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Effects of Deformation and Slip Velocity with Transverse Rough on the behaviour of a Rectangular plate with Hydromagnetic Based Squeeze film Bearing

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A B S T R A C T

This work describes the bearing deformation and slip velocity that occur as a result of the interaction in hydromagnetic squeeze film and Transverse irregularity on rectangular plate. During the investigation, the hydromagnetic lubrication theory and the slip model developed by Beavers & Joseph were used. Additionally, the generalized Reynolds type equations for the pressure of the fluid film were obtained by applying the suitable boundary conditions. Finally, the expressions for distribution of pressure and bearing's load as a function of slip parameter, irregularity parameter, and Hartmann number were derived. The stochastic averaging model that C&T developed has been utilized in this study so that the influence of Transverse irregularity can be determined. It has come to light that the implementation of the magnetic field effect results in a discernible in the load of the system as a whole. Although the joint impact of slip velocity and bearing deformation can be overcome to a great extent when negatively skewed irregularity occurs, it is made abundantly evident by the data that are graphically shown that this is not always the case. It is still necessary to keep the slip parameter as low as possible in order to achieve any type of development in the bearing performance characteristics. This is the case even if the parameter is kept as low as possible.

1. INTRODUCTION

A stochastic technique has been utilized to numerically represent the irregularity of the surfaces since it is always obvious that it has a random character [7,8,9,25]. Several functional characteristics of components, including heat transfer, light reflection, wear, friction, retaining a lubricant and coating, among others, are impacted by surface roughness. The performance of M.F. based irregular bearing systems was examined in a variety of studies, including those by Gupta & Deheri [13], Bhat [4], Christensen & Tonder [7,8,9], Guha [12], Shimpi & Deheri [24], Patel et al. [17], and Prakash & Gururajan [20].

The impact of non-uniform thickness on the M. F. based S.F. on irregular spongy long plates was investigated by Patel et al.,[14]. Additionally, the varying film thickness helped the magnetization lessen the negative effects of sponginess and irregularity.

The classic lubrication theory is built on the no-slip boundary condition. As a result, fluid at a solid boundary moves at a constant speed relative to the solid surface. The no-slip B.C. may be a useful model for prognosticate the behavior of fluids in many practical applications. Fortunately experimental study has demonstrated that the no-slip boundary criterion is essentially inapplicable for certain designed surfaces. According to measured velocity profiles, slide often happens toward the edges. Slip was extensively examined in polymer melts, and with to advancements in micro- and nano-scale technologies, this area of study is currently anticipated to be intensive. Researchers must keep in mind that gas microflows are what validate high-order velocity-slip boundary conditions. Slip has been discovered to be a significant influence at tiny sizes, because of this, slip is a crucial tribological factor for micromachine technology. There is a lot of potential for slip surfaces to be used in bearings if they are successful since it is thought that they can improve bearing performance by decreasing energy losses and increasing load carrying capacity.

The consequences of slip velocity, according to Murti, [15] were more obvious when the bearing was running at a lower eccentricity ratio and/or when the bearing matrix's permeability was low. At the porous matrix lubricant contact, tangential slip velocity was taken into consideration by Verma, [26], while Agrawal, [2] addressed the absence of a slip condition. In order to enhance the fluid film bearing performance, Salant Richard &Fortier Alicia [11] theoretically investigated the slip phenomena by carefully selecting both slip and no-slip bearing surfaces, known as heterogeneous patterns. In spongy, irregular, indefinitely long parallel plates, Shukla & Deheri, [24] studied how slip velocity affected a magnetic fluid-based S.F.'s performance.

According to Higginson, [14] the impact of film thickness on journal bearing performance and elastic deformation on the bearing liner was not insignificant. Prakash & Peeken, [21]examined how surface irregularity and One-dimensional slider bearings were influenced by elastic deformations, and it was found that there was a strong correlation between the two. According to [Chatchai & Mongko, 2010], during extreme working circumstances, the characteristics of journal bearings were considerably impacted by the power law index, irregularity pattern, and elastic deformation. In rotating curved transversely irregular spongy circular plates, Shimpi & Deheri, [23] investigated the joint impact of bearing deformation and rotation on the F.F. based S.F. By carefully selecting the curvature parameters, the (-) skewed irregularity improved performance for a wide range of deformation.

