Research Inventy: International Journal 0f Engineering And Science
Vol.3, Issue 12 (December 2013), PP 83-94
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

A Recent Approach to Wear Concept in Hydrodynamic Journal Bearings

G.V.Punna Rao[1], Y.Bhargavi[2], A.Navanth[3]
[1](Assistant Professor, Mechanical Engineering Department, CMR Engineering College, Hyderabad)
[2](Assistant Professor, Mechanical Engineering Department, CM? Engineering College, Hyderabad)
[3](Asst. Professor, Mechanical Engineering Department, CMR Engineering College, Hyderabad)

Abstract: *The importance of friction and wear control cannot be overemphasized for economic reasons and long-term reliability. This paper presents the reviews of different works in the area of wear and friction in hydrodynamic journal bearings and tries to find out latest developments and trends available in industries and other fields in order to minimize the total equipment cost, minimize damages and maximize the safety of machines, structures and materials. This paper helps us to find out the parameters on which a hydrodynamic journal bearing is selected for different conditions i.e. dry as well as lubricated conditions.*
Keywords: *Friction, Hydrodynamic Journal bearing, Machine, Materials, Wear.*

I. Introduction

Despite their presence in our everyday life, friction, wear and tribology are not phenomena that most peoples are considering on daily basis. Nevertheless, they are responsible for many problems and large cost in modern civilization and engineers and designers are always must take these factors into account when constructing technical equipment. Usually wear is undesirable, because it makes necessary frequent inspection and replacements of parts and also it will lead to deterioration of accuracy of machine parts. It can induce vibrations, fatigue and consequently failure of the parts [1]. For the particular practical application the kind of wear loading can be different, and therefore the structure of the composite material used for these applications can also be different in order to fulfill the particular requirements.

II. Wear

2.1. Introduction

Wear is progressive loss or removal of material from one or both the surfaces in contact as the result of relative motion between them [2].Wear is the single most influencing factor which shortens the effective life of machine or its components.

2.2. Types of Wear

Fig 1. Shows the types of wear.

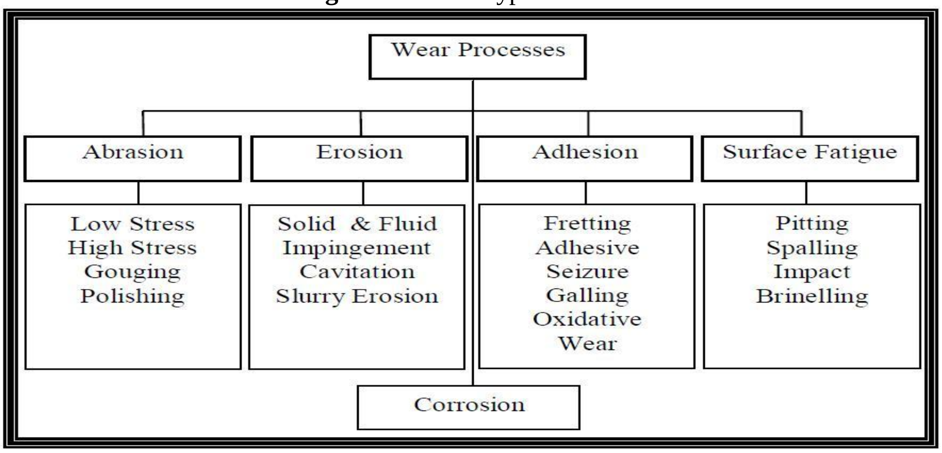


Fig. 1 Types of Wear

2.2.1. Abrasive Wear

Abrasive wear occurs when material is removed from one surface by another harder Material, leaving hard particles of debris between the two surfaces (Fig 2) It can also be called scratching, gouging or scoring depending on the severity of wear. Abrasive wear occurs under two conditions:

1. Two body abrasion: In this condition, one surface is harder than the other rubbing surface. Examples in mechanical operations are grinding, cutting, and machining.
2. Three body abrasion: In this case a third body, generally a small particle of grit or abrasive, lodges between the two softer rubbing surfaces, abrades one or both of these surfaces.

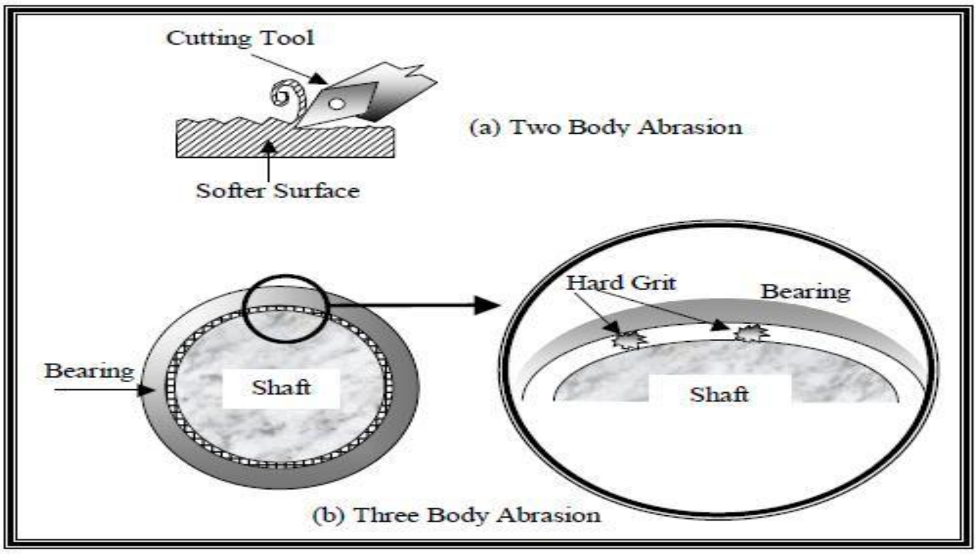
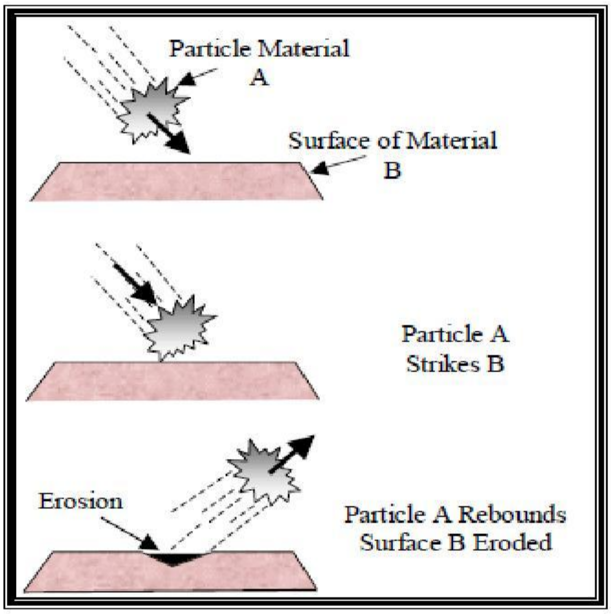


