International
Journal
Of Advanced Research in Engineering & Management (IJAREM)
ISSN: 2456-2033 || PP. 01-08

Effect of Load & Speed Variation on the Performance of Aluminum Hydrodynamic Journal Bearing System

Jagjit S. Maan[a], R. K. Awasthi[b], Niranjan Singh[c]
[a,b]Department of Mechanical Engineering, BCET Gurdaspur, Punjab
[c]Department of Mechanical Engineering, MIET Jammu

Abstract: The increasing trend towards high power output, high-speed and low power loss machines imposes greater demand on the reliability of the hydrodynamic bearing operating with extreme film thickness. Bearing being an important part of rotary machinery not only transmits the power from one end to other end but also acts as a support for stability and frictionless rotation of shaft. In most of the fluid film bearing applications involving high load result in various problems like wear-tear and vibrations leading to low service life and poor performance of bearing. In the current study, the effect of load and speed on the hydrodynamic performance of journal bearingis analyzed. An Aluminium bearing is used for the experimental work. The experimental work is performed on the DUCOM journal bearing test rig machine with a capability to operate in the speed having range from 500rpm -3000rpm and load ranging from 500-3000 kg respectively. The readings are recorded for the film thickness and maximum pressure of fluid film by the variation of the speed and load on the bearing. It was observed that the fluid film having very significant role in the design of hydrodynamic journal bearing is most affected by the speed.
Keywords: Journal Bearing System, Speed, Load, Minimum film thickness, Maximum oil pressure.

I. INTRODUCTION

Now a days, hydrodynamic journal bearings are in high demand for their excellent properties such as long-term performance, negligible friction and almost zero wear particularly in diesel engine, centrifugal compressors, pumps, motors, etc. This type of bearing works on hydrodynamic principle, which involves with the rotation of shaft, creates an oil wedge that supports the shaft and relocates it within the bearing clearances. The shaft spinning within a journal bearing is actually separated from the journal bearing's metal facing by an extremely thin film of continuously supplied oil that prohibits metal to metal contact. In other words the hydrodynamic journal bearing works on hydrodynamic lubrication theory, which is concerned with separation of two surfaces in relative motion. The main purpose of the journal bearing is to support the rotating machinery by providing sufficient lubrication to separate the moving parts and to minimise the friction due to rotation. The high pressure fluid film in the clearance between journal and the bearing due to rotation of the journal provides the hydrodynamic lubrication along with the load capacity to the bearing.

Nearly all heavy industrial turbomachines use fluid film bearings of some type to support the shaft weight and control irregular motions caused by unbalance forces. The two primary advantages of fluid film bearings over rolling element bearings are their superior ability to absorb energy to dampen vibrations, and their longevity due to the absence of rolling contact stresses. The damping is very important in many types of rotating machines where the fluid film bearings are often the primary source of the energy absorption needed to control vibrations. Fluid film journal bearings also play a major role in determining rotordynamic stability, making their careful selection and application is a crucial step in the development of superior rotor-bearing systems. Journal bearings are incredibly long-lived provided the lubricant is contaminant free and sufficiently supplied. Therefore, dynamic analysis of hydrodynamic bearings is important due to the forces imposed on the shaft from machine unbalance forces, aerodynamic forces, and external excitations from seals and couplings (Allaire, 1979).

The Hydrodynamic fluid film journal bearings act as a support for stability and frictionless rotation of a rotating shaft in order to transmit power from one. The fluid film bearing works on the principle of hydrodynamic lubrication in which the fluid film always constraint between the two mating surfaces i.e. bearing and journal. The fluid film develops between the journal bearing interface which not only supports the load but also provides necessary stiffness and damping properties of the film and may affect the stable operation of rotor.

The fluid film thickness which is an important parameter for a bearing designer is affected by the variation of load and speed due to application of load. The application of load results in reduction of film thickness which will result in wear of bearing which may be due to negligible or absence of fluid film between the journal and bearing. Similarly the film thickness is also affected by the speed of the shaft.