On this article, an effort has been made to explore the joint impact of slip velocity and deformation on the performance characteristics of a S.F. based on F.F. on rectangular plates that are infinitely long, spongy, and rough transversely.

2. ANALYSIS

Bearing system is presented in Figure 1.

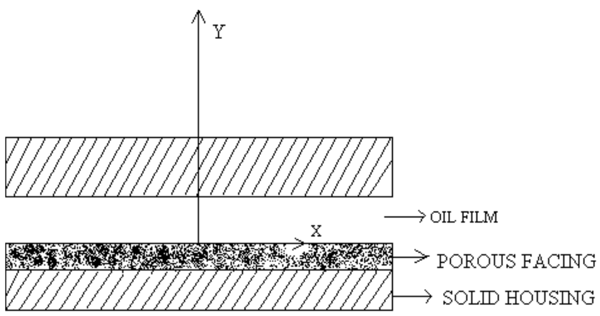

Fig. 1. Bearing system.

Surfaces are measured to be irregular. Hence, the study [7, 8, 9]

$$\frac{\partial^2 p}{\partial z^2} = \frac{\dot{h}}{\left[\frac{2.A}{\mu.M^3}\left(\tanh\frac{M}{2}-\frac{M}{2}\right)-\frac{\psi.A}{\mu.c^2}\right]} \bullet \frac{1}{\left[\frac{1+\phi_1+\phi_0}{\phi_1+\phi_0+\frac{\tanh(M/2)}{(M/2)}}\right]} \quad (1)$$

$$A = (h+p_a.p'.\delta p)^3 + 3.(\sigma^2+\alpha^2).(h+p_a.p'.\delta p) + 3.(h+p_a.p'.\delta p)^2\,\alpha + \varepsilon + 3\sigma^2.\alpha + \alpha^3 + 12\varphi H_0 \quad (2)$$

Solving this equation with the related B.C,

$$p\left(\pm\frac{b}{2}\right) = 0 \quad (3)$$

leads to the distribution of pressure as

$$p = \frac{-b^2\dot{h}.\left(\frac{1}{4}-\frac{z^2}{b^2}\right)}{2\left[\frac{2.A}{M^3}\left(\tanh\frac{M}{2}-\frac{M}{2}\right)-\frac{\psi.A}{c^2}\right]} \bullet \frac{1}{\left[\frac{1+\phi_1+\phi_0}{\phi_1+\phi_0+\frac{\tanh(M/2)}{(M/2)}}\right]} \quad (4)$$

The dimensionless (P.D) pressure distribution is obtained as

$$P = \frac{-h^3 p}{\mu\dot{h}\,ab} = \frac{\frac{1}{2(a/b)}\cdot\left(\frac{1}{4}-\frac{z^2}{b^2}\right)}{\left[\frac{2B}{M^3}\left(\tanh\frac{M}{2}-\frac{M}{2}\right)-\frac{\psi B}{c^2}\right]} \bullet \frac{1}{\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]} \quad (5)$$

Wherein

$$B = \bar{C}*(1+\bar{p}*\bar{\delta})^3 + 3*\bar{C}^{-1/3}[(\bar{\sigma}^{2}+\bar{\alpha}^{2})*(1+\bar{p}\bar{\delta}) + 4*\psi] + 3*\bar{C}^{-2/3}(1+\bar{p}*\bar{\delta})^2*\bar{\alpha} + 3\bar{\sigma}^{2}*\alpha + \bar{\alpha}^{3} + \bar{\varepsilon} \quad (6)$$

Where $\bar{C} = \frac{4+s\,(1+\bar{p}\,\bar{\delta})}{2+s\,(1+\bar{p}\,\bar{\delta})}$

finally, the Beavers–Joseph slip model adapts this equation in to the following

Where

$$\psi = \frac{\phi\, H_0}{h^3} \qquad \bar{\sigma} = \frac{\sigma}{h} \qquad \bar{\alpha} = \frac{\alpha}{h} \qquad \bar{\varepsilon} = \frac{\varepsilon}{h^3}$$

$$\bar{p} = p_a p' \quad \bar{\delta} = \frac{\delta}{h} \quad \bar{s} = s\,h \quad (7)$$

