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Slider Journal Bearing: A Review

Chetan Sharma[1] & Dr. S. S. Sen[2]
[1]M. Tech Student, Green Hills Engineering College, Kumarhatti, Solan, INDIA
[2]Professor, Green Hills Engineering College, Kumarhatti, Solan, INDIA

ABSTRACT

The importance of pressure of lubricant in slider bearing and wear control cannot be overemphasized for economic reasons and long-term reliability. The effect of change in speed and viscosity are two major factors for smooth running and long-term life of bearing. These two factors are my area of study. These advances provide the impetus for research aimed at developing a fundamental understanding of the nature of sinusoidal slider bearing and consequences of the change in speed of bearing and viscosity of lubricant interactions between materials of bearing. This paper presents the reviews of different works in the area of wear, friction, pressure, change in speed and change in the value of viscosity in sinusoidal grooved slider bearings and tries to find out latest developments and trends available in industries and other fields in order to know maximum increment in pressure in short, finite and infinite slider bearing.

Keywords- Bearing, Friction, Lubricant, Slider bearing, Wear.

I. INTRODUCTION

Machine consists of machine elements and their safe and efficient operation relies on carefully designed interfaces between these elements. The functional design of interfaces covers geometry, materials, lubrication and surface topography, and an incorrect design may lead to both lowered efficiency and shortened service life. A misalignment due to the geometrical design could lead to the large stress concentrations that in turn may lead to severe damage when mounting, a detrimental wear situation and rapid fatigue during operation, etc. Large stress concentrations also implicitly imply a temperature rise because of the energy dissipation due to plastic deformations. The choice of mating materials is also of great importance, e.g. electrolytic corrosion may drastically reduce service life. Contact fatigue due to low ductility would not only lower the service life but could lead to third body abrasion due to spilling, which in turn could end up lowering the service life of other components.

A lubricant serves several crucial objectives; when its main objective is to lower friction, the actions of additives are of concern. If the interface is subjected to excessive wear, the lubricant's ability to form a separating film becomes even more crucial. In this case, the bulk properties of the lubricant have to be carefully chosen. At some scale, regardless of the surface finish, all real surfaces are rough and their topography influences the contact condition. As implied above, these design parameters are mutually dependent, i.e. they affect the way other influence the operation of the system. For example, a change in geometry could require another choice of materials that may change the objectives of the lubricant and force the operation into another lubrication regime. All four design parameters are of great importance, though in this thesis work the effect induced by the surface topography is the main area of interest.

The influence of surface roughness on performance has of course been investigated by many researchers in the field, experimentally and numerically. However, because of the multidisciplinary nature of the field and the complexity of the theoretical models associated with tribological problems, the progress in the development of efficient, still user friendly software has not reached as far as in, e.g. computational structural mechanics and computational fluid dynamics. Moreover, the requirement on the density of the mesh to resolve not only the geometrical part of the tribological contact but also the surface topography is difficult to meet. This thesis contributes to the field of research through this connection. Namely, by development and implementation of rigorous theoretical models that allow for effective numerical treatment of some specifically chosen rough tribological problems. For example, within this thesis work, the outcome of an extremely successful collaboration has led to state-of-the-art results in applied mathematics as well as to the Reynolds equation that incorporates the effects induced by the surface roughness. Modern machinery has many moving parts that are in relative motion to each other. In these parts when one surface moves over the other, some resistance is offered to its movement and the force that opposes this movement is called friction. Lubrication improves the smoothness of this surface-to-surface movement and the agent that aids in this functioning is called a lubricant. Thus a lubricant is a substance that reduces friction and wear and provides smooth running and a satisfactory life for machine elements. This is the core of tribology, i.e. the theory of lubrication, friction, and wear.