Fig 2 Abrasive Wear

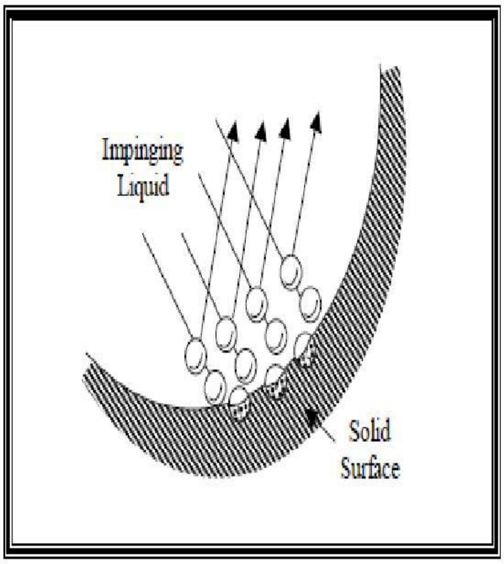
2.2.2. Erosive Wear

The impingement of solid particles, or small drops of liquid or gas often cause what is known as erosion of materials and components. Solid particle impact erosion has been receiving increasing attention especially in the aerospace industry. Examples include the ingestion of sand and erosion of jet engines and of helicopter blades. As shown in figures 3 & 4. the erosion mechanism is simple. Solid particle erosion is a result of the impact of a solid particle A, with the solid surface B, resulting in part of the surface B been removed. The impinging particle may vary in composition as well as in form. Cavitation erosion occurs when a solid and a fluid are in relative motion, due to the fluid becoming unstable and bubbling up and imploding against the surface of the solid, as shown in figure 4. Cavitation damage generally occurs in such fluid-handling machines as marine propellers, hydrofoils, dam slipways, gates, and all other hydraulic turbines, according to Bhushan and Gupta (1991) [4]. Cavitation erosion roughens a surface much like an etchant would.



Schematic of erosive wear.

Fig 3. Abrasive Wear due to solid erosion

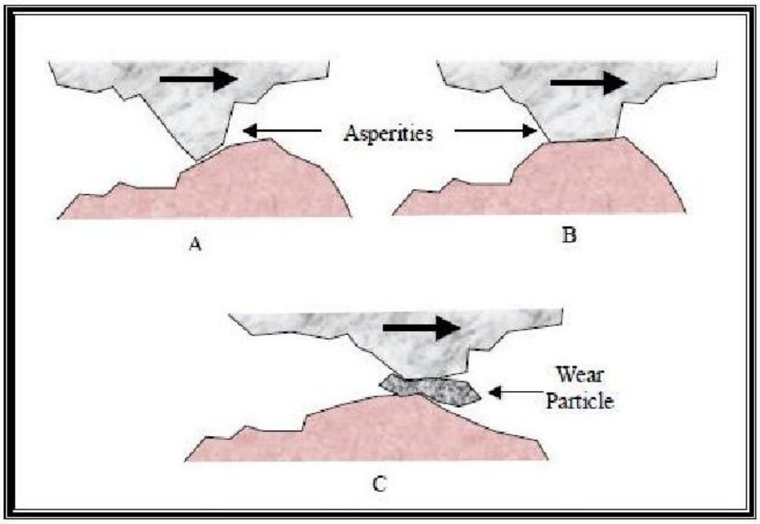


Schematic of cavitation erosion due to impingement of liquid bubbles.

Fig 4. Abrasive Wear due to liquid erosion

2.2.3. Adhesive Wear

Adhesive wear is often called galling or scuffing, where interfacial adhesive junctions lock together as two surfaces slide across each other under pressure, according to Bhushan and Gupta (1991) [4]. As normal pressure is applied, local pressure at the asperities become extremely high. Often the yield stress is exceeded, and the asperities deform plastically until the real area of contact has increased sufficiently to support the applied load, as shown in figure 5. In the absence of lubricants, asperities cold-weld together or else junctions shear and form new junctions. This wear mechanism not only destroys the sliding surfaces, but the generation of wear particles which cause cavitation and can lead to the failure of the component.

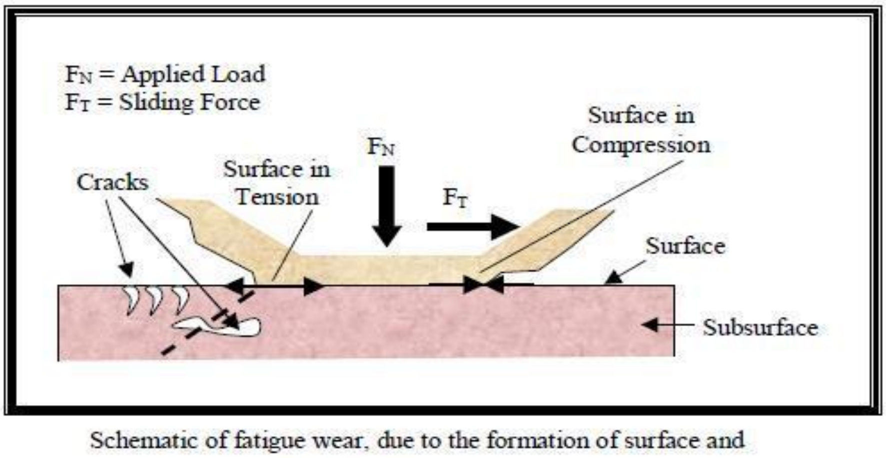


Schematic of generation of a wear particle as a result of adhesive wear process.

Fig 5 Adhesive Wear

2.2.4. Surface Fatigue

When mechanical machinery move in periodical motion, stresses to the metal surfaces occur, often leading to the fatigue of a material. All repeating stresses in a rolling or sliding contact can give rise to fatigue failure. These effects are mainly based on the action of stresses in or below the surfaces, without the need of direct physical contact of the surfaces under consideration. When two surfaces slide across each other, the maximum shear stress lies some distance below the surface, causing microcracks, which lead to failure of the component. These cracks initiate from the point where the shear stress is maximum, and propagate to the surface as shown in figure 6. Materials are rarely perfect, hence the exact position of ultimate failure is influenced by inclusions, porosity, microcracks and other factors. Fatigue failure requires a given number of stress cycles and often predominates after a component has been in service for a long period of time.



Schematic of fatigue wear, due to the formation of surface and subsurface cracks.

Fig 6 Surface Fatigue

2.2.5. Corrosive Wear

In corrosive wear, the dynamic interaction between the environment and mating material surfaces play a significant role, whereas the wear due to abrasion, adhesion and fatigue can be explained in terms of stress interactions and deformation properties of the mating surfaces. In corrosive wear firstly the connecting surfaces react with the environment and reaction products are formed on the surface asperities. Attrition of the reaction products then occurs as a result of crack formation, and/or abrasion, in the contact interactions of the materials. This process results in increased reactivity of the asperities due to increased temperature and changes in the asperity mechanical properties.

