“Analysis of Some Problems Related to Tribology”

Ph.D. Synopsis Submitted to

Gujarat Technological University
Ahmedabad

For the Award of Degree of
Doctor of Philosophy
In
Mathematics

Research Guide:
Dr. H. C. Patel
Professor of Mathematics
L D College of Engineering
Ahmedabad

Prepared by:
Mr. Pragneshkumar L Thakkar
Assistant Professor
Enrolment No.: 139997673012

GUJARAT TECHNOLOGICAL UNIVERSITY
AHMEDABAD
August 2018

Content

1. ABSTRACT

Global economic development has resulted in a big way, the progress of transportation system; alternately, accelerated growth in automotive products (cycle, two wheelers, four wheelers and luggage carriers).The adverse effect of this in automotive sectors is higher import of fossil fuel which has effected decrease in rupee versus dollar. Research is required to identify the area of fossil fuel conservation through high efficient design of product with minimum losses of power generated in vehicle. Literature review indicates that 30 to 70 percentage mechanical frictional losses are observed in automotive products.

Researchers have put efforts to minimize such frictional losses through various experimental and theoretical model studies in the realm of tribological parameters (friction, wear and lubrication). In fact, tribology is an inter disciplinary science of inter acting surfaces under dynamic conditions. A friction phenomenon is interpreted by different researchers in different ways, but here surface geometry/ topography plays vital role. The proposed research is for some theoretical model development to reduce the mechanical frictional loss at the same time holding onto a good amount of load.

2. LITERATURE REVIEW

Cameron [1974] focused on the extension of exponential film shape to secant shape in his modified version. Additionally, the basic concepts of viscosity with its standard units were enhanced. The Reynolds equation for the pressure distribution of the lubricant in a journal bearing with finite length was solved by Sfyris and Chasalevris [2012] analytically. Using the method of separation of variables in an additive and a multiplicative form, a set of particular solutions of the Reynolds equation was added in the general solution of the homogenous Reynolds equation. Dwivedi et al. [2013] considered solution of Reynolds equation for hydrodynamic journal bearing with infinitely long approximation, infinitely short bearing approximation and finite journal bearing approximation. Numerical continuation was used by Amamou et al. [2014] to predict the branch of the journal equilibrium point, the Hopf bifurcation point and the

emerging stable or unstable limit cycles. Depending on the bearing characteristics, the stability threshold occurred either at a supercritical or at a subcritical Hopf bifurcation. Incorporation of different shapes of textures on journal and/or bearing at different location of texture zone was reported by Singh et al.[2014] to have significant influence on the bearing performance. By Sandip and Vakhariya[2014] the steady state performance analysis of short circular journal bearing was conducted using the viscosity correction model under thin film lubrication conditions. The thickness of adsorbed molecular layers was the most critical factor in studying thin film lubrication and was the most essential parameter that distinguished thin film from thick film lubrication analysis. The need of a Maintenance Free Bearings (MFB) was established by Muzakir [2015].The existing technologies of well-established maintenance free bearings were described. The hybridization of bearing technologies to achieve low cost maintenance free bearings had been exemplified. In Raghavendra [2015] the analysis and design of hydrodynamic journal bearings has drawn a considerance attention of engineers. Emphasis was given to design those bearings so as to avoid metal-to-metal contact.

Fogg[1946] investigated various types of thrust bearing and showed that opposed parallel surfaces, under certain conditions of operation, had a load carrying capacity approaching to that of tilting pad bearings of the Michell type and of the same bearing area. Gregory[1974] proved that the bearing and lube oil system were instrumental to measure bearing performance under laminar and turbulent operating conditions. Aihara [1987] discussed same conventional formula for calculating the running torque of tapered roller bearings which often showed discrepancy from actual running torque, particularly, under axial load.4. Rodkiewicz et al. [1990] analyzed an operating tilting-pad thrust bearing. In this analysis entrance pressure was obtained by applying to the fore-region the momentum integral theorem. Andharia et al. [2000] observed the shape of lubricant film for the optimal performance of a longitudinally rough slider bearing. Andharia et al.[2001] discussed a generalized form of surface roughness characterized by a stochastic random variable with non-zero mean, variance and skewness was assumed to define the bearing surface topography. Deheri et al. [2004] analysed longitudinally rough slider bearing with magnetic squeeze films. This study established that for an enhanced bearing performance the role standard deviation associated with roughness remain prominent. Mazurkow [2010] observed the comparison of pressure and temperature distributions, frictional moments on a fixed bush surface, and angular velocities of a floating ring

