d}{dx}\left(\bar{p} - \frac{1}{2}\mu_0\bar{\mu}M^2\right)\right] = \frac{12\mu\dot{h}_0}{\sin^2\omega} \tag{8}$$

where

$$m(\bar{h},\bar{\alpha},\bar{\sigma},\bar{\varepsilon})=\bar{h}^{-3}\left[1-3\bar{\alpha}\bar{h}^{-1}+6\bar{h}^{-2}\left(\bar{\sigma}^{2}+\bar{\alpha}^{2}\right)-10\bar{h}^{-3}\left(\bar{\varepsilon}+3\bar{\sigma}^{2}\bar{\alpha}+\bar{\alpha}^{3}\right)\right] \tag{9}$$

The following dimensionless quantities are used,

$$H=\frac{\bar{h}}{h_0},\ X=\frac{x}{a},\ M(H,\bar{S},\alpha,\sigma,\varepsilon)=h_0^{3}m(\bar{h},\bar{\alpha},\bar{\sigma},\bar{\varepsilon}),\ \alpha=\frac{\bar{\alpha}}{h_0},\ \sigma=\frac{\bar{\sigma}}{h_0},\ \varepsilon=\frac{\bar{\varepsilon}}{h_0^{3}},\ K=\frac{b}{a},$$
$$\mu^{*}=\frac{-\mu_0\,\bar{\mu}\,h_0^{3}\,k}{\mu\,\dot{h}_0},\ P=\frac{-\bar{p}\,h_0^{3}}{\mu\,\dot{h}_0\,\pi(a^{2}-b^{2})\operatorname{cosec}\omega} \tag{10}$$

The related pressure limit settings are

$$P(K\operatorname{cosec}\omega)=0,\ P(\operatorname{cosec}\omega)=0 \tag{11}$$

Solving equation (8) with the aid of equation (11), the non-dimensional type of dispersal of pressure is

$$P=\frac{1}{2\pi\left(1-K^{2}\right)}\Big[\mu^{*}\left(1-X\sin\omega\right)\left(X-K\operatorname{cosec}\omega\right)+6\,M(H)\operatorname{cosec}^{3}\omega\left(\left(1-X^{2}\sin^{2}\omega\right)+2K^{2}\ln\left(X\sin\omega\right)\right)\Big] \tag{12}$$

where

$$M(H,\bar{S},\alpha,\sigma,\varepsilon)=\left[\frac{4+\bar{S}}{1+\bar{S}}\right]^{-1}\left[1-3\alpha\left(\frac{4+\bar{S}}{1+\bar{S}}\right)^{-1/3}+6(\sigma^{2}+\alpha^{2})\left(\frac{4+\bar{S}}{1+\bar{S}}\right)^{-2/3}-10\left(\frac{4+\bar{S}}{1+\bar{S}}\right)^{-1}(\varepsilon+3\sigma^{2}\alpha+\alpha^{3})\right] \tag{13}$$

The bearing ability of dimensionless type is obtained

$$\overline{W}=\frac{-h_0^{3}}{\mu\,\dot{h}_0\,\pi(a^{2}-b^{2})^{2}\,\pi^{2}\operatorname{cosec}^{2}\omega}\,w \tag{14}$$

$$\overline{W}=\frac{2}{\left(1-K^{2}\right)\operatorname{cosec}\omega}\left[\frac{\mu^{*}\operatorname{cosec}^{3}\omega(1-K)^{2}}{24\pi}+\frac{3M(H)\operatorname{cosec}^{5}\omega}{4\pi(1-K^{2})}\left(\left(1-K^{2}\right)\left(1-3K^{2}\right)-4K^{4}\ln(K)\right)\right] \tag{15}$$

where the load bearing capacity is calculated using

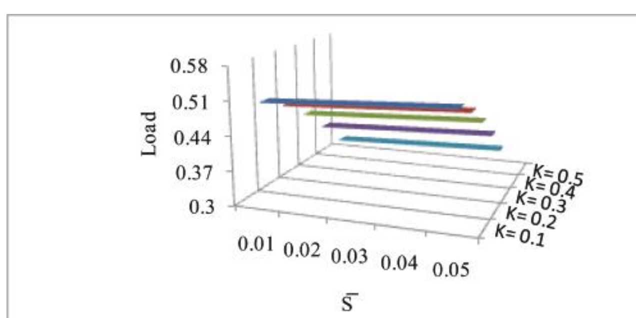
$$w=2\pi\int_{b\operatorname{cosec}\omega}^{a\operatorname{cosec}\omega}x\bar{p}\ dx \tag{16}$$