III. Hydrodynamic Journal Bearing

In hydrodynamic lubrication, the load supporting high pressure fluid-film is created due to shape and relative motion between the two surfaces [3]. The moving surface pulls the lubricant into a wedge shaped zone, at a velocity sufficiently high to create the high pressure film necessary to separate the two surface against the load.

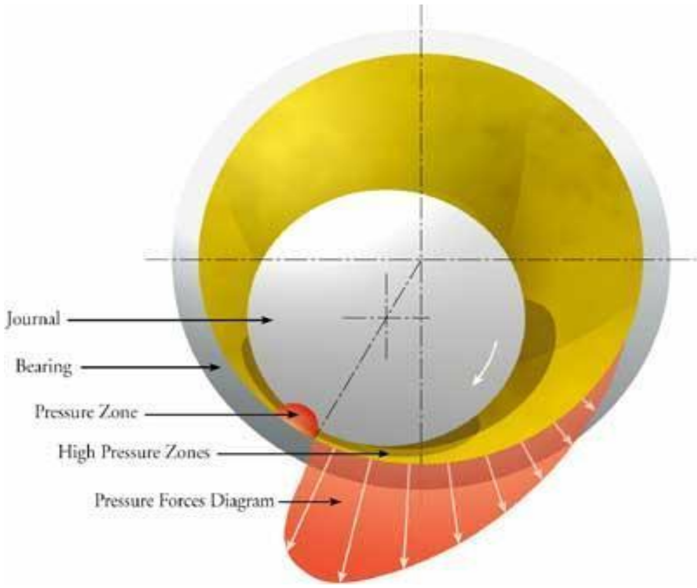


Fig.7 Hydrodynamic journal bearing

Figure 7 shows the principle of working of hydrodynamic journal bearing. Initially when the journal is at rest, it makes contact with the bearing at its lowest point A, due to load _W'. When the journal starts rotating in anticlockwise direction, it will climb the bearing surface and contact is made at point B. As the speed of the journal is further increased, the lubricant is pulled into the wedge-shaped region and forces the journal to the other side. The converging wedge-shaped film between points C and D supports the journal. Thus in hydrodynamic bearings, it is not necessary to supply the lubricant under pressure. The only requirement is to ensure sufficient and continuous supply of the lubricant.

IV. Objectives

- To find out the behavior of the material from wear & friction point of view and the effect of various sliding speeds and loads.
- To study the phenomenon of failure of transfer film by making use of SEM or optical microscope.
- To suggest the best suitable material for the journal bearing applications from the tested materials.
- To find out the mode of selection of material for hydrodynamic journal bearings.

V. Literature Survey

Journal bearings in automotive engines and other machinery are designed to operate in the hydrodynamic lubrication regime, with a film of lubricant separating the two surfaces. Despite this supposed absence of solid/solid contact during operation, however, many bearings suffer significant wear during their operating lives [5]. It is shown in this paper that wear occurs in three different locations in journal bearings, with each of the locations showing a different predominant wear mechanism. Study of the wear problem requires a different model experiment for each of the three different wear modes, and each wear mode also requires a different remedy to achieve wear reduction.

G. H. Jang et al [6]investigates the dynamic characteristics of a herringbone grooved journal bearing with plain sleeve (GJPS) and a plain journal bearing with herringbone grooved sleeve (PJGS) under static and dynamic load. FEM is used to solve the Reynolds equation in order to calculate the pressure distribution in a fluid film. Reaction forces and friction torque are obtained by integrating the pressure and shear stress along the fluid film, respectively. Dynamic behaviors of a journal, such as orbit or rotational speed, are determined by solving its nonlinear equations of motion with the Runge-Kutta method.

In the present work, a permanent magnetic–hydrodynamic hybrid journal bearing is developed [7]. The force of the journal bearing comes from the hydrodynamic film and the permanent magnetic field. When a hydrodynamic film does not form, such as during starting and stopping a machine, the journal bearing relies on the magnetic force to support the rotor system. This paper studies a model of the permanent magnetic force and develops an experimental rig of the journal bearing. Experiments show that the hydrodynamic film force uncouples with the magnetic force in the journal bearing. Predictions from the model are compared with experimental data.

Wenyi Yan et al [8] has explored that, A computational approach is proposed to predict the sliding wear caused by a loaded spherical pin contacting a rotating disc, a condition typical of the so-called pin-on-disc test widely used in tribological studies. The proposed framework relies on the understanding that, when the pin contacts and slides on the disc, a predominantly plane strain region exists at the centre of the disc wear track. The wear rate in this plane strain region can therefore be determined from a two dimensional idealization of the contact problem, reducing the need for computationally expensive three dimensional contact analyses.

S. Das et al [9] deals with the micropolar lubrication theory to the problem of the steady-state characteristics of hydrodynamic journal bearings considering two types of misalignment, e.g. axial (vertical displacement) and twisting (horizontal displacement). With the help of the steady-state film pressures, the steady-state performance characteristics in terms of load-carrying capacity, misalignment moment and friction parameter of a journal bearing are obtained at various values of eccentricity ratio, degree of misalignment and micropolar fluid characteristic parameters viz. coupling number and non-dimensional characteristic length.

The combined effects of couple stresses and surface roughness on the performance characteristics of hydrodynamic lubrication of slider bearings with various film shapes, such as plane slider, exponential, secant and hyperbolic, are studied. A stochastic random variable with non-zero mean, variance and skewness is used to mathematically model the surface roughness of the slider bearings. It is observed that, for all the lubricant film shapes under consideration, the negatively skewed surface roughness increases the load carrying capacity, frictional force and temperature rise, while it reduces the coefficient of friction10]. On the contrary, the reverse trend is observed for positively skewed surface roughness. Further, these effects are more pronounced for the couple stress fluids.

HasanBaş et al [11] studied the frictional behavior of thin-walled journal bearings produced from Zn–Al–Cu–Si alloys using a purpose-built journal bearing test rig. The alloys were produced by permanent mould casting. Mechanical properties such as ultimate tensile strength, elongation, hardness and microstructure of these alloys were determined. The friction properties of the bearings produced from these alloys were also investigated. In this investigation, the effects of surface roughness and bearing pressure on the frictional properties of the journal bearings were taken into account.

Hydrodynamic lubrication characteristics of a journal bearing, taking in to consideration the misalignment caused by shaft deformation, are analyzed. Film thickness expression of the misaligned journal bearing is inferred[12]. Film pressure, load-carrying capacity, attitude angle, end leakage flow-rate, frictional coefficient, and misalignment moment of a journal bearing are calculated for different values of misalignment degree and eccentricity ratio. The results show that there are obvious changes in film pressure distribution, the highest film pressure, film thickness distribution, the least film thickness, and the misalignment moment when misalignment takes place.

Hydrodynamic journal bearings are widely used in industry because of their simplicity, efficiency and low cost. They support rotating shafts over a number of years and are often subjected to many stops and start[13]. During these transient periods, friction is high and the bushes become progressively worn, thus inducing certain disabilities. This paper seeks to present the thermohydrodynamic performance of a worn plain journal bearing.