bearing towards a fixed bearing bush. Henry et al.[2014] conducted an experimental theory of hydrodynamic thrust bearing device and its application to the study of a tapered-land thrust bearing. Najar et al. [2014] discussed a solution of Reynolds equation by using finite difference method (FDM) on the surface of the tilting pad to find the pressure distribution in the lubricant oil film. Song, Yin, et al.[2015] discussed experimental and numerical studies of cavitation effects in a tapered land thrust bearing. Tong et al. [2016] discussed that the occurrence of angular misalignment could considerably change bearing characteristics.

This paper presented a comprehensive formula to provide the running torques for TRBs with angular misalignment between inner and outer races.

Hays [1963] made a theoretical analysis for the normal approach of flat and curved rectangular plates which were separated by a thin film of lubricant. Load capacity curves were presented and some typical pressure distributions were shown. Wu [1972] theoretically observed the squeeze film between two rectangular plates when one had a porous facing. The problem was described by the modified Reynolds equation in the film region and the Laplace equation in the porous region. Prakash and vij [1973] analysed squeeze film between porous plates of various plates. The effect of the shape of plate and porosity on the bearing performance was calculated. Prakash and Tiwari [1982] launched a theoretical analysis on the effects of unidirectional surface roughness on the response of a squeeze film between two porous rectangular plates of finite dimensions. The problem was solved analytically using Fourier series expansions. On the basis of the Stokes micro continuum theory and the Christensen stochastic model, a theoretical study of squeeze film performance for isotropic rough rectangular plates with couple stress fluids as lubricants was presented by Lin [2001]. Naduvinamani et al. [2003] observed the effect of surface roughness on the couple stress squeeze film behaviour between two rectangular plates, when one plate had a porous facing with anisotropic permeability by taking into account the slip velocity at the fluid and porous material interface. Bujurke and Kudenatti [2007] discussed the effects of surface roughness on the squeeze film behaviour between two rectangular plates with an electrically conducting fluid in the presence of a transverse magnetic field. Shimpi et al. [2011] observed squeeze film performance in porous rough rectangular plates under the presence of magnetic fluid lubricant. Lin et al. [2013] discussed the effects of couple stresses and external magnetic

fields provided an increase in the load capacity and the response time as compared to the classical Newtonian hydrodynamic rectangular squeeze-film lubrication.

3. BRIEF DESCRIPTION ON RESEARCH TOPIC

In the thesis the calculation of friction has been given due consideration throughout the course of the investigation. First of all, the performance of an infinitely short rough journal bearing was analyzed. The roughness was modelled in the light of the stochastic method of Christensen and Tonder. For the behaviour of performance characteristic load bearing capacity and friction were calculated. This investigation established that the friction was relatively increased.

Then the focus shifted onto the investigation of a transversely rough narrow width tapered pad bearing. Here also the associated stochastically averaged Reynolds type equation was solved for the pressure distribution, load carrying capacity and friction .It was noticed that the effect of friction was not that sharped in the case of negatively skewed roughness. But the overall situation was comparatively better when variance (-ve) occurred.

An investigation was launched into the effect of transverse surface roughness on the performance characteristic of a squeeze film between porous rough rectangular plates. Taking recourse to the stochastic averaging method of Christensen and Tonder, the effect of transverse surface roughness was analyzed. The bearing suffered heavily due to transverse surface roughness, barring the situation when negatively skewed roughness was increased in place.

The studies dealing with the effect of transverse surface roughness on the behaviour of narrow width tapered pad bearing. The investigation strongly suggests that due care must be taken regarding roughness aspects while designing the bearing system even if friction is reduced.

Then the focus is shifted onto the investigation of an effect of slip velocity on the performance of an infinitely short rough porous journal bearing. Mostly the effect of porosity remains negligible as far as coefficient of friction is concerned. It is interesting to note that smaller values of eccentricity have little effect on coefficient of friction.

