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Research article

Effect of Slip Velocity on Longitudinal Rough Hydromagnetic Squeeze Film Conducting Rotating Circular Plates

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A B S T R A C T

The purpose of this paper is to investigate the combined effects of longitudinally rough surface with slip velocity on the performance of rough rotated circular plates based on a H.F. Surfaces of bearing are assumed to be rough in nature (longitudinally). The outcome of slip velocity has been evaluated using Beavers and Joseph's slip model. The influence of longitudinally surface irregularity was estimated using C&T's stochastic model. To obtain the pressure distribution, he related Reynolds' type equation is solved with proper B.C., resulting to the computation of load. Further, the terminologies for friction and pressure are obtained. Here results are given graphically, to obtain the P.D., the related Reynolds' type equation is solved with proper B.C., resulting to the computation of load. The results indicate that longitudinal irregularities are more beneficial than transverse irregularities. The slip velocity further enhances this opposing effect. Despite the fact that slip velocity and S.D. raise the load, When variance (-ve) develops, the magnetization rescues the situation in the event of negatively skewed irregularities. Smaller values of slip parameter, on either hand, may be preferable for overall bearing efficiency.

1. INTRODUCTION

Several experimental and theoretical research on plane metal bearing hydromagnetic lubrications have been discussed. Kuzma, et.al. [1,2] calculated the performance of M.H.D. S.F.. The impact of plate conductivity on the efficiency system of bearing has been investigated in this paper. After some run in and wear, it is nature that the surfaces of bearing grow surface irregularity. Investigators studied the impact of surface irregularity C&T [3-5]. C&T [3-9] Stochastic averaging method suggested a detailed general study for both L.R. and T.R. In a number of studies, Prajapati [8], Gupta & Daheri [10], Andharia, et.al [11], this method provided the base for the study and review of the impact of irregularity [12-15].

Hydromagnetic S.F. properties have been explored for various geometries by Chou et. al. [14]. Between spongy rotating uneven circular plates, the M.F. based S.F. was scrutinized by Patel et. al. [16]. In Andhariya and Deheri [13, 17-19], L.R. was studied in detail, Andharia, et. al. [12], Lin [20] and Shimp & Daheri [21]. Twice of these researches concluded that, in contrast with the case of T.R, L.R. had a less detrimental effect.

It was therefore mentioned to inspect the impact of L.R. on hydromagnetic S.F. among rotating circular plates in the present research. The S.D. related to L.R. plays an important role in this.

Patel et. al. [22] discussed M.F. lubrication of a two layered spongy S.F. in L.R. truncated conical plates considering slip velocity. Munsu et. al [23] states L. R. truncated conical plates with slip velocity and the effect of f.f. lubrication.

2. ANALYSIS

Fig. 1 displays the system of bearing geometry and configuration. Although the upper side plate travels along its normal toward the lower side plate, the lower plate is assumed rotating. The plates are electrically conductive and a lubricant (electrically conductive) fills the clearance space in between. Among two plates, a uniform transverse magnetic field is applied.

The surfaces of bearing are taken to be L.R.. The film width is brought from C&T [3-5].

The layer of the lubrication is incompressible, isoviscous and the flow is normally laminar. The updated Reynolds equation describing the lubricant pressure is obtained as, according to the normal assumptions of hydromagnetic lubrication (Prajapati [9], Bhat [15]).

$$\frac{1}{r}\frac{\partial}{\partial r}\left[r\frac{\partial p}{\partial r}\right] = \frac{\mu\dot{h}}{AB} + 2\rho\left(\frac{3}{10}\Omega_r^2 + \Omega_r\Omega_l + \Omega_l^2\right) \quad (1)$$

where

$$A = \left[\frac{2}{M^3}\left[\frac{M}{2} - \tanh\frac{M}{2}\right]\right],\ B = \left[\frac{\phi_0+\phi_1+1}{\phi_0+\phi_1+\left(\tanh\frac{M}{2}\right)/\left(\frac{M}{2}\right)}\right]$$

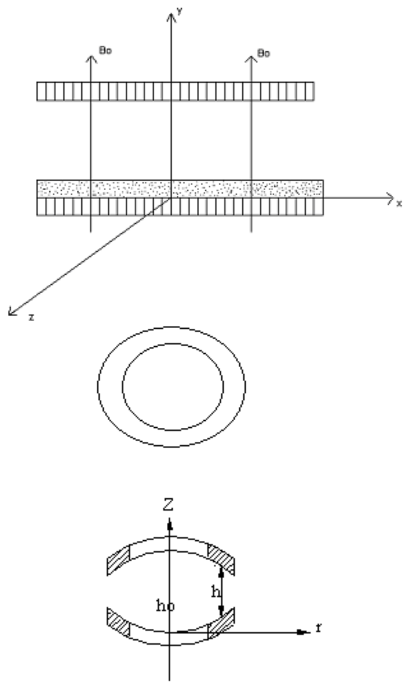

Fig. 1. Geometry of bearing.