The dynamic characteristics of hydrodynamic journal bearings lubricated with micropolar fluids are presented [14]. The modified Reynolds equation is obtained using the micropolar lubrication theory. Applying the first order perturbation of the film thickness and steady state film pressure, the dynamic characteristics in terms of the components of stiffness and damping coefficients, critical mass parameter and whirl ratio are obtained with respect to the micropolar property for varying eccentricity ratios and slenderness ratios. The results show that micropolar fluid exhibits better stability in comparison with Newtonian fluid.

Klaus Friedrich et al [15]have observed during the wear test that , if the particle sizes of the filler material used in PTFE are diminishing down to Nano-scale, significant improvements of the wear resistance of polymers were achieved at very low Nano-filler content (1–3 vol.%). A combinative effect of nanoparticles with short carbon fibers exhibited a clear improvement of the wear resistance of both thermosetting and thermoplastic composites. In addition, this concept allowed the use of these materials under more extreme wear conditions, i.e., higher normal pressures and higher sliding velocities.

Paulo Flores et al [16] use the analytical mobility method to analyze journal bearings subjected to dynamic loads, with the intent to include it in a general computational program that has been developed for the dynamic analysis of general mechanical systems. A simple journal bearing subjected to a dynamic load is chosen as a demonstrative example, in order to provide the necessary results for a comprehensive discussion of the methodology presented.

Gwidon W. Stachowiak et al [17] describes the fundamental wear mechanisms operating in non-metallic materials together with some prognoses concerning the future developments of these materials. Two classes of materials with entirely different characteristics—polymers and ceramics—are discussed. Polymers can provide low friction and low wear coefficients but their use is limited to lower temperatures and consequently low speeds and loads. Ceramics are resistant to high temperatures and often have a good wear resistance but their applications are limited by poor friction coefficients, especially in unlubricated applications. Ceramics and polymers are surprisingly vulnerable to accelerated wear in the presence of corrosive reagents and care should be taken in the selection of materials that are appropriate for particular operating conditions.

H.Unalet al [18] has studied and explored the influence of test speed and load values on the friction and wear behavior of pure Polytetrafluoroethylene (PTFE), glass fiber reinforced (GFR) and bronze and carbon (C) filled PTFE polymers. Friction and wear experiments were run under ambient conditions in a pin -on-disc arrangement. Tests were carried out at sliding speed of 0.32 m/s, 0.64 m/s, 0.96 m/s and 1.28 m/s and under a nominal load of 5 N, 10 N, 20 N and 30 N. From this study the have observed that, PTFE + 17% GFR exhibited best wear performance and is a very good tribo-material between materials used in this study. The friction coefficient of pure PTFE and its composites decreases when applied load increases.

N.B. Naduvinamani et al [19] presents the theoretical study of the effect of surface roughness on the hydrodynamic lubrication of porous step-slider bearings. A more general form of surface roughness is mathematically modeled by a stochastic random variable with non-zero mean, variance and skewness. The numerical computations of the results show that the negatively skewed surface roughness pattern increases the load carrying capacity and decreases the coefficient of friction whereas the adverse effects were found for the positively skewed surface roughness pattern.

It is well known that in journal bearings, friction occurs in all lubrication regimes. However, shaft misalignment in rotating systems is one of the most common causes of wear. In this work, the bearing is assumed to operate in the hydrodynamic region, at high eccentricities, wear depths, and angular misalignment [20]. The Reynolds equation is solved numerically; the friction force is calculated in the equilibrium position. The friction coefficient is presented versus the misalignment angles and wear depths for different Somerfield numbers, thus creating friction functions dependent on misalignment and wear of the bearing. The variation in power loss of the rotor bearing system is also investigated and presented as a function of wear depth and misalignment angles.

According to J. D. Bressana et al [21]the disc wear was more severe as difference in hardness between pin and disc is increased. It can be observed that decrease in pin hardness yields to lower pin wear resistance distance the trends of pin wear rate curves with sliding distance is approximately constant and linear. However, the final stage, some pins are presented the tendency to decrease the wear rate. This is due to the decrease in real contact pressure with increase in the pin contact area and/or increase in hardness of disc track.

A steady-state thermo hydrodynamic analysis of an axial groove journal bearings in which oil is supplied at constant pressure is performed theoretically [22]. Thermo hydrodynamic analysis requires simultaneous solution of Reynolds equation, energy equation and heat conduction equations in the bush and the shaft. From parametric study it is found that the temperature of the fluid film raises due to frictional heat thereby viscosity, load capacity decreases. Increased shaft speed resulted in increased load carrying capacity, bush temperature, flow rate and friction variable. It is difficult to obtain the solution due to numerical instability when the bearing is operated at high eccentricity ratios.

Steady state thermo-hydrodynamic analysis and its comparison at five different feeding locations of an axial grooved oil journal bearing is obtained theoretically [23]. Reynolds equation is solved simultaneously along with the energy equation and heat conduction equation in bush and shaft. From parametric study it is found that 12° feeding groove position is better in comparison to other feeding locations. Feeding from the bottom is very less preferable since the load capacity is lesser and temperature development is more. It is very difficult to obtain the solution due to numeric instability when the bearing operates at higher eccentricity ratio.

Detecting mechanical faults of rotating machines particularly in hydrodynamic bearings has been recognized as important for preventing sudden shut downs [24]. This technical note presents an experimental investigation that is aimed at understanding the influence of operational variables (speed, load, etc.) on generation of acoustic emission in a hydrodynamic bearing. It is concluded that the power losses of the bearing are directly correlated with acoustic emission levels.

Journal bearings are widely applied in different rotating machineries [25]. These bearings allow for transmission of large loads at mean speed of rotation. These bearings are susceptible to large amplitude lateral vibration due to self-exited instability which is known as oil whirl or Synchronous whirl. This paper presents a method to determine the Synchronous whirl i.e. Stability of hydrodynamic Journal bearings by using dynamic characteristics such as stiffness coefficients.

From time-to-time, experts endeavor to estimate the amount of energy lost due to friction and wear[26]. According to one such estimate, over 4.22×10^{18} J of energy were lost in the United States in 1978 alone – enough to supply New York city for the entire year. A major factor in limiting our energy efficiency is energy loss through friction in tribo -elements are. In recognition of this, there have been significant efforts made during the past decades towards increasing the efficiency of bearing operations. The major influencing aspects of hydrodynamic lubrication are the structure of the lubricant film, the properties of the bearing surfaces, and the properties of the lubricant. Major past approaches for seeking efficiency improvement focused on the latter two of these aspects and concerned surface modification techniques and modification of lubricant properties. The CFB construction appears to be particularly suitable to power generating equipment. The journal bearings of these large rotating apparatus dissipate considerable energy; the CFB has the potential to cut these losses.