Tribology is defined as the science and technology of interacting surfaces in relative motion. The word is derived from the Greek word "tribo" which means "rubbing". The design of the interfaces between two surfaces is important to the performance of the particular mechanical device. The wear rate must be limited so that the tribological interface maintains the desired properties throughout its service life. In order to reduce friction and wear, a lubricant may be added in the interface between the two surfaces. This tends to separate the sliding surfaces from direct mechanical contact, reducing wear and the risk of failure [1] [2]. The pressure generated within the fluid carries the applied load and the frictional resistance to motion arises entirely from the shearing of the viscous fluid. Thus, friction force F is proportional to the load W exerted by one surface on the other and its relation is given by

$$F = \text{constant} \times W \qquad (1.1.1)$$

The constant here is called the coefficient of friction (μ) and is dependent on the materials that are in sliding contact. Its value varies from 0.003 to 3.0. The coefficient of friction between two bodies is in fact not quite constant and varies with change in load and with sliding speed.

II. OBJECTIVES

- To find out the positive effect of surface texturing on the performance of slider bearing
- To suggested the best position of groove on sliding surface of slider bearing so as to generate extra pressure and thus support higher load.
- To analyze different configurations (spherical shape, cylindrical shape, parallelepipedical shape) assuming the shaft is smooth and rigid and the bearing surface is numerically textured.

III. LITERATURE SURVEY

Tribology is the study of lubrication, friction, wear, and contact mechanics in order to understand surface interactions and to suggest solutions to fundamental problems. The expanding range of tribological applications, from the traditional industrial machinery to recent applications in micro fabrication has demonstrated its importance and also revived interest in this field. The introduction of a range of micro fabrication techniques coupled with developments in microscopy has a profound effect on the reappearance of tribological applications at microscopic level. With the help of this new technology, it is now possible to produce microstructures on journal bearing surfaces to improve the overall tribological performance including reduction in friction, improvement in reliability, increase the pressure and load carrying capacity and lowering the power consumption. Surface texturing has been a subject of several theoretical and experimental studies. This is due to the fact that small improvements in bearing performance can be greatly economically beneficial. Most theoretical results reported so far are for isothermal studies and some are obtained for single stationary unit cell with periodic boundary conditions. The case of flow between two surfaces, one of which is textured, has been investigated by different researchers in past [6-22]. A positive effect of surface texturing on the lubricated contact performance is found in almost all the cases analyzed.

Patir et al. (1979) [6] pointed out that the load carrying of the sliding surfaces increases appreciably if the moving surface is smooth and decrease if the moving surface is rough.

Tonder (2001) [7] suggested that by introducing a series of dimples or roughness at inlet of a sliding surface contact could generate extra pressure and thus support higher load.

Ronen et al. (2001) [8] presented a model to study the potential use of micro surface structure in the form of micro pores to improve tribological properties of reciprocating automotive components. It is shown that surface texturing can efficiently be used to maintain hydrodynamic effects even with nominally parallel surfaces, and that optimum surface texturing may substantially reduce the friction losses in reciprocating automotive components.

Brizmer et al. (2003) [9], discussed the potential use of a new technology of laser surface texturing (LST) in parallel thrust bearings. In this work the surface texturing has the form of micro dimples with preselected diameter, depth, and area density. These authors adopted optimum parameters of the dimples, and best LST mode, to obtain maximum load carrying capacity for a thrust bearing having parallel mating surfaces. There exists an optimal depth for which the dimples can provide the highest load carrying capacity as underlined by Yu et al [10]. (2000).

Siripuram et al. (2004) [11] presented a numerical study of the effects of different shapes of micro asperities in sliding surface lubrication for hydrodynamic films. Positive and negative asperities of constant heights are considered with circular, square, diamond, hexagonal, and triangular asperities give the smallest leakage rate whereas, the square asperities provide the largest. The minimum coefficient of friction for all shapes is found to occur at an asperity area fraction of 0.2 for positive asperities and 0.7 for negative asperities as reported by Siripuram et al. (2004) [11]. In a study of corrugated surfaces, Huynh (2005) [12] pointed out that the load could be increased when the corrugated surface is well located on a fixed-incline slider bearing. Nevertheless, by introducing such a pattern, comparison with the smooth case is not reasonable since the global film thickness is reduced such that pressure increases when the corrugation amplitude increases. Brajdic-Mitidieri et al. (2005) [13] studied the influence of the convergence ratio and position of a pocket on the global friction coefficient for a pocketed pad bearing. Pocket depth and position were also found to be of importance for reduction in the friction coefficient by these authors.