As a consequence, conventional hydromagnetic lubrication hypotheses and follow-up discussions of Vadhr et al.,[19], Andharia & Daheri [18], C & T [3, 4, 5], and Petel et. al. [16], one comes to the stochastically averaged Reynolds' form equation involveded, resorting to the roughness (longitudinal) formula as a per model of roughness (longitudinal).

$$\frac{1}{r}\frac{\partial}{\partial r}\left[r\frac{\partial p}{\partial r}\right] = \frac{\mu\dot{h}\zeta(h)}{AB} + 2\rho\left(\frac{3}{10}\Omega_r^2 + \Omega_r\Omega_l + \Omega_l^2\right) \quad (2)$$

where

$$\zeta(h) = \left(\frac{1}{h^3}\right)[1 - \alpha h^{-1} + 6h^{-2}(\sigma^2 + \alpha^2) - 10h^{-3}(\varepsilon + 3\sigma^2\alpha + \alpha^3)] * \left(\frac{1+4\bar{s}\bar{h}}{1+2\bar{s}\bar{h}}\right) \quad (3)$$

With the use of Reynolds' B.C.

p = 0 when r = a

and

$$\frac{\partial p}{\partial r} = 0 \text{ at } r = 0 \quad (4)$$

Now integrate equation (2) and solving it using B.C. (4), one can have the S.F. of P.D. in the form of

$$p = \left(\frac{\mu\dot{h}\zeta(h)}{AB} + 2\rho\left(\frac{3}{10}\Omega_r^2 + \Omega_r\Omega_l + \Omega_l^2\right)\right)\left(\frac{r^2-a^2}{4}\right) \quad (5)$$

Using the following N.D.T. in equation (4)

$$R = \frac{r}{a}, \sigma^* = \frac{\sigma}{h}, \alpha^* = \frac{\alpha}{h}, \varepsilon^* = \frac{\varepsilon}{h^3},$$

$$S = -\frac{h^3 \rho \Omega_u{}^2}{\mu \dot{h}}, \; s = \bar{s}\,\bar{h} \qquad (6)$$

one can get the Dist. of pressure in N.D.T. form as

$$P = -\frac{ph^3}{\mu \dot{h} \pi a^2} = \left(\frac{\bar{\zeta}(h)}{AB} - \frac{S}{5}\left(3\Omega_f^2 + 4\Omega_f + 3\right)\right)\frac{(1-R^2)}{4\pi} \qquad (7)$$

where

$$\bar{\zeta}(h) = \zeta(h)h^3 = \left(1 - 3\times\alpha^* + 6\times\left(\sigma^{*2} + \alpha^{*2}\right) - 10\times\left(\varepsilon^* + 3\times\sigma^{*2}\alpha^* + \alpha^{*3}\right)\right) * \left(\frac{1+4s^*}{1+2s^*}\right) \qquad (8)$$

In reality, the load is internal pressure created by dynamic motion between the opposing surfaces. The letter of recommendation load supplied by

$$w = 2\pi \int_0^a p(r)\cdot r dr,$$

is computed in N.D.T. form as

$$W = -\frac{h^3 w}{\mu \dot{h} \pi a^4} = \frac{1}{8\pi}\left(\frac{\bar{\zeta}(h)}{AB} - \frac{S}{5}\left(3\Omega_f^2 + 4\Omega_f + 3\right)\right) \qquad (9)$$

3. RESULTS AND DISCUTIONS

The fact that the Dist. of pressure and the load are dependent on distinct factors is obvious from equations (5) and (9), such as M, $\phi_0+\phi_1$, σ^*, ε^*, α^*, S ,Ω_f and s^*. Setting the values of σ^*, α^*, ε^*, S, Ω_f and s^* The current research simply comes down to a Shukla-Prasad analysis of a smooth, non-porous, irrotating conducting plate, When M $\rightarrow$ is used as a limiting case, the scrutiny of Praksh-Vij for the nonmagnetic circumstance is used. When the electrical permeability of twice surfaces is set to zero, the results of Petal-Gapta are obtained.

The load rises with given values of the hydromagnetization limitation and electrical permeability of two surfaces, as can be shown σ^*, α^*, ε^*, S, Ω_f and s^*. The effect of conductivity on the equation of pressure and Dist. of load originates from the factor

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

This factor tends to

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

for bigger number of M ($\because \tanh(M/2) \rightarrow 0$). These function is increasing functions of $\phi_0+\phi_1$ and from the mathematical expressions one can see that as $\phi_0 + \phi_1$ increses, the pressure and L.C.C. increase as well.