Then the W given by

$$w = \int_{-a/2}^{a/2}\int_{-b/2}^{b/2} p\cdot dxdz$$

$$= \frac{-\dot{h}\,b^3 a}{12\left[\frac{2A}{M^3}\left(\tanh\frac{M}{2}-\frac{M}{2}\right)-\frac{\psi A}{c^2}\right]} \bullet \frac{1}{\left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\frac{\tanh(M/2)}{(M/2)}}\right]} \quad (8)$$

The W in dimensionless form is attained as

$$W = -\frac{wh^3}{\mu\dot{h}\,a^2 b^2} = \frac{\frac{1}{12(a/b)}}{\left[\frac{2.B}{M^3}\left(\tanh\frac{M}{2}-\frac{M}{2}\right)-\frac{\psi.B}{c^2}\right]} \bullet \frac{1}{\left[\frac{1+\phi_1+\phi_0}{\phi_1+\phi_0+\frac{\tanh(M/2)}{(M/2)}}\right]} \quad (9)$$

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3. RESULTS AND DISCUSSIONS

The impact of conductivity on the load is evident.

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

where becomes for high values of M

$$\frac{\phi_0+\phi_1}{\phi_0+\phi_1+1},$$

due to the fact that, in contrast to a normal lubricant-based bearing system, tanh M~1 and 2 / M ~ 0. For smooth bearing systems, this inquiry simplifies to an examination of Acharya et al., [1] in the absenteeism of deformation and slip, and Prakash & Vij, [13] in the absence of magnetization, when there is no slide and deformation.

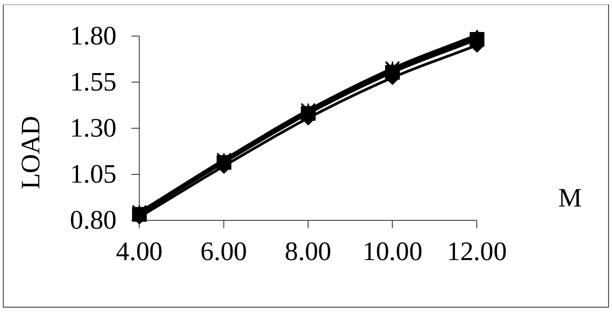

Fig. 2. Load of M and s*.

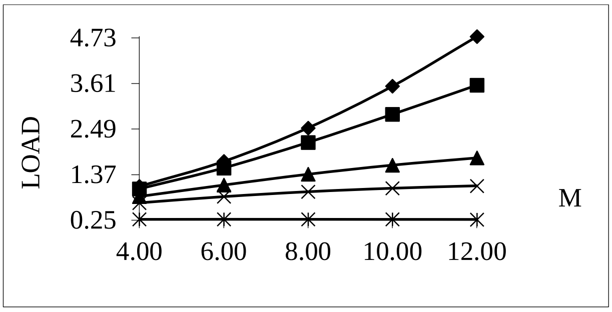

Fig. 3. Load of M and ψ.

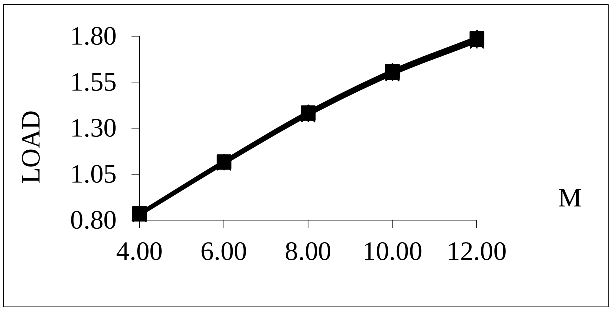

Fig. 4. Load of M and δ*.