Sinanoglu et al. (2005) [14] compared the experimental result with numerical result. Authors used two types of surface textures one is Trapezoidal surface and other is Saw teeth surface. Authors found that Trapezoidal textured shaft can carry more loads then the saw textured sh**a**ft. In many studies, Reynolds or Stokes equations are employed neglecting pressure gradient across the lubricating film and inertia effects.

However, Arghir et al. (2003) [20] have shown that Stokes equations are inadequate to predict pressure build-up with the presence of macro-roughness as inertia effects can be of importance. This finding was confirmed later by Sahlin et al. (2005) [21] who also presented an optimization of the geometry.

Lu et al. (2007) [22] investigated the dimple effect on the Stribeck curve of journal bearings experimentally. Authors pointed out that the typical friction a characteristic of a dimpled journal bearing is similar in trend to that of a conventional bearing, as prescribed by Stribeck curve. Further they reported that proper dimple size, shape and depth are essential to improve the friction performance and that it becomes more pronounced if oil with lower viscosity is utilized.

Influence of surface corrugation on the performance of slider bearings has attracted the attention of many investigators [29–37]. Sinusoidal corrugations with striation parallel or perpendicular to the sliding direction were considered by Michell [29], Mitsuya and Fukui [34], Burton [39], White et al. [40], and Tonder [41][42]. More complex striated corrugations, for example, of a random nature or with striations skewed at an angle to the sliding direction, were treated in Refs. [30], [31], [33], [43–48]. Extension to situations where corrugation amplitude varies over bearing surfaces has been presented by Lunde and Tonder [37], Patir and Cheng [48], and Tonder [49]. However, in the above works, invariably corrugation extends over the full length in the direction of sliding motion of the bearing gap. On the other hand, there can be many situations where corrugation occurs not over the whole bearing, but rather in some sections only. This could happen as a result of manufacturing error, or some non-uniform flow pattern causing localized erosion and corrugation. This could also happen intentionally; since surface corrugation has been recognized as affecting bearings' characteristics, it is thus possible that some corrugation patterns would be beneficial for a given application. In an effort to explore such patterns and provide further understanding of lubrication flow in bearings, this work considers the effects of sinusoidal corrugation of limited extent on the performance of fixed-incline slider bearings, using viscous fluids of a Newtonian type for lubricant. A finite element numerical method is used for computation of the flow under non isothermal conditions. Also, unlike many previous works where often approximations of a Reynolds type [3] [4] [7] [11] [14], or to a lesser extent, approximations of a Stokes type [6] [16] have been used, no simplifying assumptions will be made in the present study.

Tala-ighil et al. (2007) [23] analyzed two cases, one in which the shaft is assumed to be smooth and rigid and one in which the bearing surface is numerically textured with spherical dimples. The numerical results indicate that textures affect the most important bearing characteristics viz: film thickness, pressure distributions, axial film flow, and frictional torque. The analyses of spherically dimpled surface indicate that appropriate selection of size, depth, and number of dimples may affect bearing characteristics.
Tala-ighil et al. (2008) [24] also analyzed different configurations (spherical shape, cylindrical shape, parallelepipedical shape) assuming the shaft is smooth and rigid and the bearing surface is numerically textured and reported that the positive effect of textured on contact characteristics becomes significant for the parallelpipedic shape rather than for cylindrical or spherical shapes, suggesting the advantage of parallelepipedic shape over other geometries.

Jourak (2008) studied one dimple effect on the shaft of the bearing and found that due to the one dimple, there is no significant effect on load carrying capacity. Author suggested that increases the number of dimples may improve the journal bearing performance.

Cupillard et al. (2008) [26] studied a complete textured bearing using the full Navier-Stokes equations and a cavitations model. As the authors illustrated, the coefficient of friction can be reduced if dimples of suitable width are introduced. According to the authors, this can be achieved either in the region of maximum hydrodynamic pressure for a bearing with a high eccentricity ratio or just downstream of the maximum film for a bearing with a low eccentricity ratio. The authors reported an additional effect of pressure build up that is generated by surface texturing for journal bearing at low eccentricity ratios.