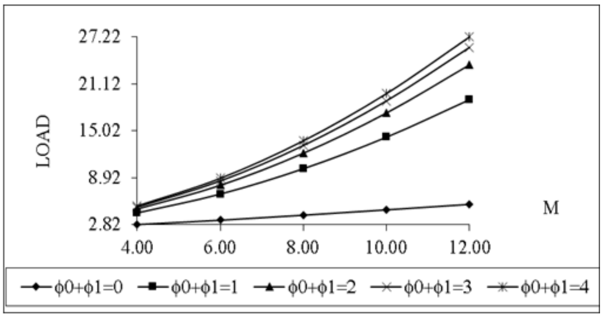

Fig. 2. Load of M& $\phi_0+\phi_1$.

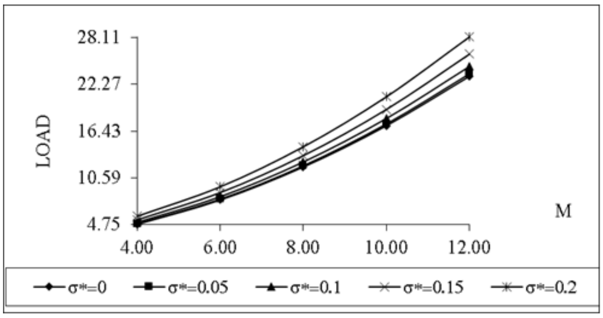

Fig. 3. Load of M & $\sigma*$.

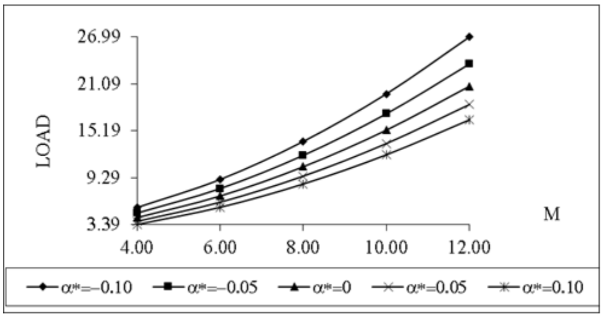

Fig. 4. Load of to M & α^*.

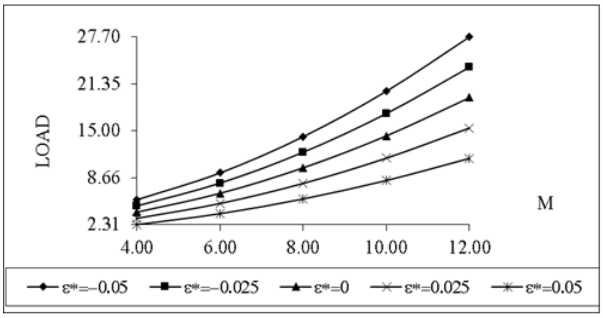

Fig. 5. Load of M & ε^*

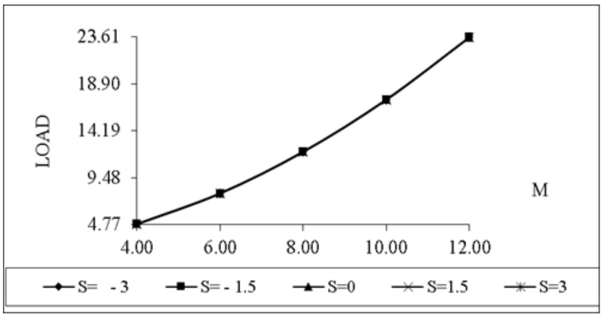

Fig. 6. Load of M & S

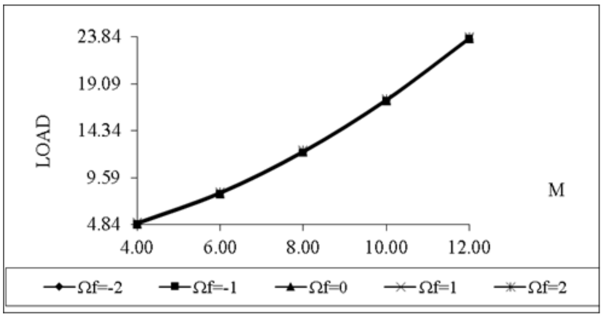

Fig. 7. Load of M & Ω_f.

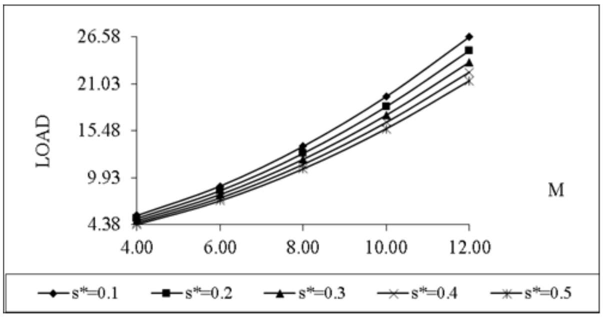

Fig. 8. Load of M & s*.