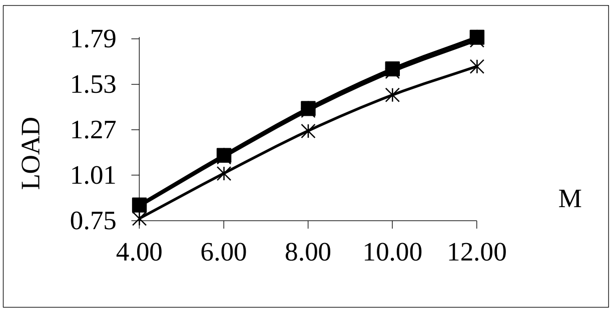

Fig. 5. Load of M and p*.

It is observed that the magnetization significantly increased the load. The impact of magnetization seen in figures (2)-(5) present the variation of load carrying capacity with respect to the magnetization parameter for various values of porosity Ψ, slip perameter s* , Non-dimensional pressure p* ,local elastic deformation δ* respectively. It is clearly seen that the load carrying capacity increases significantly with respect to the magnetization parameter M. Further, the increase in load carrying capacity due to variance is more as compared to the other parameters.

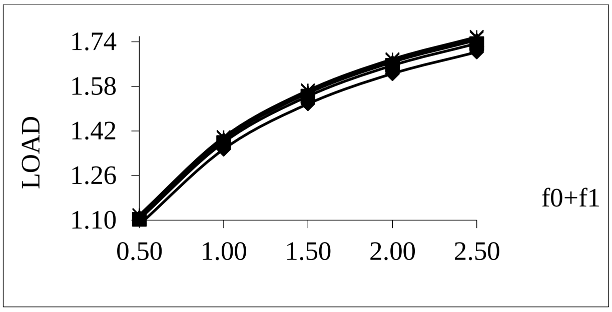

Fig. 6. Load of $\phi_0 + \phi_1$ and s*.

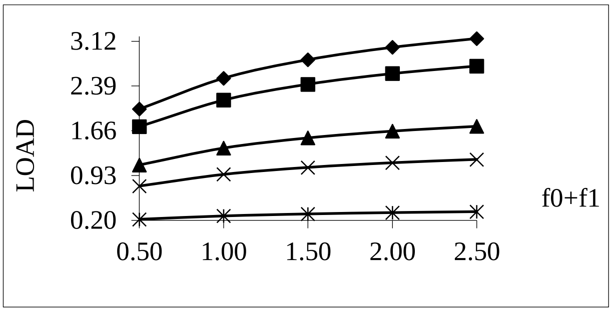

Fig. 7. Load of $\phi_0+\phi_1$ and ψ.

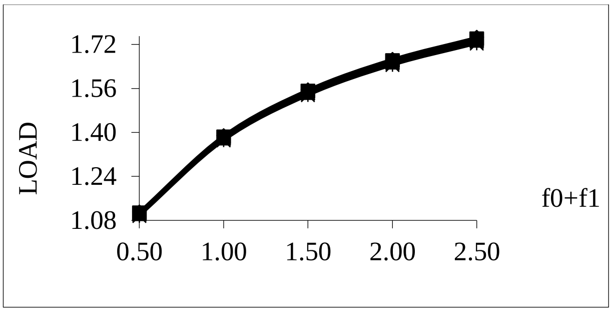

Fig. 8. Load of $\phi_0 + \phi_1$ and δ*.

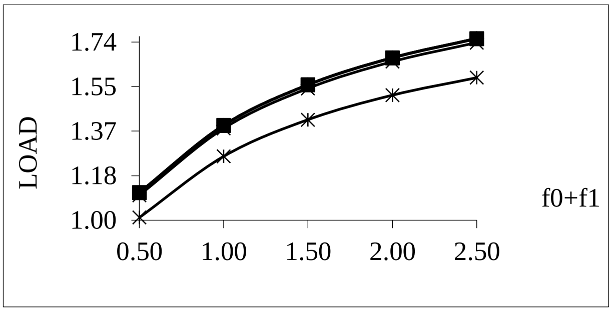

Fig. 9. Load of $\phi_0 + \phi_1$ and p*.