Cupillard et al. (2008) [27] explained a mechanism of pressure build up in a convergent gap due to texture. Authors have found that the mechanism of pressure build up in a convergent gap between two sliding surfaces due to texture is similar to that obtained with variation of convergence ratio for smooth surfaces. As the fluid receives energy from the moving wall, lower losses in the inlet than in the outlet part produce positive variation of the mechanical energy in the inlet part and pressure build up. Pressure gradient decreases when recirculation occurs, i.e. when a too large value of dimple depth or the convergence ratio is used. Lower pressure is generated locally. Wall shape controls the velocity profile, which determines the pressure gradient and the pressure build up by means of the continuity equation.

IV. SUMMARY OF LITERATURE SURVEY

The summery researches done by experts in the area of Slider hydrodynamic journal bearings have been presented in Table 1 which carries the Author name, year and investigated problem types.

Table 1: Summary of the developments in wear and friction in journal bearings on literature survey.

Sr. no.	Author Name (Year)	Investigated Problem Type
3	Noronha et al (2005)	Analysis of Lubrication Groove Geometry
4	S. Cupillard (2007)	Lubrication of conformal contacts with surface texturing
5	R. Kumar (2008)	Studies of the Hydrodynamic Bearings with Surface Profiling and Entrained Solid Particulate
6	N. Patir et al (1979)	Application of average flow model to lubrication between rough sliding surfaces
7	K. Tonder (2001)	Inlet roughness tribo-devices: Dynamic coefficient and leakage
8	A. Ronen et al (2001)	Friction-reducing surface texturing in reciprocating automotive components
9	V. Brizmer (2003)	A laser textured parallel thrust bearing
10	T.H Yu et al (2000)	Groove effects on thrust washer lubrication
11	R.B. Siripuram et al (2004)	Effect of deterministic asperity geometry hydrodynamic lubrication
12	P.B. Huynh (2005)	Numerical study of slider bearing with limited corrugation
13	P. Brajdic-Mitidieri et al (2005)	CFD analysis of low friction pocketed pad bearing
14	C. Sinanoglu et al (2005)	Effect of Shaft surface texturing on journal bearing pressure distribution
15	P. L. Andharia et al (2005)	Effect of surface roughness on hydrodynamic lubrication of slider bearings
16	R.K. Sharma et al (2009)	Experimental studies of pressure distributions infinite slider bearing with single continuous surface profiles on the pads
17	A. Charnes et al (1955)	On the solution of the Reynolds equation for slider-bearing Lubrication—VII: the optimum slider profile for viscosity as function of the pressure
18	M. B. Dobrica et al (2006)	Thermohydrodynamic behavior of a slider pocket bearing
19	F.P. Snegovskii et al (1983)	Study of lubrication of sliding bearings with microgrooves on the sliding shafts
20	M. Arghir et al (2003)	Theoretical analysis of the incompressible laminar flow in a macro-roughness cell
21	F. Sahlin et al (2005)	Two Dimensional CFD Analysis of Micro Patterned Surfaces in Hydrodynamic Lubrication
22	X. Lu et al (2007)	An experimental investigation of dimple effect on the stribeck curve of journal bearings
23	N. Talaighil et al (2007)	Effects of surface texture on journal bearing characteristics under steady state operating conditions
24	N. Talaighil et al (2008)	Hydrodynamic effects of texture geometries on journal bearing surfaces
25	A. Jourak (2008)	CFD Analysis of a Journal Bearing with a Microgroove on the Shaft
26	S. Cupillard et al (2008)	CFD Analysis of Journal Bearing with Surface Texturing