3. Results and Discussion

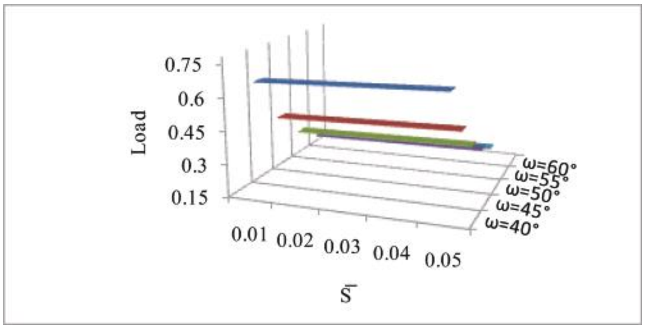
From equation (15), the load bearing ability increase as per the following equation

$$\frac{\mu^{*}}{12\pi}\operatorname{cosec}^{2}\omega\left(\frac{1-K}{1+K}\right)$$

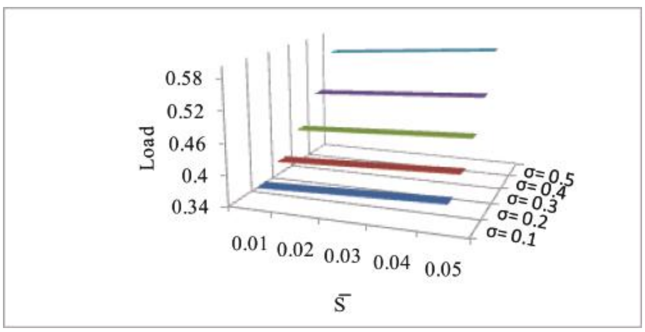
more than the regular lubricant-based bearing system. In the nonexistence of slip this investigation diminishes to the study of (Andharia and Deheri 2011). As the equation (15) is linear with regards to μ^{*}, a boost in the magnetization would introduce an enhancement in the load bearing ability. A comparison of overall performance with (Andharia and Deheri 2011) suggests that the impact of slip effect is not all bad. The graphical results are presented below.