II. Literature Review

Hughes and Osterle was the first to perform the thermo-hydrodynamic study of journal bearing and described the relationship between temperature and pressure of lubricant inside the bearing [1]. Basri and Gethin investigated the thermal aspects of various non-circular journal bearing using adiabatic model[2] . Cupillard et. al resented an analysis of lubricated conformal contact to study the effect of surface texture on bearing friction and load carrying capacity using computational fluid dynamics. They reported that the coefficient of friction can be reduced if a texture of suitable geometry was introduced[3]. Gertzos et. al investigated journal bearing performance with a Non-Newtonian fluid i.e. Bingham fluid considering the thermal effect[4]. Huiping Liu et. al studied hydrodynamic journal bearings with elastic insert and found that the elastic deformation of the bearing had a significant influence on the rotor–bearing system, particularly for the polymeric-based materials[5] . Jaw-Ren Lin et. al numerically calculated oil film pressure by using Fourth Runge-Kutta method and this pressure was utilised to evaluate the load carrying capacity and the friction parameter. For comparision of results, Darcy and Brinkman models were used to show the viscous shear effects provide an increase in the load capacity, as well as a decrease in the friction parameter [6] . Nabhan et. al solved Navier-Stokes equation with the aid of Simpson rule and calculated the pressures, drags and load carrying capacities by taking binary fluid mixture with different viscosity ratio[7]. Hassan E. Rasheed theoretically presented the effects of circumferential, axial and combined surface waviness on the performance of the hydrodynamic journal bearings Newtonian isoviscous lubricant. It was observed that when waviness number was approximately below nine, then circumferential waviness increasedthe load carrying capacity and decreased the friction variable. But the axial waviness had an opposite effect on the load carrying capacity and friction variable[8]. S.k.guha analized the effect of isotropic roughness on the steady-state characteristics of hydrodynamic journal bearing's load capacity, attitude angle, end leakage flow rate, misalignment moment and friction coefficient were estimated for different values of roughness parameter, eccentricity ratio and degree of misalignment at unit slenderness ratio. Finite difference method was used to measure steady-state oil film pressures with Reynolds equation[9]. Myung-Rae Cho et. al presented the effects of circumferential groove on the minimum oil film thickness in engine bearings and used mobility method for journal locus analysis. It was observed that the circumferential 360° groove only decreases the magnitude while 180° half groove affects the shape and position of the minimum oil film thickness[10]. Nabarun Biswas and Prasun Chakrabortiused used SAE-50 lubricant in journal bearing for analysis. They involved with six time steps 10, 30, 50, 70, 90, and 110 sec for unsteady analysis and found out that after 110 sec the flow became steady. It was also observed that maximum pressure was observed at minimum oil film thickness with increasing value of roughness[11]. Sep et. al analysed new design of journal bearing with two-component surface layer and experimentally proved its usefulness where oil was contaminated by hard particles. In this new design, the helical grooves were made on the bearing journal surface to eliminate contaminants from the frictional contact zone. Their work concluded that if soft material was placed in the vicinity of grooves, it will restrict the hard particles driving into the bearing surface and decreased the sensitivity[12]. Byoung-Hoo Rho et. al investigated acoustical properties of hydrodynamic journal bearing. The universal Reynolds equation was solved at each time step with finite difference method. the nonlinear transient motion of journal centre was obtained by numerical integration of its acceleration using fourth order Runge-Kutta method[13]. Byoung-Hoo Rho et. al investigated the effects of design parameters on the noise of rotor-bearing system supported by oil lubricated journal bearing. The Reynolds equation for finite width