27	S. Cupillard et al (2008)	Pressure build up mechanism in a textured inlet of a hydrodynamic contact
28	B.R. Reason et al (1982)	Rapid Design and Performance Evaluation of Steady State Journal Bearings-A Technique Amenable to Programmable Hand Calculators
29	A. G. M. Michell (1950)	Lubrication its principals
30	S. T. Tzeng et al (1967)	Surface Roughness Effect on Slider Bearing Lubrication
31	H. Christensen et al (1971)	The Hydrodynamic Lubrication of Rough Bearing Surfaces of Finite Width
32	H. G. Elrod (1979)	A General Theory for Laminar Lubrication with Reynolds Roughness
33	N. Phan-Thien (1981)	On the Effect of Parallel and Transverse Stationary Random Surface Roughness in Hydrodynamic Lubrication
34	Y. Mitsuya et al (1986)	Stokes Roughness Effects on Hydrodynamic Lubrication. Part 1—Comparison Between Incompressible and Compressible Lubricating Films
35	R. F. Gans (1987)	On Random Reynolds Roughness
36	G. Bayada et al (1988)	New Models in the Theory of the Hydrodynamic Lubrication of Rough Surfaces
37	L. Lunde et al (1997)	Numerical Simulation of the Effects of Three-Dimensional Roughness on Hydrodynamic Lubrication: Correlation Coefficients
38	R. A. Burton (1963)	Effects of Two-Dimensional, Sinusoidal Roughness on the Load Support Characteristics of a Lubricant Film
39	J. W. White et al (1986)	A Numerical Study of Surface Roughness Effects on Ultra-Thin Gas Films
40	K. Tonder (1984)	A Numerical Assessment of the Effect of Striated Roughness on Gas Lubrication
41	K. Tonder (1996)	Dynamics of Rough Slider Bearings
42	H. G. Elrod (1973)	Thin-Film Lubrication Theory for Newtonian Fluids With Surfaces Possessing Striated Roughness or Grooving
43	S. K. Rhow et al (1974)	The Effects on Bearing Load-Carrying Capacity of Two-Sided Striated Roughness
44	D. C. Sun et al (1977)	First Effects of Stokes Roughness on Hydrodynamic Lubrication
45	P. L. Chow et al (1978)	On the Roughness Effect in Hydrodynamic Lubrication
46	K. Tonder (1977)	Mathematical Verification of the Applicability of Modified Reynolds Equations to Striated Rough Surfaces
47	K. Tonder (1986)	The Lubrication of Unidirectional Striated Roughness: Consequences for Some General Roughness Theories
48	N. Patir et al (1979)	Application of Average Flow Model to Lubrication Between Rough Sliding Surfaces
49	K. Tonder (1980)	Simulation of the Lubrication of Isotropically Rough Surfaces

V. DISCUSSION

1. The load carrying of the sliding surfaces increases appreciably if the moving surface is smooth and decrease if the moving surface is rough.
2. Surface texturing can efficiently be used to maintain hydrodynamic effects even with nominally parallel surfaces, and that optimum surface texturing may substantially reduce the friction losses in reciprocating automotive components.
3. Positive and negative asperities of constant heights are considered with circular, square, diamond, hexagonal, and triangular asperities give the smallest leakage rate whereas, the square asperities provide the largest.

4. The minimum coefficient of friction for all shapes is found to occur at an asperity area fraction of 0.2 for positive asperities and 0.7 for negative asperities.
5. Stokes equations are inadequate to predict pressure build-up with the presence of macro-roughness as inertia effects can be of importance.
6. Proper dimple size, shape and depth are essential to improve the friction performance and that it becomes more pronounced if oil with lower viscosity is utilized.
7. A finite element numerical method is used for computation of the flow under non isothermal conditions.
8. The analyses of spherically dimpled surface indicate that appropriate selection of size, depth, and number of dimples may affect bearing characteristics.
9. The coefficient of friction can be reduced if dimples of suitable width are introduced.
10. As the fluid receives energy from the moving wall, lower losses in the inlet than in the outlet part produce positive variation of the mechanical energy in the inlet part and pressure build up.
11. Pressure gradient decreases when recirculation occurs, i.e. when a too large value of dimple depth or the convergence ratio is used. Lower pressure is generated locally.
12. Wall shape controls the velocity profile, which determines the pressure gradient and the pressure build up by means of the continuity equation.

VI. CONCLUSION

Based on the literature review, it is concluded that position of grooves on slider bearing, speed of bearing and viscosity of lubricants are very important parameters for the generation of pressure and thus support higher load. Selection of bearing for supporting a load is done by selecting the parameters like position of grooves on bearing, speed of bearing and viscosity of lubricant.

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