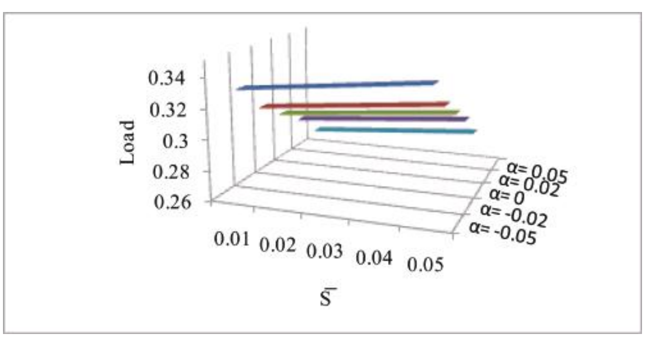
(a)K



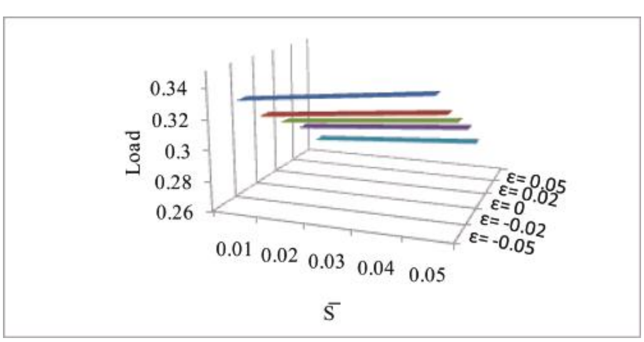
(b) ω



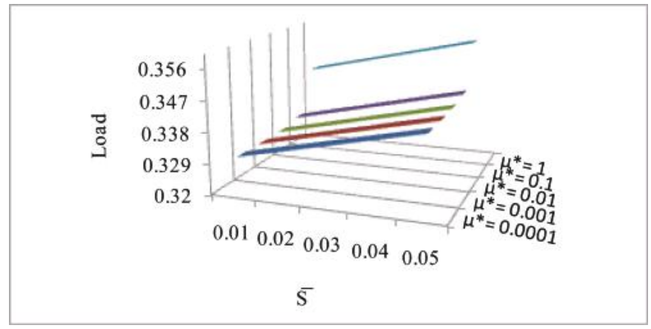
(c) σ



(d) α

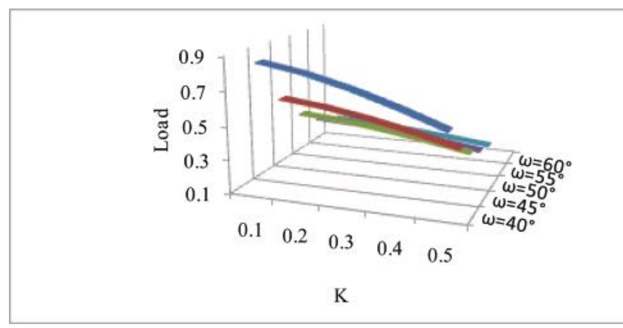


(e) ε

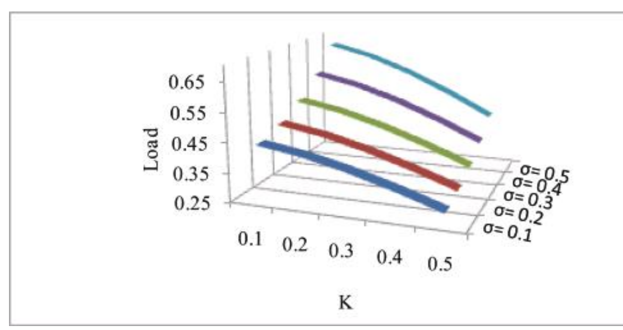


(f) μ^*

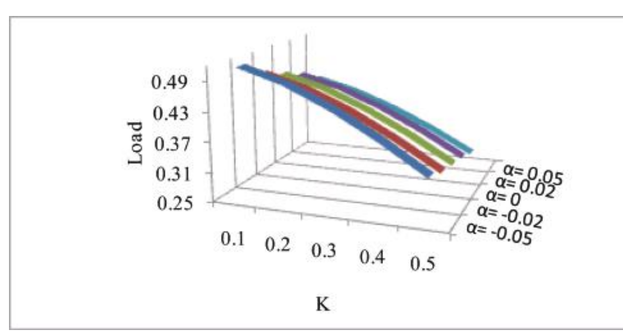
Figure 2. Trends of $\overline{W}$ concern to $\overline{S}$