Fatu Aurelian et al [27] demonstrate that like surface texturing, well-chosen slip/no-slip surface patterning can considerably improve the performance of fluid bearings. Firstly, a finite element analysis is proposed in order to study the influence of wall slip over the load carrying capacity and power loss in hydrodynamic fluid bearings. A systematic comparison is made with textured bearing conditions. Secondly, the study is extended to the influence of wall slip in highly loaded compliant bearings, for steady-state and dynamical load conditions. The predictions show that well-chosen slip/no-slip surface pattern can considerably improve the bearing behavior and largely justify future numerical and experimental works.

Textured surfaces can significantly improve the performance of hydrodynamic bearings. However, there is no generally accepted method for their accurate and automated 3D characterization [28]. A promising solution to this problem is partition iterated function system (PIFS) model, which encapsulates information about 3D topography of textured surfaces. However, some loss in surface details can occur.

For some hydrodynamic bearing applications polymer-lined bearings are chosen over traditional metal alloy bearings due to their better wear and friction properties when operating at very thin films, e.g. in the mixed lubrication region [29]. The introduction of a compliant layer also affects the dynamic behavior of the bearing. The influence of the liner stiffness on the dynamic response of a highly dynamically loaded journal bearing is evaluated by varying the stiffness and comparing the response. The primary findings are that the maximum pressures are reduced significantly and this comes at the expense of slightly higher eccentricity ratios during operation.

Kim Thomsen et al [30] gives a numerical simulation presented for the thermo-hydrodynamic self-lubrication aspect analysis of porous circular journal bearing of finite length with sealed ends. It consists in analyzing the thermal effects on the behavior of circular porous journal bearings. The effects of dimensionless permeability parameter and eccentricity ratio on performance parameters are presented and discussed. The results showed that the temperature influence on the journal bearings performance is important in some operating cases, and that a progressive reduction in the pressure distribution, in the load capacity and attitude angle is a consequence of the increasing permeability.

A growing interest is given to the textured hydrodynamic lubricated contacts. The present study examines the texture location influence on the hydrodynamic journal bearing performance [31]. A numerical modelling is used to analyze the cylindrical texture shape effect on the characteristics of a hydrodynamic journal bearing. The theoretical results show that the most important characteristics can be improved through an appropriate arrangement of the textured area on the contact surface.

M. Fillon et al [32] deal with the friction coefficient during running, given a constant rotational speed. In order to understand the mechanisms occurring during the transition between mixed lubrication and hydrodynamic lubrication, several studies have been conducted over the past three years. The aim of this paper is to provide an overview of the results of these studies and also to draw several general conclusions on the behavior of a plain journal bearing during start-up. The main focus of this work is then to provide useful experimental data for bearing users and designers.

A growing interest is given to the textured hydrodynamic lubricated contacts. The use of textured surfaces with different shapes of microcavities (textures) and at different locations of the texture zone can be an effective approach to improve the performance of bearings [33]. The present study examines the texture location influence on the hydrodynamic journal bearing performance. A numerical modeling is used to analyze the cylindrical texture shape effect on the characteristics of a hydrodynamic journal bearing. The theoretical results show that the most important characteristics can be improved through an appropriate arrangement of the textured area on the contact surface.

E.N. Santos et al [34] deal with analysis of hydrodynamic lubrication of radial journal bearings. The Reynolds equation was treated in order to obtain a hybrid numerical–analytical solution through the Generalized Integral Transform Technique (GITT) for the problem. Comparisons with results presented in the literature were also performed in order to verify the present results, as well as to demonstrate the consistency of the final results and the capacity of the GITT approach in handling journal bearing problems.

Priyanka Tiwari et al [35] presents a survey of important papers pertaining to analysis of various types of methods, equations and theories used for the determination of load carrying capacity, minimum oil film thickness, friction loss, and temperature distribution of hydrodynamic journal bearing. Predictions of these parameters are the very important aspects in the design of hydrodynamic journal bearings. The present study mainly focuses on various types of factors which tremendously affect the performance of hydrodynamic journal bearing

The magneto-hydrodynamic (MHD) dynamic characteristics of a wide power-law film-profile slider bearing lubricated with an electrically conducting fluid under the application of transverse magnetic fields has been proposed [36]. A closed-form solution is obtained for the MHD power-law film-shape slider bearings, in which special bearing characteristics of the inclined-plane shape and the parabolic-film profile can also be included. Comparing with the non-conducting-fluid power-law film-shape bearing, the MHD bearing provides an increase in the load capacity, and the stiffness and damping coefficients.

An analytic model is developed to predict static characteristics of a new hydrodynamic–rolling hybrid bearing (HRHB). Experiments are carried out to measure the equilibrium positions, the load sharing, and the rotational speeds of the rolling bearing cage [37]. The results show that the working states of HRHB are divided into two distinct phases by a transition speed at which the hydrodynamics and contact models are decoupled. The cage speeds can be used to determine transition speed. The theoretical results agree with the experimental results, and it can be employed to design the bearing parameters according to the expected performance.

In this work, performance degradation in scratched journal bearings is evaluated by means of numerical simulations. A hydrodynamic numerical model with global thermal effects is employed (lubricant temperature and viscosity are assumed to be uniform) [38]. A very fine mesh is used, which allows a deterministic representation of a large number of circumferential scratches of various sizes and rectangular cross-shape. The severity of the scratches is quantified using four parameters: their depth, the extent of the scratched region, the density of the scratches and the position of the scratched region with respect to the bearing mid-plane. Lastly, charts are presented showing the evolution of the different bearing operating parameters as a function of the scratch severity, allowing the identification of critical scratch configurations that can lead to bearing damage.

The effect of couple stress fluid on the elasto-hydrodynamically lubricated finite line contact is studied [39]. Modified Reynolds equation is derived from Stokes micro continuum theory and solved numerically using finite difference method. Owing to the finite contact analysis, the effect of couple stress fluid at the edges of the roller is examined. The study reveals that overall film thickness increases significantly with couple stress parameter.

The hydrodynamic journal bearing system has found wide spread application in high speed rotating machine such as compressors, gas turbines, water turbines, steam turbines, alternators etc. [40]. As rotor generally operates at high speed, the lubricant flow in the clearance space of journal bearing does not remain laminar and for accelerated/decelerated journals the threshold speed of instability is crossed from both sides. In this paper the numerical method has been used to compute the static and dynamic performance parameter.

Ana M. Balasoiu et al [41] present 3D, isothermal numerical analysis of a cylindrical porous journal bearing characterized by a self-circulating lubricating system that eliminates the necessity of an external circulating pump. The system includes a stationary porous bushing whose inner diameter faces the bearing clearance while the outer diameter faces a wrapped-around reservoir. The loaded, eccentric shaft is generating a high pressure zone in the convergent region followed by a low pressure zone in the divergent region causing the fluid to circulate naturally between the bearing clearance and the reservoir, as it passes through the porous bushing. The fundamental physics of the circulating mechanism are described, and its operation is numerically simulated. The study uses the complete 3D Navier–Stokes Equations (NSE) for the fluid motion in the bearing clearance and the adjacent reservoir. The results which include the flow patterns, pressure maps and attitude angles, are presented on a parametric basis, and confirm the functionality of the proposed self-circulating system. It was found that the load capacity decreases and the attitude angle increase as permeability increases, and depending on permeability ranges, the increase in the reservoir depth may result in a reduction of the load capacity.