Figure (6) to (9) we have the distribution of load carrying capacity with respect to conductivity parameter $\phi_0 + \phi_1$ for several values of porosity Ψ, slip perameter s* ,Non-dimensional pressure p* , local elastic deformation δ* respectively. Here also, it is noticed that the load carrying capacity increases considerably due to the conductivities of the plates. Further, it is easily noticed that the increase in load carrying capacity with respect to the conductivities in the case of variance is more as compared to the other parameters namely Ψ, σ* , ε* and k.

W decreases when the standard deviation of the roughness in figure (10) to (13) depict the distribution of load carrying capacity with respect to standard deviation σ* for various values of porosity Ψ, slip perameter s* , Non-dimensional pressure p*, local elastic deformation δ* respectively. It is clearly seen from these figures that the load carrying capacity decreases considerably due to the standard deviation associated with roughness while, the combined effect of the aspect ratio and the standard deviation is substantially adverse.

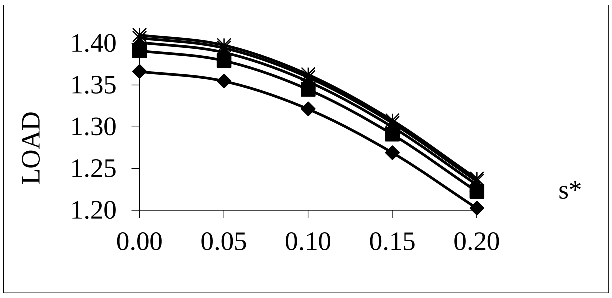

Fig. 10. Load of σ* and s*.

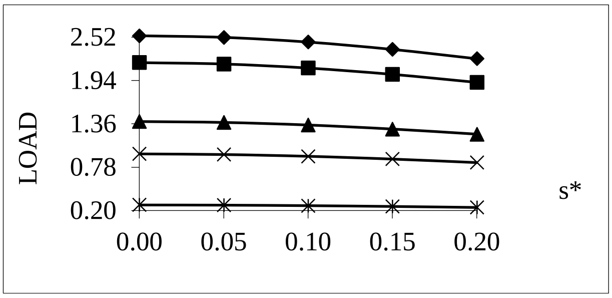

Fig. 11. Load of σ* and ψ.

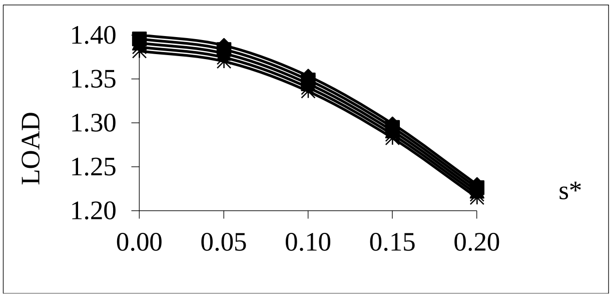

Fig. 12. Load of σ* and δ*.

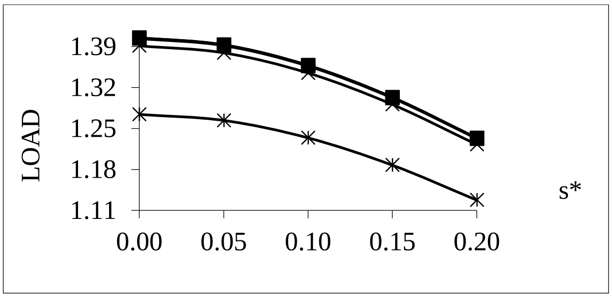

Fig. 13. Load of σ* and p*.

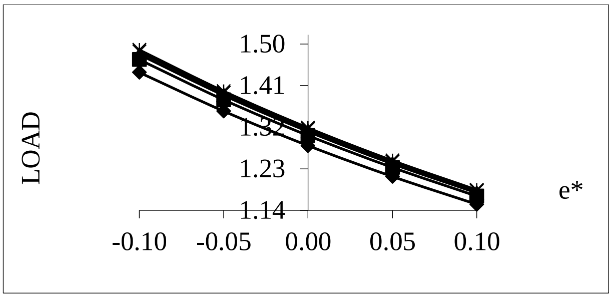

Fig. 14. Load of ε* and s*.