bearing under unsteady condition was applied for calculating pressure. It was observed that the radial clearance, mass eccentricity of the rotor and the width of the bearing considerably affect the sound pressure level of the bearing[14]. Nikolakopoulo et. al developed an analytical modal which established the relationship between friction force, wear depth and misalignment angles The Reynolds equation was used to calculate the friction force in equilibrium condition and found that friction function dependent on wear and misalignment of the bearing[15]. Singh et. al theoretically performed steady-state thermodynamic analysis of an axial groove bearing by using Reynolds equation, energy equation and heat conduction equation with appropriate boundary conditions in the journal bearing. It was found that the fluid film temperature increased with frictional heat resulting decrease in viscosity and load carrying capacity. It was also observed that groove angle of 360° and groove length decreased the maximum temperature and increased the load carrying capacity [16]. Ron A.J. Van Ostayen presented a mathematical optimization method to find the optimal film height distribution for a hydrodynamic bearing. Firstly this methodology was applied for a bearing with constant load and sliding speed and then applied for a bearing with periodic load and sliding speed. Slider bearings with different shapes, loads and speeds were analyzed by new heuristic load optimization procedure along with Reynolds equation and found more efficient than general optimization routine procedure[17]. Andras Z. Szeri modified the structure of lubricant film by using double layer of lubricant into clearance space of bearing surfaces in place of single layer of lubricant. Basic Reynolds equation was used for composite films under the restrictive assumptions by applying boundary conditions. The low-viscosity lubricant reduced viscous dissipation, while the high-viscosity lubricants maintained the desirable thickness to separate out the bearing surfaces. It was also found that composite-film bearings have considerably lower frictional losses in comparison to other traditional bearings[18]. K. M. Panday et. al. Analysed thin film lubricated journal bearing with different L/D ratios such as 0.25, 0.5, 1, 1.5, and 2. It was observed that maximum pressure present at minimum oil film thickness. Their work also reported that shear stress was reduces on bearing and journal surface with increase in L/D ratio whereas turbulent viscosity of lubricant risen with increase in L/D ratio [19] . NacerTala-Ighil et. al developed a numerical model based on finite difference method by using Reynolds equation to study the cylindrical textures shape effect on the performance of hydrodynamic journal bearing. Twenty five cases were conducted based on geometric arrangement of textures on the bearing surface anditwas found that the minimum oil film thickness increased approximately by 1.8% and friction torque was decreased approximately by 1.0% as compared with untextured surface[20].Meybodi et. al developed a general methodology, to design the proper bearing in order to eliminate the deviation of final product in extrusion process. Three smooth curved dies with non-symmetric T-shaped sections at different off-centricities have been taken and for each die proper bearing has designed. It was found that the deviation of final product is eliminated to a great extent[21]. McAllister and Rohde optimized the load-carrying capacity of one-dimensional journal bearings for a given minimum film thickness by using a long bearing approximation which was inaccurate in most practical design ranges[22]. Hashimoto presented an optimum study for high speed short journal bearings using successive quadratic programming. For Eccentricity > 0.8 and L/D > 0.3, the short bearing approximation predicted highly unreliable results[23]. Peeyush vats et. al presented thermal analysis of journal bearing with FEM and parameters like heat generated, temperature distribution and heat dissipation were studied. Their results reported that difference between heat dissipation and heat generation oil film was very large, which increased the temperature of the bearing and damaged the bearing pads[24].