The concept of dynamic pressure ratio (γ) is put forward in this paper to measure the hydrodynamic effect on bearing land [42]. The Reynolds equation and flow continuity equation have been solved using finite difference method, over relaxation method and under relaxation method. Taking the four-pocket capillary compensated hydrostatic journal bearing as an example, variations of dynamic pressure ratio(γ) with eccentricity ratio (ε)and rotating speed(N) are studied.

Emiliano Mucchi et al [43] propose an experimental methodology for the analysis of the lubrication regime and wear that occur between vanes and pressure ring in variable displacement vane pumps. The knowledge of the lubrication regime is essential for the improvement of the performance of high pressure vane pumps by reducing wear, increasing the volumetric efficiency and decreasing maintenance costs. Tests using pressure rings of different materials were carried out in order to identify the best material in terms of wear and friction.

Kazuyuki Yagi et al [44] found that a small elastic deformation of less than 100 nm plays an important role in load capacity in thin film hydrodynamic lubrication. As the film thickness decreases, a flat film shape appears from the leading side of the contact area. The expansion of the flat film thickness over the contact area leads to considerably lower load capacity.

Tribological performances of non-grooved and micro-grooved journal bearings were studied under dynamic loading. Numerous experiments were performed using purpose-built test rig and then simulated using various numerical methods [45]. Friction force, friction coefficient, shaft center orbit, and film thickness were determined experimentally and numerically. The experimental and numerical results were in good agreement and the friction forces progressively increased on plain and circumferential, herringbone, and transversally micro-grooved bearing. The results show that it is necessary to complete detailed investigation about the tribological properties of the micro-grooved journal bearing by taking their shape, depth and operating condition into account.

Vijay Kumar Dwivedi et al [46] describe a theoretical study concerning static performance of four pocket rectangular recess hybrid journal bearing. Effect of recess length and width variation, number of recess variation on the load bearing capacity and oil flow parameter for rectangular recess has been carried out. The Reynolds equation for non-rotating recessed hybrid bearing was solved on a high speed computer satisfying appropriate boundary conditions and using finite difference method. Various results for different recess axial length to bearing axial length, different recess circumferential length to circumferential length of bearing, various L/D ratios and number of recesses are presented.

Gengyuan Gao et al [47] aims to provide references for designing water-lubricated plain journal bearings. Considering the differences between the physical properties of the water and of the oil, the effects of eccentricity ratio on pressure distribution of water film are analyzed by computational fluid dynamics (CFD). Then numerical analysis of journal bearings with different dimensions is undertaken under different rotational speeds. Based on the analysis, a reference is produced for selecting the initial diameter dimension which is used to design an efficient water-lubricated plain bearing under the given load and rotational speed.

VI. Summary Of Literature Survey

The summery researches done by experts in the area of wear and friction in hydrodynamic journal bearings have been presented in Table1 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*
5	F.E. Kennedy et al. (2001)	Wear of hydrodynamic journal bearings
6	G. H. Jang et al (2002)	Nonlinear Dynamic Analysis of a Hydrodynamic Journal Bearing Considering the Effect of a Rotating or Stationary Herringbone Groove.
7	Wei Li et al (2002)	Investigations on a permanent magnetic–hydrodynamic hybrid journal bearing.
8	Wenyi Yan et al (2002)	Numerical study of sliding wear caused by a loaded pin on a rotating disc
9	S. Das et al (2002)	On the steady-state performance of misaligned hydrodynamic journal bearings lubricated with micropolar fluids
10	N.B. Naduvinamani et al (2003)	Hydrodynamic lubrication of rough slider bearings with couple stress fluids
11	HasanBaş et al (2004)	Investigation of the tribological properties of silicon containing zinc–aluminum based journal bearings
12	Jun Sun et al (2004)	Hydrodynamic lubrication analysis of journal bearing considering misalignment caused by shaft deformation
13	M. Fillon et al (2004)	Thermo hydrodynamic analysis of a worn plain journal bearing
14	S. Das, S.K. Guha et al (2005)	Linear stability analysis of hydrodynamic journal bearings under micropolar lubrication
15	Klaus Friedrich et al (2005)	Effects of various fillers on the sliding wear of polymer composites
16	Paulo Flores et al (2006)	Journal bearings subjected to dynamic loads: theanalytical mobility method
17	Gwidon W. Stachowiak et al (2006)	Wear of Non-Metallic Materials
18	H. Unal et al (2006)	an approach to friction and wear properties of polytetraflouroethylene composite
19	N.B. Naduvinamani et al (2007)	Effect of surface roughness on the hydrodynamic lubrication of porous step-slider bearings with couple stress fluids
20	G. Padelis et al (2008)	A study of friction in worn misaligned journal bearings under severe hydrodynamic lubrication
21	J. D. Bressana et al (2008)	Influence of hardness on the wear resistance of 17-4 PH stainless steel evaluated by the pin-on-disc testing

22	U. Singh et al (2008)	Steady-state thermo-hydrodynamic analysis of cylindrical fluid film journal bearing with an axial groove
23	L. Roy et al (2009)	Thermo-hydrodynamic performance of grooved oil journal bearing
24	S.A. Mirhadizadeh et al (2010)	Influence of operational variables in a hydrodynamic bearing on the generation of acoustic emission
25	Ravindra R. Navthar et al (2010)	Stability Analysis of Hydrodynamic Journal Bearing using Stiffness Coefficients
26	Andras Z. Szeri et al (2010)	Composite-film hydrodynamic bearings
27	Fatu Aurelian et al (2011)	Wall slip effects in (elasto) hydrodynamic journal bearings
28	M. Wolski et al (2011)	Effects of information loss in texture details due to the PIFS encoding on load and friction in hydrodynamic bearings
29	Kim Thomsen et al (2011)	A study on compliant layers and its influence on dynamic response of a hydrodynamic journal bearing
30	S. Boubendir et al (2011)	Numerical study of the thermo-hydrodynamic lubrication phenomena in porous journal bearings
31	Michel Fillon et al (2011)	Effect of textured area on the performances of a hydrodynamic journal bearing
32	M. Fillon et al (2011)	Experimental measurement of the friction torque on hydrodynamic plain journal bearings during start-up
33	NacerTala-Ighil et al (2011)	Effect of textured area on the performances of a hydrodynamic journal bearing
34	E.N. Santos et al (2012)	Integral transform solutions for the analysis of hydrodynamic lubrication of journal bearings
35	Priyanka Tiwari et al (2012)	Analysis of Hydrodynamic Journal Bearing: A Review
36	Jaw-Ren Lin (2012)	Dynamic characteristics for wide magneto-hydrodynamic slider bearings with a power-law film profile
37	Dun Lu et al (2012)	Static characteristics of a new hydrodynamic–rolling hybrid bearing
38	M.B. Dobrica et al (2012)	Performance degradation in scratched journal bearings
39	S.P. Chippa et al (2013)	Elastohydrodynamically lubricated finite line contact with couple stress fluids
40	Satish Chand et al (2013)	Effect of Different Flow Regime on the Static and Dynamic Perfomance Parameter of Hydrodynamic Bearing
41	Ana M. Balasoiu et al (2013)	A parametric study of a porous self-circulating hydrodynamic bearing
42	Peng Liang et al (2013)	A method for measuring the hydrodynamic effect on the bearing land
43	Emiliano Mucchi et al (2013)	On the wear and lubrication regime in variable displacement vane pumps
44	Kazuyuki Yagi et al (2013)	Elastic deformation in thin film hydrodynamic lubrication
45	Hakan Adatepe et al (2013)	An investigation of tribological behaviors of dynamically loaded non-grooved and micro-grooved journal bearings
46	Vijay Kumar Dwivedi et al (2013)	Effect of Number and Size of Recess on the Performance of Hybrid (Hydrostatic/Hydrodynamic) Journal Bearing
47	Gengyuan Gao et al (2014)	Numerical analysis of plain journal bearing under hydrodynamic lubrication by water