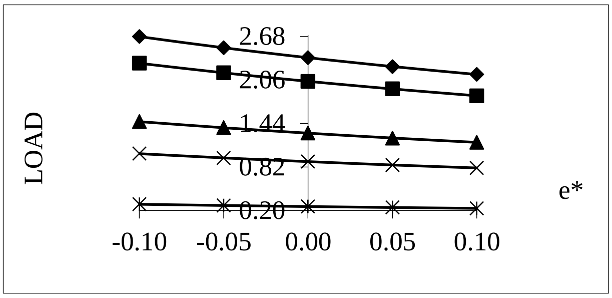

Fig. 15. Load of ε* and ψ.

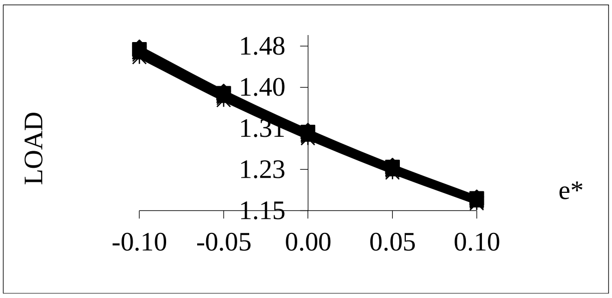

Fig. 16. Load of ε* and δ*.

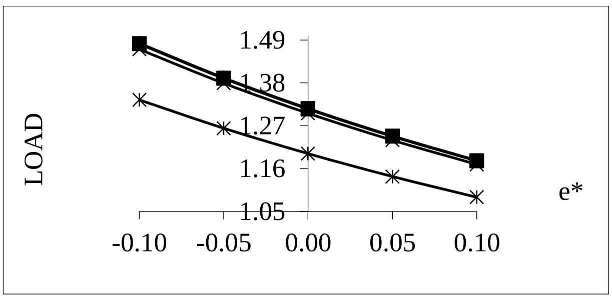

Fig. 17. Load of ε* and p*.

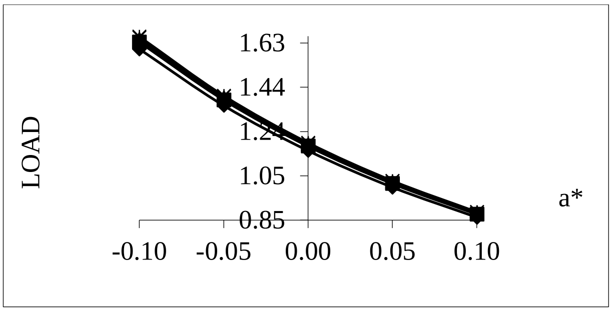

Fig. 18. Load of α* and s*.

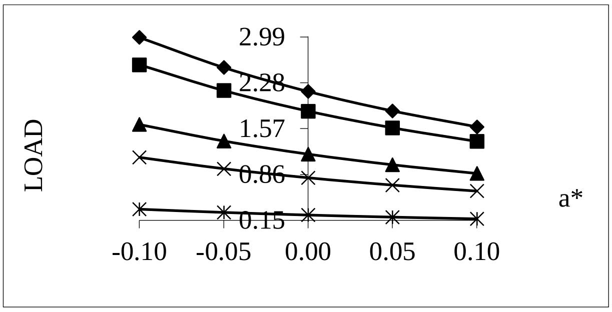

Fig. 19. Load of α* and ψ.

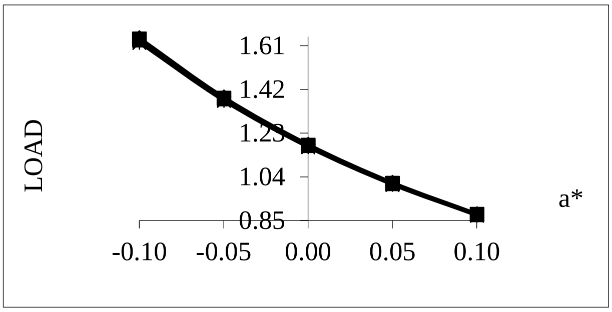

Fig. 20. Load of α* and δ*.