The load distribution wrt the magnetization constraint M for various values of $\phi_0+\phi_1$, σ^*, α^*, ε^*, S, Ω_f and s* respectively given isn Fig.s (2) to (8). A detailed examination of these graphs reveals that the load W increases somewhat as the magnetization parameter M increases. Furthermore, (-ve) skewed irregularity, like (-ve) variance, aid in improving bearing behaviour. It's interesting to observe that the load increase caused by (-ve) Data is sharper, and (+) variance has a (-ve) impact on the system in general.

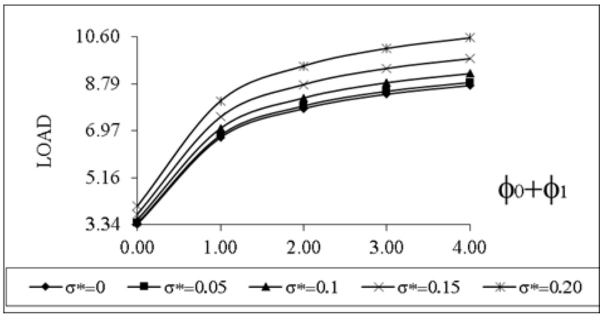

Fig. 9. Load of $\phi_0+\phi_1$ & σ^*.

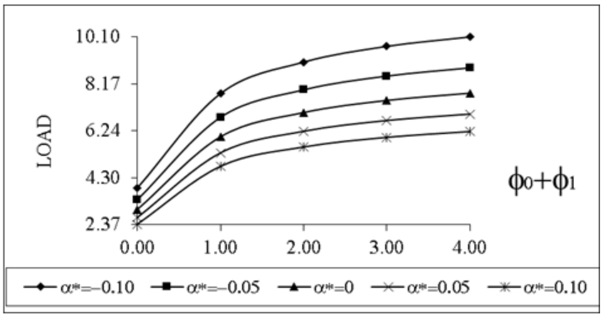

Fig. 10. Load of $\phi_0+\phi_1$ & α^*.

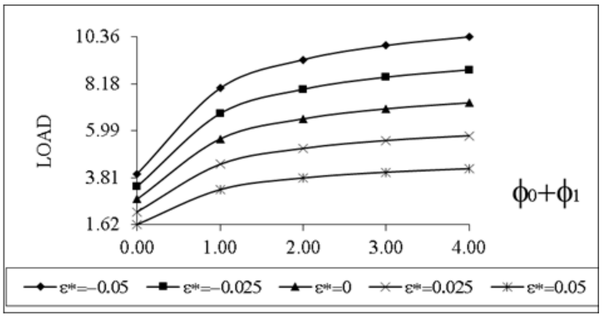

Fig. 11. Load of $\phi_0+\phi_1$ & ε^*.

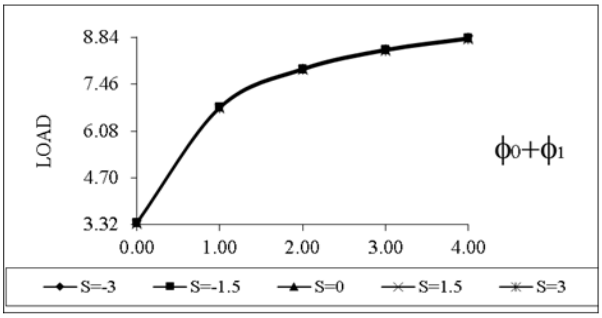

Fig. 12. Load of $\phi_0+\phi_1$ & S.

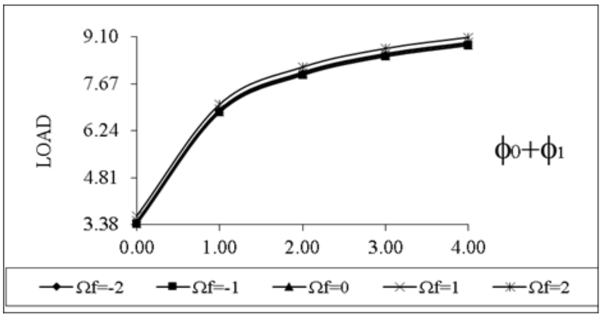

Fig. 13. Load of $\phi_0+\phi_1$ & Ω_f.