VII. Discussion

- Journal bearings in automotive engines and other machinery are designed to operate in the hydrodynamic lubrication regime, with a film of lubricant separating the two surfaces
- When a hydrodynamic film does not form, such as during starting and stopping a machine, the journal bearing relies on the magnetic force to support the rotor system.
- Friction factor decreased with increasing bearing pressure especially in the mixed and full-film lubrication zones.
- Polymers can provide low friction and low wear coefficients but their use is limited to lower temperatures and consequently low speeds and loads.
- Ceramics are resistant to high temperatures and often have a good wear resistance but their applications are limited by poor friction coefficients, especially in unlubricated applications.
- Decrease in pin hardness yields to lower pin wear resistance distance the trends of pin wear rate curves with sliding distance is approximately constant and linear.
- The configurations with different liner stiffnesses are evaluated on the parameters that are traditionally used to evaluate hydrodynamic bearing designs: dynamic response, maximum pressure, minimum film thickness, wear, Power loss and temperature response.
- The coefficient of friction, which is of greater importance in lubrication, also decreases with increase in the couple-stress parameter.
- As rotor generally operates at high speed, the lubricant flow in the clearance space of journal bearing does not remain laminar and for accelerated/decelerated journals the threshold speed of instability is crossed from both sides.

- The knowledge of the lubrication regime is essential for the improvement of the performance of high pressure vane pumps by reducing wear, increasing the volumetric efficiency and decreasing maintenance costs.
- As the film thickness decreases, a flat film shape appears from the leading side of the contact area. The expansion of the flat film thickness over the contact area leads to considerably lower load capacity.
- It is necessary to complete detailed investigation about the tribological properties of the micro-grooved journal bearing by taking their shape, depth and operating condition into account.
- Based on the analysis, a reference is produced for selecting the initial diameter dimension which is used to design an efficient water-lubricated plain bearing under the given load and rotational speed.

VIII. Conclusion

Based on the literature review, it is concluded that wear is very important criteria for the selection of material of journal bearings. Selection of material is done by selecting the parameters like rate of wear, coefficient of friction, duration of use and conditions in which journal bearing is used. Wear can be observed in dry and lubricated conditions which are affected by speed, load, and temperature and working time. Wear rate analysis can be done on the different materials and in the different conditions. The main conditions are dry and lubricated condition in which some of lubricants can be used.

References

[1]. H.P. Jost, Tribology - origin and future, Wear 136, 1989.

[2]. I.M. Hutchings, Tribology - friction and wear of engineering materials, Edward Arnold, 1992.

[3]. Bharat Bhushan; Introduction to Tribology; John Wiley, 2001.

[4]. Bharat Bhushan, Balkishan K. Gupta; Technology & Engineering;McGraw-Hill, 1991.

[5]. L. Rozeanu, F.E. Kennedy; Wear of hydrodynamic journal bearings; Tribology Series, Volume 39, Pages 161-166, 2001.

[6]. G. H. Jang, J. W. Yoon; Nonlinear Dynamic Analysis of a Hydrodynamic Journal Bearing Considering the Effect of a Rotating or Stationary Herringbone Groove; ASME, Vol. 124/297, April 2002.

[7]. Qingchang Tan, Wei Li, Bo Liu; Investigations on a permanent magnetic–hydrodynamic hybrid journal bearing; Tribology International, Volume 35, Issue 7, Pages 443-448, July 2002.

[8]. Wenyi Yan, Noel P. O'Dowd, Esteban P. Busso, ―Numerical study of sliding wear caused by a loaded pin on a rotating disc‖ Journal of the Mechanics and Physics of Solids, Vol. 50, pp. 449 – 470, 2002.

[9]. S. Das, S.K. Guha, A.K. Chattopadhyay; On the steady-state performance of misaligned hydrodynamic journal bearings lubricated with micropolar fluids; Tribology International, Volume 35, Issue 4, Pages 201-210, April 2002.

[10]. N.B. Naduvinamani, Syeda Tasneem Fathima, P.S. Hiremath; Hydrodynamic lubrication of rough slider bearings with couple stress fluids; Tribology International, Volume 36, Issue 12, Pages 949-959, December 2003.

[11]. Hamdullah Çuvalcı, Hasan Baş; Investigation of the tribological properties of silicon containing zinc–aluminum based journal bearings; Tribology International, Volume 37, Issue 6, Pages 433-440, June 2004.

[12]. Jun Sun, GuiChanglin; Hydrodynamic lubrication analysis of journal bearing considering misalignment caused by shaft deformation; Tribology International, Volume 37, Issue 10, Pages 841-848, October 2004.

[13]. M. Fillon, J. Bouyer; Thermohydrodynamic analysis of a worn plain journal bearing; Tribology International, Volume 37, Issue 2, Pages 129-136, February 2004.

[14]. S. Das, S.K. Guha, A.K. Chattopadhyay; Linear stability analysis of hydrodynamic journal bearings under micropolar lubrication; Tribology International, Volume 38, Issue 5, Pages 500-507, May 2005.

[15]. Klaus Friedrich, Zhong Zhang, Alois K. Schlarb, Effects of various fillers on the sliding wear of polymer composites, Composites Science and Technology, Vol. 65, pp. 2329–2343, (2005).

[16]. Paulo Flores, JC Pimenta Claro1, Jorge Ambrósio; Journal bearings subjected to dynamic loads: theanalytical mobility method; Mecânica Experimental, Vol. 13, Pg. 115-127, 2006

[17]. Gwidon W. Stachowiak, Andrew W. Batchelor; Wear of Non-Metallic Materials; Engineering Tribology (Third Edition), Pages 651-704, 2006.