4. RESEARCH GAP

A broad literature review pushed that very little significance has been given on deliberately utilizing of roughness aspects in various kind of bearing systems specifically

journal bearing, rectangular plates and tapered pad bearing. Besides, literature review suggested that there is use of only single kind of beta distribution function and known roughness parameter displayed of Christensen and Tonder. Here different form of beta distribution and different type of roughness parameter are used on tapered pad bearing and journal bearing and evaluated pressure distribution, load bearing capacity and friction. Therefore, it was concluded to deal with such gaps in the study. The study discovered and found that if such kind of bearing framework is outline then it will upgrade the bearing performance and more useful in industry.

5. OBJECTIVES AND SCOPE OF THE STUDY

5.1 RESEARCH OBJECTIVES

The objectives of proposed research work are as follows:

1. To discuss different type of bearings with roughness parameter, slip velocity and porosity in particularly journal bearing and tapered pad bearing.
2. To get pressure distribution, load bearing capacity and friction.
3. To identify nature of journal bearing and tapered pad bearing using roughness parameter with the help of different form of beta distribution.

5.2 SCOPE OF THE STUDY

The broad objective of this research tells that investigations can be modified and developed in the following directions:

1. Longitudinal roughness can be considered for analyzing the performance for various kinds of bearing systems, for example, journal bearing, tapered pad bearing and porous rectangular plates.
2. The effect of slip velocity can be accounted in different types of bearings.
3. The influence of deformation might be assessed in various sorts of bearings by using the magnetic fluid flow model of Shliomis and Jenkins.
4. The effect of different porous structures in some other squeeze film bearings like, slider bearings, conical plates, truncated conical plates, triangular plates, elliptic plates can be investigated.

6. ORIGINAL CONTRIBUTION BY THE THESIS

The original contribution by the thesis is mathematical modelling on journal bearing, tapered pad bearing and rectangular plates for squeeze film lubrication.

1. The effect of slip velocity on the performance of an infinitely short rough porous journal bearing.
2. The effect of transverse surface roughness on the performance of narrow width porous tapered pad bearing.
3. The effect of surface roughness on the characteristics on squeeze film between porous rectangular plates.

7. CONCLUSION

The performance characteristics of an infinitely short rough bearing are significantly affected by standard deviation associated with roughness characteristics. The bearing suffers due to transverse roughness.

The investigation for tapered pad bearing suggests that the roughness parameter must be considered while designing the bearing system. The positively effect of negatively skewed roughness may be channelized to improve the bearing performance when variance (-ve) occurs.

In the case of squeeze film between porous rectangular plates variance (-ve) makes the situation better even if moderate values of porosity are involved.

The performance a characteristic of a narrow width tapered pad bearing is significantly affected by the standard deviation associated with the roughness characteristics.

The proper design of infinitely short journal bearing requires the consideration of effect of various roughness, porosity and slip velocity parameters for better performance.