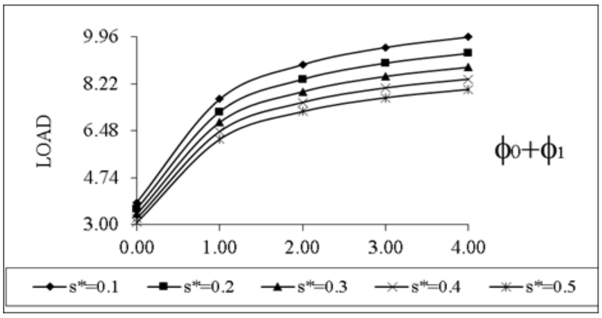

Fig. 14. Load of $\phi_0+\phi_1$ & s*.

Fig.s (9) to (14) charactrizes the data of L.T.C w.r.t. electrical permeability of both the surfaces for different values of σ^*, α^*, S, ε^*, Ω_f and s* respectivlvely. It is obvious from these figures that the L.C.C. grows considerably w.r.t $\phi_0 + \phi_1$. The S.D. connected with L.R. helps in increasing the load which is unlikely in the case of T.R. (Fig. (15) to (19)).

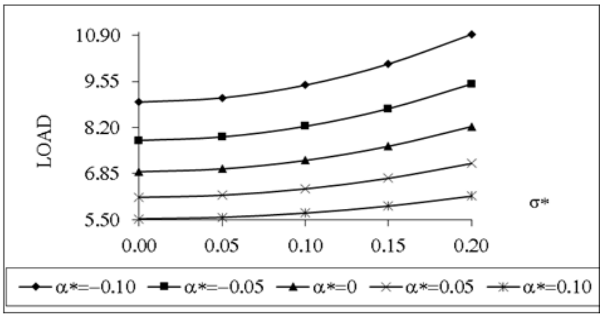

Fig. 15. Load of σ* & α*.

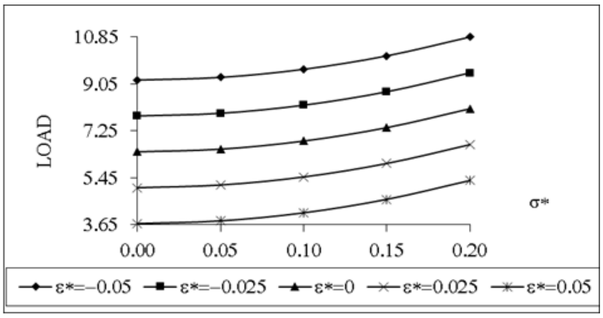

Fig. 16. Load of σ* & ε*.

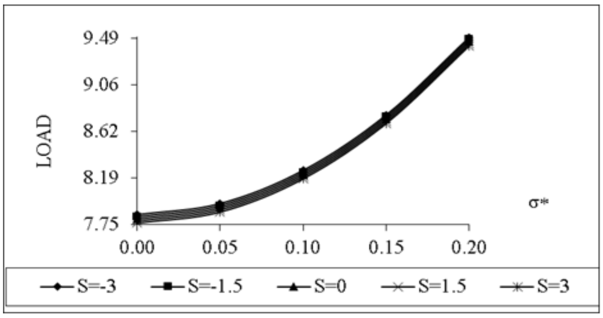

Fig. 17. Load of σ* & S.

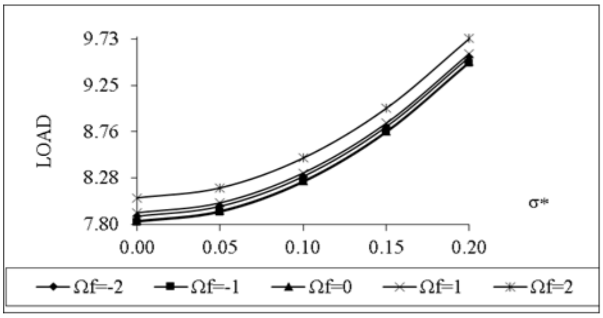

Fig. 18. Load of σ* & Ω_f.

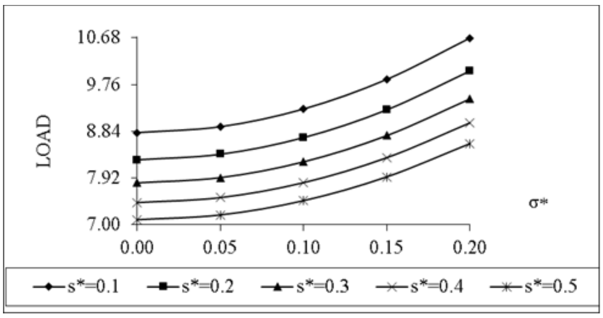

Fig. 19. Load of σ* & s*.