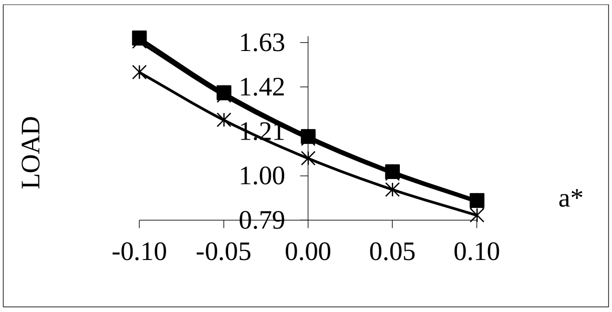

Fig. 21. Load of α* and p*.

The slip effect performs poorly, as anticipated figures (14)–(17). Additionally, the (-) skewed irregularity increases load. Additionally, the patterns of W in terms of variance resemble those of skewness almost exactly. See figurer (18) to (21).

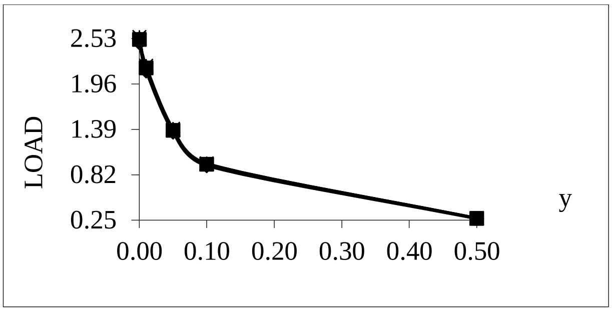

Fig. 22. Load of ψ and s*.

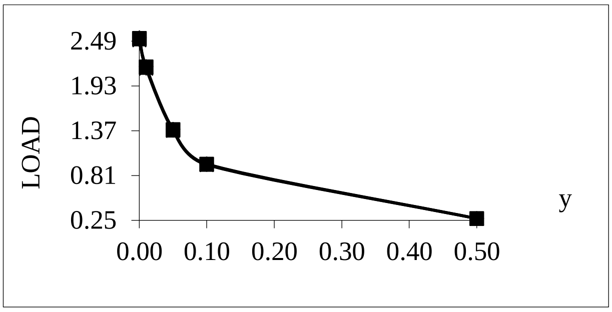

Fig. 23. Load oφ ψ and δ*.

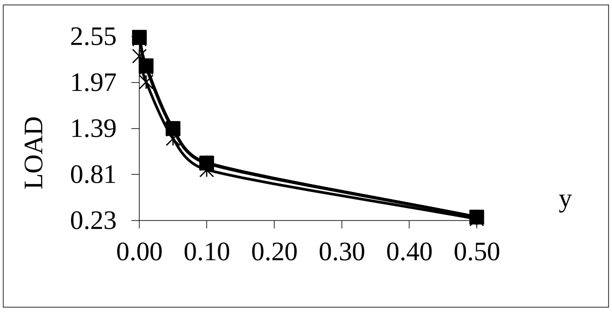

Fig. 24. Load of ψ and p*.

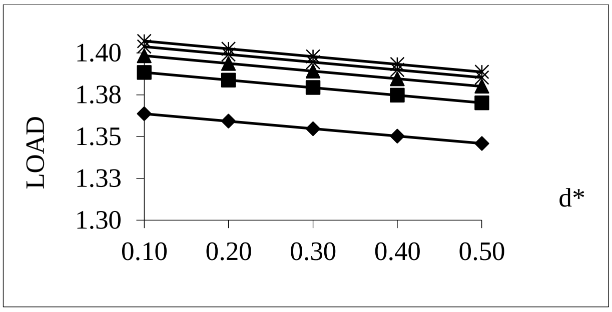

Fig. 25. Load of δ* and s*.

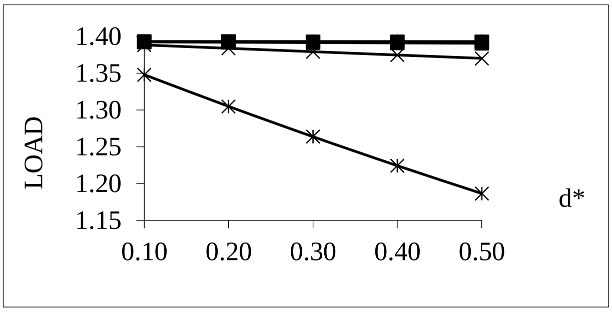

Fig. 26. Load of δ* and p* .