[18]. H. Unal, U.sen, A Mimaroglu, 2006, ―an approach to friction and wear properties of polytetraflouroethylene composite‖, Materials and Design, Vol. 27, pp. 694–699, 2006.

[19]. N.B. Naduvinamani, A. Siddangouda; Effect of surface roughness on the hydrodynamic lubrication of porous step-slider bearings with couple stress fluids; Tribology International, Volume 40, Issue 5, Pages 780-793, May 2007.

[20]. Padelis G. Nikolakopoulos, Chris A. Papadopoulos; A study of friction in worn misaligned journal bearings under severe hydrodynamic lubrication; Tribology International, Volume 41, Issue 6, Pages 461-472, June 2008.

[21]. J. D. Bressana, D. P. Darosa, A. Sokolowskib, R. A. Mesquitac, C. A. Barbosad, Influence of hardness on the wear resistance of 17-4 PH stainless steel evaluated by the pin-on-disc testing, journal of material processing technology, Vol. 2, pp 353-359, 2008.

[22]. U. Singh, L. Roy, M. Sahu; Steady-state thermo-hydrodynamic analysis of cylindrical fluid film journal bearing with an axial groove; Tribology International, Volume 41, Issue 12, December 2008, Pages 1135-1144

[23]. L. Roy; Thermo-hydrodynamic performance of grooved oil journal bearing; Tribology International, Volume 42, Issue 8, Pages 1187-1198, August 2009.

[24]. S.A. Mirhadizadeh, E.P. Moncholi, D. Mba; Influence of operational variables in a hydrodynamic bearing on the generation of acoustic emission; Tribology International, Volume 43, Issue 9, Pages 1760-1767, September 2010.

[25]. Ravindra R. Navthar, Dr. N.V. Halegowda; Stability Analysis of Hydrodynamic Journal Bearing using Stiffness Coefficients; International Journal of Engineering Science and Technology Vol. 2, pp. 87-93 2010.

[26]. Andras Z. Szeri; Composite-film hydrodynamic bearings; International Journal of Engineering Science, Volume 48, Issue 11, Pages 1622-1632, November 2010.

[27]. Fatu Aurelian, Maspeyrot Patrick, Hajjam Mohamed; Wall slip effects in (elasto) hydrodynamic journal bearings; Tribology International, Volume 44, Issues 7–8, Pages 868-877, July 2011.

[28]. M. Wolski, P. Podsiadlo, G.W. Stachowiak; Effects of information loss in texture details due to the PIFS encoding on load and

friction in hydrodynamic bearings**;** Tribology International, Volume 44, Issue 12, Pages 2002-2012, November 2011.
[29]. Kim Thomsen, Peder Klit; A study on compliant layers and its influence on dynamic response of a hydrodynamic journal bearing**;** Tribology International, Volume 44, Issue 12, Pages 1872-1877, November 2011.
[30]. S. Boubendir, S. Larbi, R. Bennacer; Numerical study of the thermo-hydrodynamic lubrication phenomena in porous journal bearings; Tribology International, Volume 44, Issue 1, Pages 1-8, January 2011.
[31]. Nacer Tala-Ighil, Michel Fillon, Patrick Maspeyrot; Effect of textured area on the performances of a hydrodynamic journal bearing**;** Tribology International, Volume 44, Issue 3, Pages 211-219, March 2011.
[32]. J.Bouyer, M.Fillon; Experimental measurement of the friction torque on hydrodynamic plainjournal bearings during start-up;Tribology International, Volume44,Issues 7-8,pages 772-781,July 2011.
[33]. Nacer Tala-Ighil, Michel Fillon, Patrick Maspeyrot**;** Effect of textured area on the performances of a hydrodynamic journal bearing**;** Tribology International, Volume 44, Issue 3, Pages 211-219, March 2011.
[34]. E.N. Santos, C.J.C. Blanco, E.N. Macêdo, C.E.A. Maneschy, J.N.N. Quaresma; Integral transform solutions for the analysis of hydrodynamic lubrication of journal bearings; Tribology International, Volume 52, Pages 161-169, August 2012.
[35]. Priyanka Tiwari and Veerendra Kumar, Analysis of Hydrodynamic Journal Bearing: A Review, International Journal of Engineering Research & Technology (IJERT) Vol. 1, Issue 7, ISSN: 2278-018 September 2012.
[36]. Jaw-Ren Lin; Dynamic characteristics for wide magneto-hydrodynamic slider bearings with a power-law film profile**;** Applied Mathematical Modelling, Volume 36, Issue 9, Pages 4521-4528, September 2012,
[37]. Dun Lu, Wanhua Zhao, Bingheng Lu, Jun Zhang;Static characteristics of a new hydrodynamic–rolling hybrid bearing; Tribology International, Volume 48, Pages 87-92, April 2012.
[38]. M.B. Dobrica, M. Fillon; Performance degradation in scratched journal bearings**;** Tribology International, Volume 51, Pages 1-10, July 2012.
[39]. S.P. Chippa, M. Sarangi; Elastohydrodynamically lubricated finite line contact with couple stress fluids; Tribology International, Volume 67, Pages 11-20, November 2013.
[40]. Vijay Kumar Dwivedi, Satish Chand, K.N. Pandey; Effect of Different Flow Regime on the Static and Dynamic Performance Parameter of Hydrodynamic Bearing**;** Procedia Engineering, Vol. 51, Pages 520-528, 2013.
[41]. Ana M. Balasoiu, Minel J. Braun, Stefan I. Moldovan; A parametric study of a porous self- circulating hydrodynamic bearing; Tribology International, Volume 61, Pages 176-193, May 2013.
[42]. Peng Liang, Changhou Lu, Jie Ding, Shujiang Chen; A method for measuring the hydrodynamic effect on the bearing land**;** Tribology International, Volume 67, Pages 146-153, November 2013.
[43]. Emiliano Mucchi, Alessandro Agazzi, Gianluca D'Elia, Giorgio Dalpiaz; On the wear and lubrication regime in variable displacement vane pumps**;** Wear, Volume 306, Issues 1–2, Pages 36-46, 30 August 2013.
[44]. Kazuyuki Yagi, Joichi Sugimura; Elastic deformation in thin film hydrodynamic lubrication; Tribology International, Volume 59, Pages 170-180, March 2013.
[45]. Hakan Adatepe, Aydın Bıyıklıoglu, Hasan Sofuoglu; An investigation of tribological behaviors of dynamically loaded non-grooved and micro-grooved journal bearings; Tribology International, Volume 58, Pages 12-19, February 2013.
[46]. Vijay Kumar Dwivedi, Satish Chand, K.N. Pandey; Effect of Number and Size of Recess on the Performance of Hybrid (Hydrostatic/Hydrodynamic) Journal Bearing**;** Procedia Engineering, Volume 51, Pages 810-817, 2013.
[47]. Gengyuan Gao, Zhongwei Yin, Dan Jiang, Xiuli Zhang; Numerical analysis of plain journal bearing under hydrodynamic lubrication by water; Tribology International, Volume 75, Pages 31-38, July 2014.