The current study deals with the effect of load and speed on bearing and its influence on bearing performance. The study is carried on DUCOM made Journal Bearing Test Rig which operates up to load 3000 kg and speed 3000 rpm along with the application of inlet pressure at 4 bar, 6 bar and 8 bar. Further in order to visualize the effect of load, a bearing having aspect ratio 1/2 is chosen which help to build a very large pressure gradient in the axial direction compared to finite length bearing.

III. EXPERIMENTAL DETAIL

The schematic diagram of the journal bearing system is shown in Fig.1. In order to perform the experiment the bearing is placed in the fixture having a screw at the bottom.

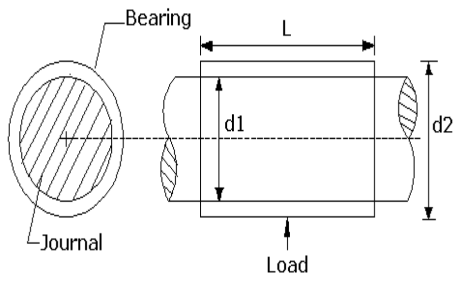


Fig. 1: Schematic diagram of journal bearing system

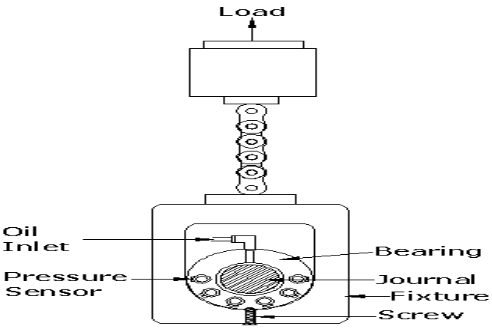


Fig. 2: Schematic diagram of journal bearing test rig

The schematic diagram of the journal bearing test rig is shown in Fig.2. The load is applied vertically in upward direction. The pressure development is measured by the six LVDT sensors that are placed at an angle of 36^0 at the lower semicircular portion of the bearing as shown in the Fig. 3

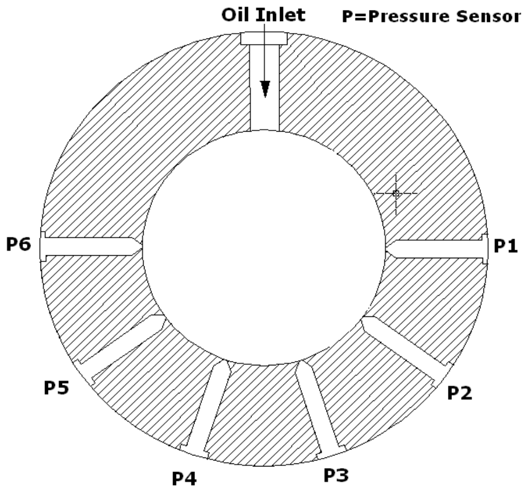


Fig.3: Bearing with pressure sensors

The performance of Bearing was determined on the basis of fluid film thickness and maximum pressure developed at various points of the bearing measured by pressure sensors and outlet temperature. The specifications of the journal and bearing are shown in the Table 1.The fixture for holding journal bearing is shown in Figure 1(b). The machine operates at wide range of speed (500-3000rpm) and load (500-3000 kg) and oil inlet pressure 4 bar. For the experimentation purpose the readings are firstly taken at inlet oil pressure of 4 bar under different speed and load conditions. The parameters like film thickness and maximum film pressure are recorded.

In the following table, the geometric parametrs of hydrodynamic journal are defined

Journal Diameter(d1) (mm)	**Bearing inner diameter (d2) (mm)**	**L/d1**	**Radial Clearance (microns)**	**Bearing Type**	**Bearing Material**
79.99	80.16	0.5	80	Circular	Aluminum

Table 1: The geometric parameters of hydrodynamic journal bearing

IV. RESULTS & DISCUSSION

After the experimentation the readings are recorded and the plots are made for the comparison purpose. As shown in the Fig.4, it is observed that with the increase in load the fluid film thickness decreases. At constant load the film thickness developed is more at speed of 2000 rpm and the film thickness going on decreasing with the decrease in speed.