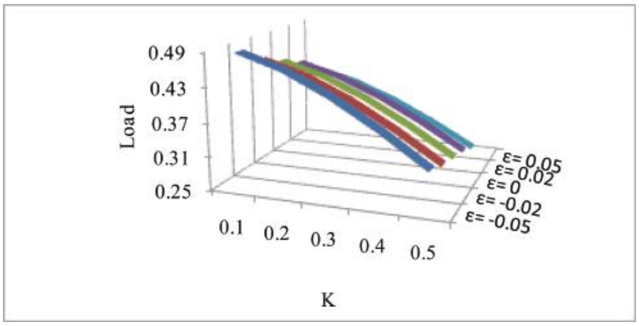
(a) ω



(b) σ

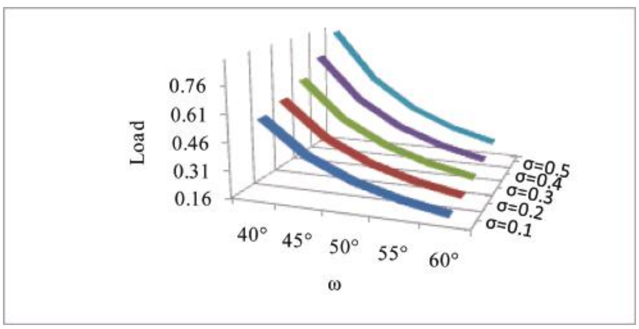


(c) α

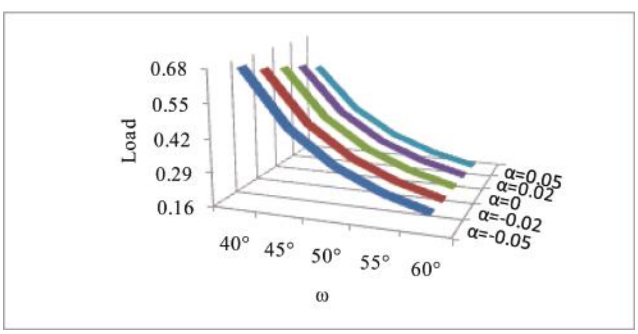


(d) ε

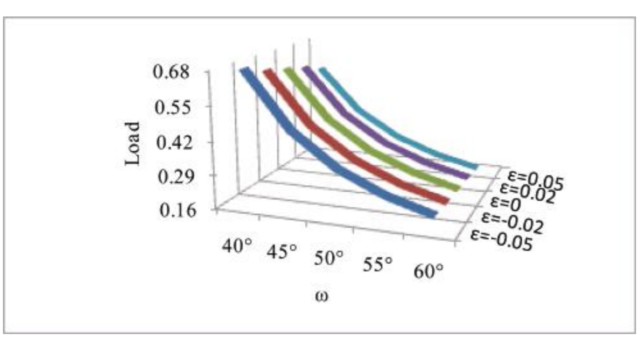
Figure 3. Trends of $\overline{W}$ concern to K