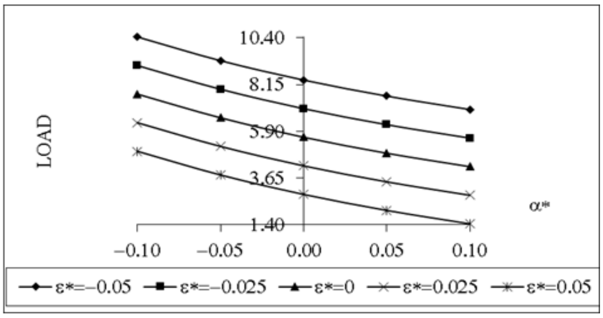

Fig. 20. Load of α* & ε*.

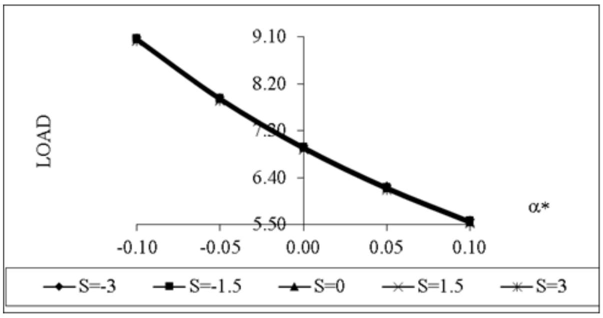

Fig. 21. Load of α* & S.

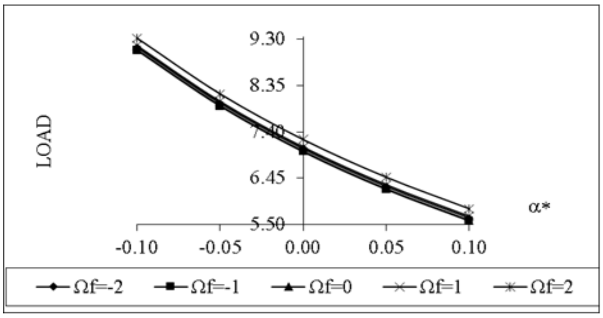

Fig. 22. Load of α* & Ω_f.

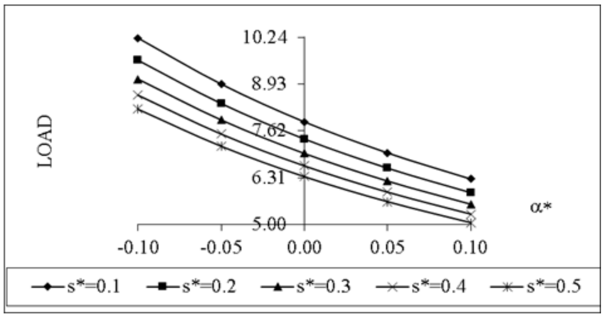

Fig. 23. Load of α* & s*.

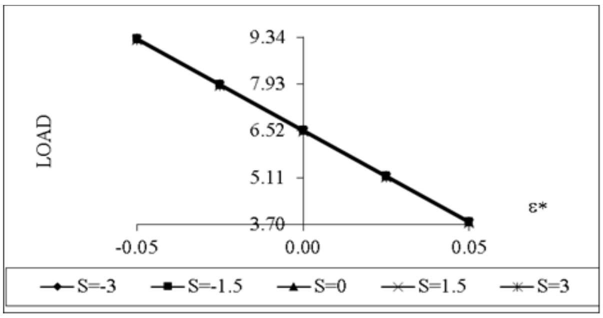

Fig. 24. Load of ε* & S.

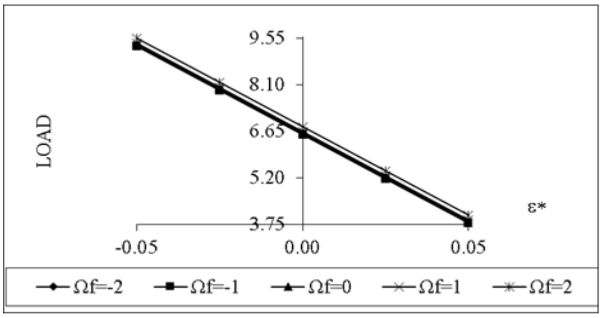

Fig. 25. Load of ε^* & Ω_f .

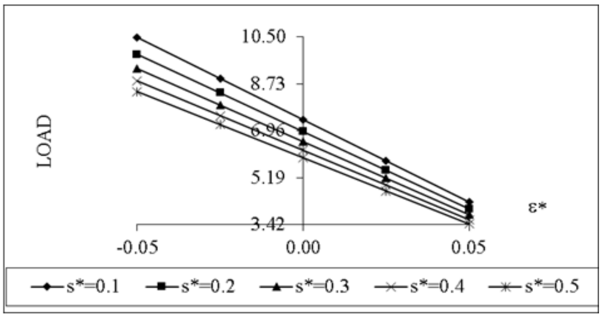

Fig. 26. Load of ε^* & s^* .