It is evident from the effect of deformation shown in figures (22) through (26) that deformation significantly affects a bearing system's performance. It is saw that the deformation significantly lowers the load.

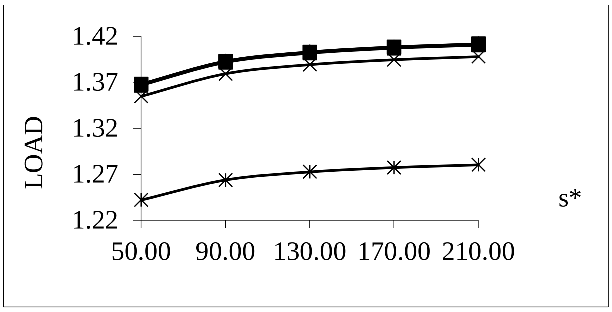

Fig. 27. Load of s* and p*.

W increases slip parameter w.r.t. pressure perimeter. See figure (27).

Furthermore, the following facts are seen:

1. When the slip is at its lowest level, the joint positive effects of negatively skewed irregularity and variance (-ve) may offer a superior choice for improving bearing performance. This impect further advances when small values of deformation are involved.
2. When slip parameter is at a low level, the combination of sponginess and deformation significantly reduces the load.
3. The combination of standard deviation and slip velocity has a considerable impact on the bearing performance for a wide range of deformation parameters.

4. CONCLUSION

Deformation, slip, and porosity together result in a considerable load decrease. When high standard deviation values are present, the problem gets much worse. Although magnetization causes a dramatic rise in W, M.F. lubrication has a limited ability to reduce the aforementioned negative effect. However, when roughness is adversely skewed, the situation is still better. This suggests that while designing these kinds of bearing systems, roughness is still an important factor to consider.

Even when lower slip and deformation values are taken into account, the magnetic fluid lubrication provides a limited solution for mitigating the negative effects of porosity and standard deviation. The bearing system is able to withstand a significant amount of load even in the absence of flow, which is very different from the usual fluid-based bearing systems.

With a model that emphasizes wear and temperature rise, it may be used as censors and shock absorbers.

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NOMENCLATURE

a	Radius of the plates (m)
H	Lubricant film thickness (m)
K	Permeability ($col^2 kgm/s^2$)
m	Porosity of the porous matrix
h'	=dh/dt Squeeze velocity
M	$= B_0 h \left(\frac{s}{\mu}\right)^{1/2}$ = Hartmann number
p	Pressure distribution (N/m^2)
p*	Non-dimensional pressure = $\frac{-ph^3}{\mu \dot{h} \pi a^2}$
s	Electrical conductivity of the lubricant
w	Load carrying capacity (kgm/s^2)
W	Dimensionless load carrying capacity = $-\frac{wh^3}{\mu \dot{h} \pi^2 a^4}$
B_0	Uniform transverse magnetic field applied between the plates.
c^2	$= 1 + \frac{KM^2}{h^2 m}$
h_0'	Surface width of the lower plate (m)
h_1'	Surface width of the upper plate (m)
s_0	Electrical conductivity of lower surface (mho)
s_1	Electrical conductivity of upper surface (mho)
δ^*	local elastic deformation

$\phi_0(h)$ = $\frac{s_0 h_0^{'}}{sh}$ = Electrical permeability of the lower surface

$\phi_1(h)$ = $\frac{s_1 h_1^{'}}{sh}$ = Electrical permeability of the upper surface

ψ = $\frac{D_c^2 e^3}{180(1-e)^2}$ = Porosity

e Eccentricity ratio

μ Viscosity (kg/ms)f

σ^* Non-dimensional standard deviation (σ/h)

α^* Non-dimensional variance (α/h)

ε^* Non-dimensional skew ness (ε/h^3)

k Aspect ratio

ω Semi Vertical angel