8. REFERENCES

1. Aihara, S.(1987)"A new running torque formula for tapered roller bearings under axial load." ASME J. Tribol 109.3, 1987, pp. 471-477.
2. Amamou, A., & Chouchane, M. (2014). Nonlinear stability analysis of long hydrodynamic journal bearings using numerical continuation. Mechanism and Machine Theory, 72, 17-24.
3. Andharia, P. I., Gupta, J. L., & Deheri, G. M. (2001). Effect of surface roughness on hydrodynamic lubrication of slider bearings. Tribology transactions, 44(2), 291-297.
4. Andharia, P. I., Gupta, J. L., & Deheri, G. M. (2000). On the shape of the lubricant film for the optimum performance of a longitudinal rough slider bearing. Industrial Lubrication and Tribology, 52(6), 273-276.
5. Bujurke, N. M., and R. B. Kudenatti. (2007). "MHD lubrication flow between rough rectangular plates." Fluid dynamics research 39.4,334-345.
6. CAMERON, A. (1974). Principles of Lubrication, Longman,
7. Deheri, G. M., Andharia, P. I., & Patel, R. M. (2004). Longitudinally rough slider bearings with squeeze film formed by a magnetic fluid. Industrial Lubrication and Tribology, 56(3), 177-187.
8. Dwivedi, V. K., Chand, S., & Pandey, K. N. (2013). Analysis of Hybrid (Hydrodynamic/Hydrostatic) Journal Bearing. In Advanced Materials Research (Vol. 650, pp. 385-390). Trans Tech Publications.
9. Fogg, A. (1946). Fluid film lubrication of parallel thrust surfaces. Proceedings of the Institution of Mechanical Engineers, 155(1), 49-67.
10. Gregory, R. S. (1974). Performance of thrust bearings at high operating speeds. Journal of Lubrication Technology, 96(1), 7-13.
11. Hays, D. F. (1963). Squeeze films for rectangular plates. Journal of Basic Engineering, 85(2), 243-246.
12. Henry, Y., Bouyer, J., & Fillon, M. (2014). An experimental hydrodynamic thrust bearing device and its application to the study of a tapered-land thrust bearing. Journal of Tribology, 136(2), 021703.
13. Lin, J. R. (2001). The effects of couple stresses in the squeeze film behavior between isotropic rough rectangular plates. International Journal of Applied Mechanics and Engineering, 6(4), 1007-1024.

14. Lin, J. R., Chu, L. M., Hung, C. R., & Wang, P. Y. (2013). Derivation of two-dimensional couple-stress hydromagnetic squeeze film Reynolds equation and application to wide parallel rectangular plates. Meccanica, 48(1), 253-258.
15. Mazurkow, A. (2010). The verification of adiabatic model of a lateral sliding bearing with a floating ring bearing. Indian Journal of Science and Technology, 3(6), 620-626.
16. Muzakkir, S. M., & Hirani, H. (2015). Maintenance Free Bearings. International Journal of Engineering Research, 4(3), 133-136.
17. Naduvinamani, N. B., Syeda Tasneem Fathima, and P. S. Hiremath. (2003). "Effect of surface roughness on characteristics of couplestress squeeze film between anisotropic porous rectangular plates." Fluid dynamics research32.5,217-231.
18. Najar, F. A., & Harmain, G. A. (2014). Numerical Investigation of Pressure Profile in Hydrodynamic Lubrication Thrust Bearing. International scholarly research notices, 2014.
19. Prakash, J., & Tiwari, K. (1982). An analysis of the squeeze film between porous rectangular plates including the surface roughness effects. Journal of Mechanical Engineering Science, 24(1), 45-49.
20. Prakash, J., & Vij, S. K. (1973). Load capacity and time-height relations for squeeze films between porous plates. Wear, 24(3), 309-322.
21. Raghavendra, N., M. C. Math, and Pramod R. Sharma. (2015)."Finite Element Method Analysis of Hydrodynamic Journal Bearing." European Journal of Advances in Engineering and Technology 2.2, 92-101.
22. Rodkiewicz, C. M., Kim, K. W., & Kennedy, J. S. (1990). On the significance of the inlet pressure build-up in the design of tilting-pad bearings. Journal of Tribology, 112(1), 17-22.
23. Sfyris, D., & Chasalevris, A. (2012). An exact analytical solution of the Reynolds equation for the finite journal bearing lubrication. Tribology International, 55, 46-58.
24. Shimpi, M. E., & Deheri, G. (2011). Analysis of squeeze film performance in porous rough rectangular plates under the presence of a magnetic fluid lubricant. Acta Technica Corviniensis-Bulletin of Engineering, 4(1), 49.
25. Singh, Pratibha, et al. (2014). "Optimum design of journal bearing through surface texturing-a review." International Journal 2.1.
26. Song, Y., Ren, X., Gu, C. W., & Li, X. S. (2015). Experimental and numerical studies of cavitation effects in a tapered land thrust bearing. Journal of Tribology, 137(1), 011701.

27. Tong, V. C., & Hong, S. W. (2016). The effect of angular misalignment on the running torques of tapered roller bearings. Tribology International, 95, 76-85.

28. Wu, H. (1972). An analysis of the squeeze film between porous rectangular plates. Journal of Lubrication Technology, 94(1), 64-68.