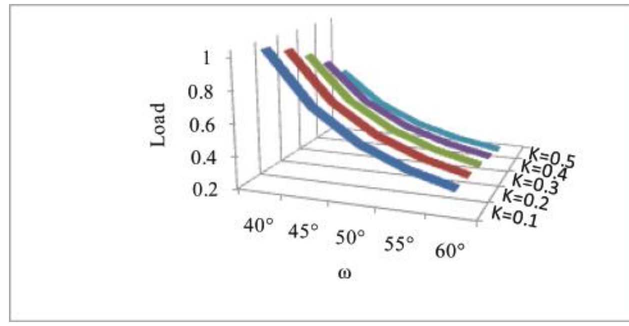
(a) σ



(b) α

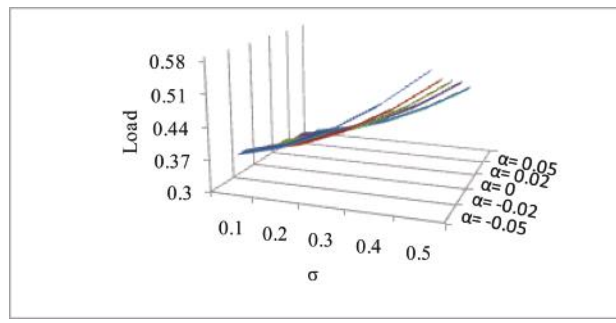


(c) ε

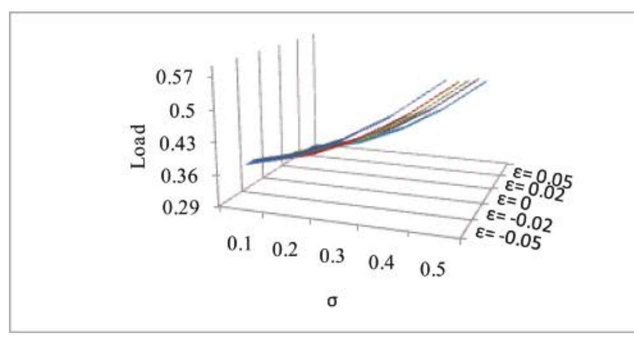


(d) K

Figure 4. Trends of $\overline{W}$ concern to ω

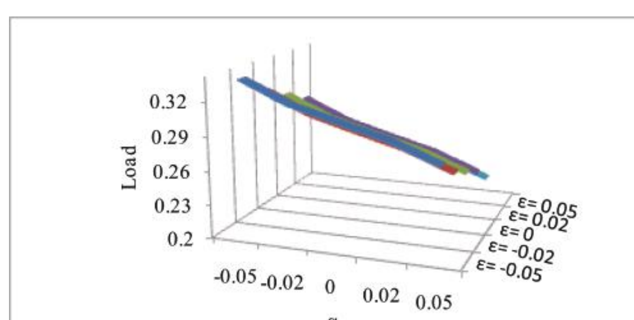


(a) α

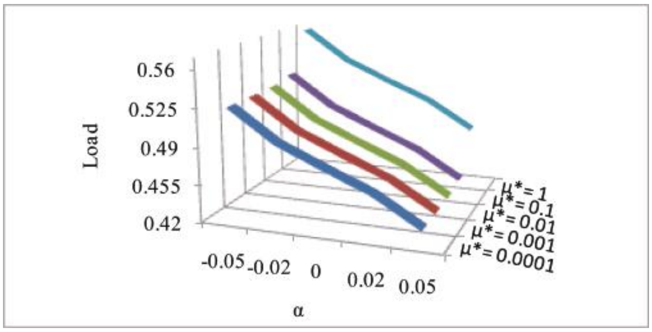


(b) ε

Figure 5. Trends of $\overline{W}$ concern to σ

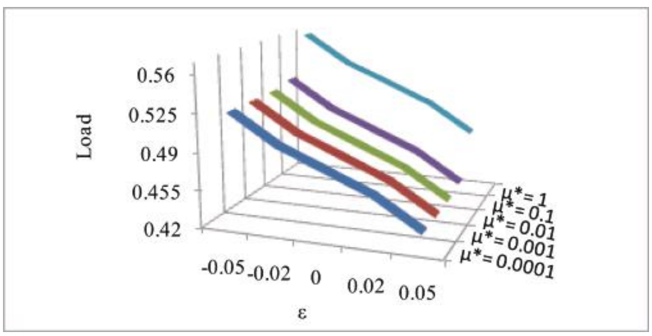


(a) ε



(b) μ^*

Figure 6. Trends of $\overline{W}$ concern to α



(a) μ^*

Figure 7. Trends of $\overline{W}$ concern to ε

Following conclusion can be drawn from the above load profiles.

1. There is a substantial increase because of the roughness standard deviation. This performance increases when there is a high negative skewness value for the surface roughness.
2. The slip velocity decreases the system's bearing capacity.
3. The positive impact of magnetization isn't strong enough to counter the adverse effect of roughness and slip velocity.
4. However, with an appropriate combination of aspect ratio and semi vertical angle of the cone, the adverse impact created by surface roughness can be decreased to a significant extent, especially in the case of smaller slip parameter values.

A comparison of the graphical results presented in (Deheri *et. al.* 2007) goes on to show that the longitudinally surface roughness can be more adoptable as compare to transverse surface roughness when no slip is involved.