Figures (20) to (26) show that the burden is increased by negatively skewed anomalies, just as it is in the case of variance (-ve). Positively skewed irregularity and variance (+ ve) counter these patterns. Figures (27) and (28) show the curve of rotational inertia load vs. rotation ratio and slip parameter (28). When the plates spin in opposing directions, the load is at its maximum. For $\Omega_f \approx -0.667$, the load reaches its higher value. In terms of the slip parameter, the load profile shows a rise in rotational ratio.

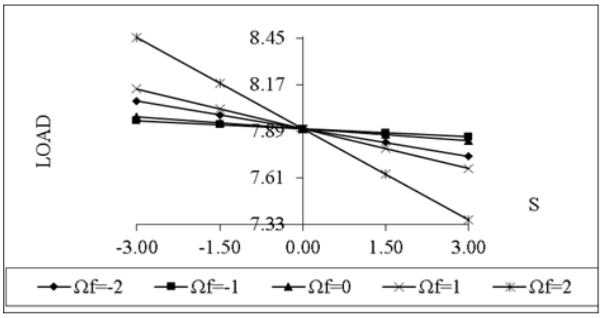

Fig. 27. Load of S & Ω_f.

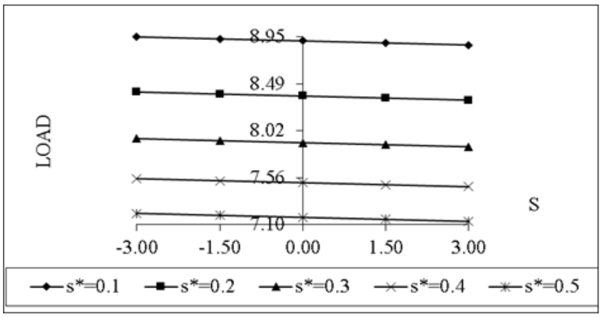

Fig. 28. Load of S & s*.

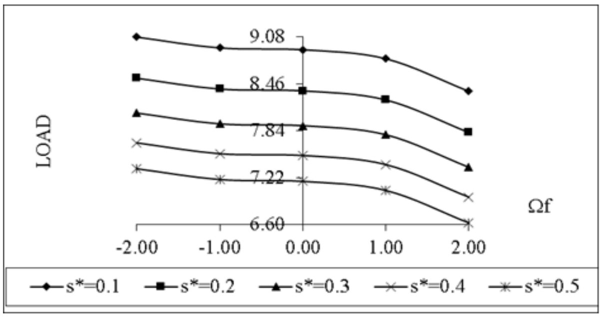

Fig. 29. Load of Ω_f & s*.

These figures show that in the case of skewness, the opposite impact caused by rotational inertia, positive skewness and positive variance may be neutralised to some extent (-ve), Particularly when negative variance is present. Roughness causes the bearing to suffer in general. The given analysis provides numerous opportunities for improving bearing performance in the case of (-ve) skewed roughness, particularly when variance (ve) is taken into account. This positive effect is enriched further by the joint effect of electrical permeability of bearing faces and parameter of magnetization (M).

Using these results alone mentions that the machine's life period can be extended in the case of L.R. bearing systems. This analysis also makes it clear that the L.R. constraints must given due deliberation while creating the such type of systems of bearing, even if the proper choice of m and $\phi_0+\phi_1$ has been taken into account.

4. CONCLUSION

This article proposes that the slip parameter must be put down to minimum value for an overall better-quality bearing system effectiveness. Therefore, this research demonstrates that the irregularities aspect must be carefully considered when planning the bearing design. This study appears to show that in the case of negative skewed roughness, the adverse effect of slip velocity can be substantially reduced by hydromagnetic lubrication as the S.D. associated with irregularities causes increased load. As compared to the case of T.R patterns, it is noted that the condition remains relatively better even though slip velocity is involved. In spite of the fact that there are numerous constraints causing load reduction.

REFERENCES

[1] D. C. Kuzma, E. M. Maki, and R. J. Donnelly, "The magnetohydrodynamic squeeze films," *J. Fluid Mech.*, vol. 19, pp. 395-400, 1964, doi: 10.1115/1.3653131.

[2] J. B. Shukla and R. Prasad, "Hydromagnetic squeeze films between two conducting surfaces," *J. Basic Eng. Trans. ASME*, vol. 87, pp. 818-822, 1965, doi: 10.1115/1.3650824.

[3] H. Christensen and K. C. Tonder, "Tribology of rough surfaces: stochastic models of hydrodynamic lubrication," SINTEF, Rep. 10/69-18, 1969.

[4] H. Christensen and K. C. Tonder, "Tribology of rough surfaces: parametric study and comparison of lubrication models," SINTEF, Rep. 22/69-18, 1969.