4. Validation

Table 1. Comparison of $\overline{W}$ calculated for μ^*

Quantity	Load bearing Capacity (calculated for $\alpha = -0.05, \sigma = 0.3, \varepsilon = -0.05, \omega = 55^\circ, K = 0.5, \overline{S} = 0.03$)	
μ^*	Result of the current study	Result of (Andharia and Deheri 2011)
0.0001	0.2575338	0.2446277
0.001	0.2575457	0.2446395
0.01	0.2576643	0.2447581
0.1	0.2588503	0.2459441
1	0.2707102	0.2578040

Table 2. Comparison of $\overline{W}$ calculated for α

Quantity	Load bearing Capacity (calculated for $\mu^* = 0.01, \sigma = 0.3, \varepsilon = -0.05, \omega = 55^\circ, K = 0.5, \overline{S} = 0.03$)	
α	Result of the current study	Result of (Andharia and Deheri 2011)
-0.05	0.2576640	0.2447581
-0.02	0.2432010	0.2298273
0	0.2340100	0.2202664
0.02	0.2251560	0.2109807
0.05	0.2124570	0.1974948

Table 3. Comparison of $\overline{W}$ calculated for σ

Quantity	Load bearing Capacity (calculated for $\mu^* = 0.01, \alpha = -0.05, \varepsilon = -0.05, \omega = 55^\circ, K = 0.5, \overline{S} = 0.03$)	
σ	Result of the current study	Result of (Andharia and Deheri 2011)
0.1	0.2187241	0.2088460
0.2	0.2333267	0.2223130
0.3	0.2576643	0.2447581
0.4	0.2917369	0.2761812
0.5	0.3355446	0.3165824

Table 4. Comparison of $\overline{W}$ calculated for ε

Quantity	Load bearing Capacity (calculated for $\mu^* = 0.01, \alpha = -0.05, \sigma = 0.3, \omega = 55^\circ, K = 0.5, \overline{S} = 0.03$)	
ε	Result of the current study	Result of (Andharia and Deheri 2011)
-0.05	0.2576643	0.2447581
-0.02	0.2443342	0.2237814
0	0.2354474	0.2097969
0.02	0.2265606	0.1958125
0.05	0.2132305	0.1748358

Table 5. Comparison of $\overline{W}$ calculated for ω

Quantity	Load bearing Capacity (calculated for $\mu^* = 0.01, \alpha = -0.05, \sigma = 0.3, \varepsilon = -0.05, K = 0.7, \overline{S} = 0.03$)	
ω	Result of the current study	Result of (Andharia and Deheri 2011)
40°	0.6794927	0.6454508
45°	0.4641394	0.4408880
50°	0.3369186	0.3200416
55°	0.2576643	0.2447581
60°	0.2062889	0.1959567

Table 6. Comparison of $\overline{W}$ calculated for K

Quantity	Load bearing Capacity (calculated for $\mu^* = 0.01, \alpha = -0.05, \sigma = 0.3, \varepsilon = -0.05, \omega = 55^\circ, \overline{S} = 0.03$)	
K	Result of the current study	Result of (Andharia and Deheri 2011)
0.1	0.3941064	0.3743720
0.2	0.3728085	0.3541385
0.3	0.3412229	0.3241333
0.4	0.3021199	0.2869877
0.5	0.2576643	0.2447581

Undoubtedly, Tables 1-6 underline that at least 4% enhancement in the load bearing capacity is registered here. Further the effect of variance is more sharp in comparison with the investigation of (Andharia and Deheri 2011). The consolidated effect of ε and α are akin to that of (Andharia and Deheri 2011). However the effect of semi vertical angle ω surges ahead. However, the negative impact of roughness displays more variation in this situation despite the fact that standard deviation raises the load bearing capacity.

Conclusions

From this study, it can be concluded that appropriate magnetic strength can counter the slip effect in the case of small order of roughness. Thus, for industrial applications using such a system is more appropriate, especially if the slip is at the lowest level. Considering the life period perspective, this study is beneficial sine it aids the process of choosing the ideal aspect ratio, angle. Such an angle can, in turn, reduce the negative effects of roughness slip combine, even for moderate magnetic field.

Acknowledgement

The authors acknowledge with thanks the comments and suggestions of the referee, which resulted in an improvement for the materials presented in the paper.

References

Andharia, P. I., Deheri, G. M. (2010). Longitudinal roughness effect on magnetic fluid based squeeze film between conical plates, Industrial Lubrication and Tribology, **62(5),** 285–291. https://doi.org/10.1108/00368791011064446

Andharia, P. I., Deheri, G. M. (2011). Effect of longitudinal roughness on magnetic fluid based squeeze film between truncated conical plates, Fluid Dynamics and Materials Processing, **7(1),** 111–124.

Beavers, G. S., Joseph, D. D. (1967). Boundary conditions at a naturally permeable wall, Journal of Fluid Mechanics, **30(1),** 197–207. https://doi.org/10.1017/s0022112067001375

Berthe, D., Godet, M. (1974). A more general form of Reynolds equation-application to rough surfaces, Wear, **27(3),** 345-357. https://doi.org/10.1016/0043-1648(74)90119-7

Bhat, M. V., Deheri, G. M. (1991). Squeeze film behaviour in porous annular disks lubricated with magnetic fluid, Wear, **151(1),** 123–128. https://doi.org/10.1016/0043-1648(91)90352-u

Bhat, M. V., Deheri, G. M. (1992). Magnetic fluid based squeeze film between two curved circular plates, Bulletin of Calcutta Mathematical Society, **85,** 521–524.

Burton, R. A. (1963). Effect of two dimensional, sinusoidal roughness on the load support characteristics of a lubricant film, Journal of Basic Engineering, **85(2),** 258–262. https://doi.org/10.1115/1.3656572

Christensen, H., Tonder, K. C. (1969a). Tribology of rough surfaces: stochastic models of hydrodynamic lubrication, SINTEF Report 10/69-18.

Christensen, H., Tonder, K. C. (1969b). Tribology of rough surfaces: parametric study and comparison of lubrication model, SINTEF Report 22/69-18.

Christensen, H., Tonder, K. C. (1970). The hydrodynamic lubrication of rough bearing surfaces of finite width, ASME-ASLE Lubrication Conference, Paper no.70-lub-7.

Deheri, G. M., Patel, H. C., Patel, R. M. (2007). Magnetic fluid-based squeeze film between rough porous truncated conical plates, Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, **221(4),** 515–524. https://doi.org/10.1243/13506501jet226

Gadelmawla, E. S., Koura, M. M., Maksoud, T. M. A., Elewa, I. M., Sollman, H. H. (2002). Roughness parameters, Journal of materials processing Technology, **123(1),** 133–145. https://doi.org/10.1016/s0924-0136(02)00060-2

Lin, J. R., Lin, M. C., Hung, T. C., Wang, P. Y. (2013). Effects of fluid inertia forces on the squeeze film characteristics of conical plates- ferromagnetic fluid model, Lubrication Science, **25(7),** 429–439. https://doi.org/10.1002/ls.1206

Munshi, M. M., Patel, A. R., Deheri, G. M. (2017). Effect of slip velocity on a magnetic fluid based squeeze film in rotating transversely rough curved porous circular plates, Industrial Engineering Letters, **7(8),** 28–42.

Neuringer, J. L., Rosensweig, R. E. (1964). Magnetic Fluids, Physics of Fluids, **7(12),** 1927–1937. https://doi.org/10.1063/1.1711103

Patel, J. R., Deheri, G. M. (2016). The effect of slip velocity on the Ferrofluid based squeeze film in longitudinally rough conical plates, Journal of the Serbian Society for Computational Mechanics, **10(2),** 18–29. https://doi.org/10.5937/jsscm1602018p

Patel, J. R., Shimpi, M. E., Deheri, G. M. (2017). Ferrofluid based squeeze film for a rough conical bearing with deformation effect, International Conference on Research and Innovations in Science, Engineering &Technology, **2,** 119–129. https://doi.org/10.29007/wlbc

Patel, N. D., Deheri, G. M. (2011). Shliomis model based Ferrofluid lubrication of a plane inclined slider bearing with slip velocity, International journal of fluids engineering, **3(3),** 311–324.