[5] H. Christensen and K. C. Tonder, "Tribology of rough surfaces: a stochastic model of mixed lubrication," SINTEF, Rep. 18/70-21, 1970.

[6] J. Prakash and S. K. Vij, "Load carrying capacity and time height relation for squeeze film between porous plates," *Wear*, vol. 24, pp. 309-332, 1973, doi: 10.1016/0043-1648(73)90161-0.

[7] K. C. Patel and J. L. Gupta, "Behaviour of hydromagnetic squeeze film between porous plates," *Wear*, vol. 56, pp. 327-339, 1979, doi: 10.1016/0043-1648(79)90236-9.

[8] B. L. Prajapati, "Squeeze film behaviour between rotating porous circular plates with concentric circular pocket: surface roughness and elastic deformation effects," *Wear*, vol. 152, pp. 301-307, 1992, doi: 10.1016/0043-1648(92)90127-T.

[9] B. L. Prajapati, "On certain theoretical studies in hydrodynamic and electromagnetohydrodynamic lubrication," Ph.D. dissertation, Dept. Mathematics, S.P. Univ., Vallabh Vidyanagar, Gujarat, India, 1995.

[10] J. L. Gupta and G. M. Deheri, "Effect of roughness on the behaviour of squeeze film in a spherical bearing," *Tribol. Trans.*, vol. 39, pp. 99-102, 1996.

[11] P. I. Andharia, J. L. Gupta, and G. M. Deheri, "Effect of longitudinal surface roughness on hydrodynamic lubrication of a slider bearing," in *Proc. 10th Int. Conf. Surface Modification Technologies*, 1997, pp. 872-880.

[12] P. I. Andharia, J. L. Gupta, and G. M. Deheri, "Effect of transverse surface roughness on the behaviour of squeeze film in spherical bearing," *J. Appl. Mech. Eng.*, vol. 4, pp. 19-24, 1999.

[13] P. I. Andharia and G. M. Deheri, "Effect of longitudinal surface roughness on the behavior of squeeze film in a spherical bearing," *Int. J. Appl. Mech. Eng.*, vol. 6, no. 4, pp. 885-897, 2001.

[14] T. L. Chou, J. W. Lai, and J. R. Lin, "Magneto-hydrodynamic squeeze film characteristics between a sphere and a plane surface," *J. Marine Sci. Technol.*, vol. 11, no. 3, pp. 174-178, 2003, doi: 10.51400/2709-6998.2281.

[15] M. V. Bhat, *Lubrication with a Magnetic Fluid*. Team Spirit, India, Pvt. Ltd, 2003.

[16] H. Patel, G. M. Patel, and R. M. Patel, "Magnetic fluid based squeeze film between porous rotating rough circular plates," *Ind. Lubr. Tribol.*, vol. 61, no. 3, pp. 140-145, 2009, doi: 10.1108/00368790910953659.

[17] P. I. Andharia and G. M. Deheri, "L.R. effect on magnetic fluid-based squeeze film between conical plates," *Ind. Lubr. Tribol.*, vol. 62, no. 5, pp. 285-291, 2010, doi: 10.1108/00368791011064446.

[18] P. I. Andharia and G. M. Deheri, "Performance of magnetic fluid based squeeze film between longitudinally rough elliptical plates," *ISRN Tribology*, Article ID 482604, 2013, doi: 10.5402/2013/482604.

[19] P. A. Vadher, P. C. Vinodkumar, G. M. Deheri, and R. M. Patel, "Behavior of hydromagnetic squeeze films between two conducting rough porous circular plates," *J. Eng. Tribol.*, vol. 222, no. 4, pp. 569-579, 2016, doi: 10.1243/13506501JET390.

[20] J. R. Lin, "Longitudinal surface roughness effects in magnetic fluid lubricated journal bearing," *J. Marine Sci. Technol.*, vol. 24, no. 4, pp. 711-716, 2016, doi: 10.6119/JMST-016-0201-1.

[21] M. E. Shimpi and G. M. Deheri, "Combined effect of bearing deformation and L.R. on the performance of a ferrofluid based squeeze film together with velocity slip in truncated conical plates," *Imperial J. Interdisciplinary Res.*, vol. 2, no. 8, pp. 1423-1430, 2016.

[22] S. A. Patel, A. Patil, and G. Deheri, "Magnetic fluid lubrication of a double layered porous squeeze film in longitudinally rough truncated conical plates considering slip velocity," *J. Emerging Technol. Innovative Res.*, vol. 5, no. 7, pp. 327-339, 2018.

[23] M. Munsu, A. Patil, and G. Deheri, "Influence of ferrofluid lubrication on longitudinally rough truncated conical plates with slip velocity," *Math. J. Interdisciplinary Sci.*, vol. 7, no. 2, pp. 93-101, 2019, doi: 10.15415/mjis.2019.72012.