Patel, N. S., Vakharia, D. P., Deheri, G. M. (2012). A study on the performance of a magnetic fluid based hydrodynamic short porous journal bearing, Journal of the Serbian Society for Computational Mechanics, **6(2),** 28–44.

Patel, R. M., Deheri, G. M. (2007). Magnetic fluid based squeeze film between porous conical plates, Industrial lubrication and Tribology, **59(3),** 143–147. https://doi.org/10.1108/00368790710746110

Patel, R. M., Deheri, G. M. (2007). Performance of magnetic fluid based squeeze film between porous truncated conical plates, Journal of engineering and technology, Sardar Patel University, **20,** 25–30.

Patel, R. M., Deheri, G. M. (2013). Magnetic fluid based squeeze film between porous rough conical plates, Journal of computational methods in science and engineering, **13(5-6),** 1–16.

Prakash, J., Vij, S. K. (1973). Load capacity and time-height relations for squeeze films between porous plates, Wear, **24(3),** 309–322. https://doi.org/10.1016/0043-1648(73)90161-0

Shah, R. C., Bhat, M. V. (2002). Ferrofluid lubrication in porous inclined slider bearing with velocity slip, International Journal of Mechanical Sciences, **44(12),** 2495–2502. https://doi.org/10.1016/s0020-7403(02)00187-x

Shimpi, M. E., Deheri, G. M. (2014). Effect of slip velocity and bearing deformation on the performance of a magnetic fluid based rough porous truncated conical plates, Iranian Journal of Science and Technology - Transactions of Mechanical Engineering, **38,** 195–206.

Shimpi, M. E., Deheri, G. M. (2016). Combined effect of bearing deformation and longitudinal roughness on the performance of a Ferrofluid based squeeze film together with velocity slip in truncated conical plates, Imperial Journal of Interdisciplinary Research, **2(8),** 1423–1430.

Shukla, S. D., Deheri, G. M. (2013). Effect of slip velocity on magnetic fluid lubrication of rough porous Rayleigh step bearing, Journal of Mechanical Engineering and Sciences, **4,** 532–547. https://doi.org/10.15282/jmes.4.2013.17.0050

Sparrow, E. M., Beavers, G. S., Hwang, I. T. (1972). Effect of velocity slip on porous walled squeeze films, Journal of Lubrication Technology, **94(3),** 260–265. https://doi.org/10.1115/1.3451704

Ting, L. L. (1975). Engagement behaviour of lubricated porous annular disks Part I: squeeze film phase, surface roughness and elastic deformation effects, Wear, **34(2),** 159–172. https://doi.org/10.1016/0043-1648(75)90062-9

Vadher, P. A., Deheri, G. M., Patel, R. M. (2011). Effect of transverse surface roughness on the performance of hydromagnetic squeeze film between conducting truncated conical plates, Journal of Marine Science and Technology, **19(6),** 673–680.

Nomenclature

a,b	dimensions of the bearing
h	film thickness(mm)
$\bar{h}$	mean film thickness(mm)
h_s	deviation from mean level
h_0	central film thickness(mm)
h_1	initial film thickness(mm)
h_2	film thickness after time Δt
K	aspect ratio b/a (width/height)
$\overline{M}$	magnetic field (Gauss)
M^2	magnitude of magnetic field (N/A.m)
p	pressure found in the area covered by the film (N/mm²)
$\bar{p}$	anticipated degree of pressure
P	non-dimensional pressure generated due to the film
w	load capacity (N)
$\overline{W}$	non-dimensional load capacity
α	variance (mm)
ε	skewness (mm^3)
σ	standard deviation (mm)
$\bar{\alpha}$	non- dimensional variance
$\bar{\varepsilon}$	skewness in dimensionless form
$\bar{\sigma}$	dimensionless standard deviation
$\bar{S}$	slip parameter
ω	semi vertical angle of the cone
μ	fluid viscosity ($N.s/m^2$)
μ_0	permeability of the free space (N/A^2)
$\bar{\mu}$	magnetic susceptibility of particles
μ^*	dimensionless magnetization parameter
$\dot{h}_0$	normal velocity (m/s)