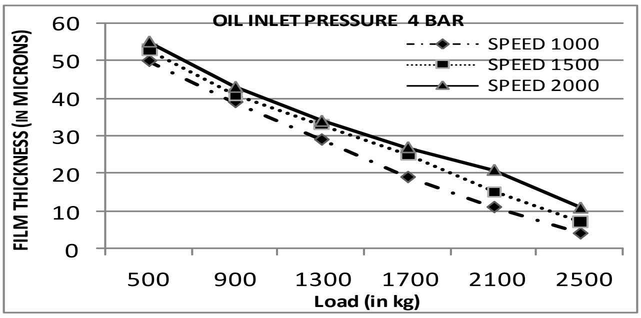


Fig.4: Film thickness v/s Load

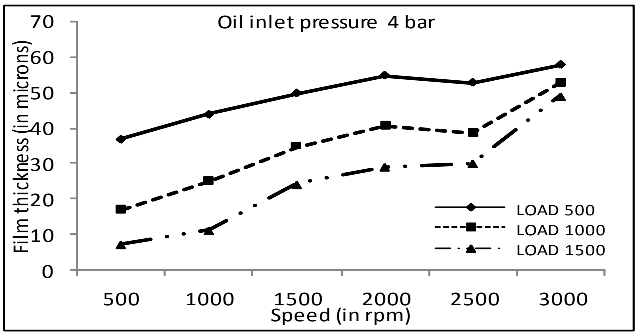
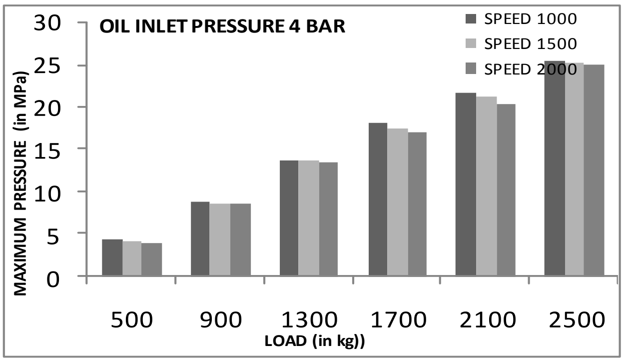


Fig.5: Film thickness v/s Speed

As shown in the Fig.5, it is observed that with the increase in speed the fluid film thickness increases.



.

Fig.6: Maximum Pressure v/s Load

At constant speed the film thickness developed is more at load of 500 kg and the film thickness going on decreasing with the increase in load. Again from the Fig.6, it is clear that the with the increase in load the maximum pressure also increases .This is due to fact that with the increase in load the film thickness decreases, and due to this the maximum pressure will develop more in the case of thin film. It is also observed that at constant load the value of maximum pressure is minimum at speed 2000 rpm and maximum at speed of 1000 rpm.

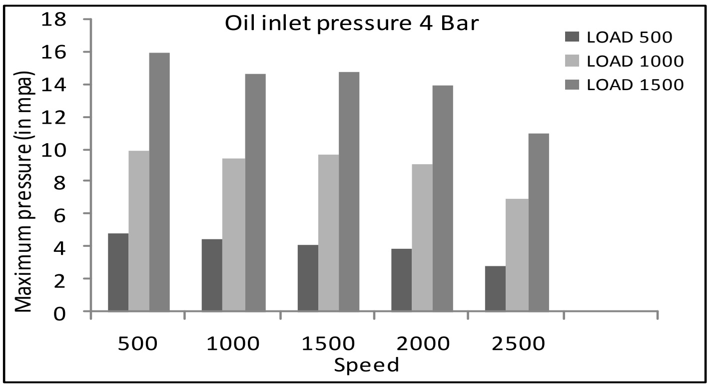


Fig.7: Maximum Pressure v/s Speed

Further as shown in Fig.7, it is clear that, with the increase in speed the maximum pressure decreases, this is due to fact that with the increase in speed the film thickness increases, and due to this the maximum pressure will develop less in the case of thick film as compared to thin film. It is also observed that at constant speed the value of maximum pressure is minimum at load 500 kg and maximum at speed load of 1500 kg.

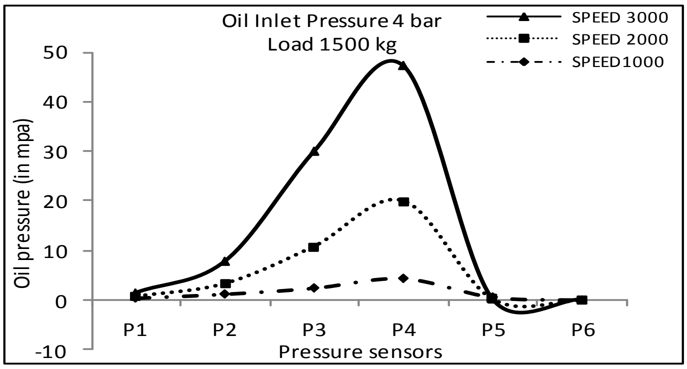


Fig. 8: Pressure distribution along circumferential direction

As shown in the Fig.8, the pressure distribution of lower half of the bearing along circumferential direction is made. It is observed that among the six sensors the maximum pressure develops in P4 sensor. Also the pressure development increases with the increase in load. The pressure developed for different loads in P1 sensor are very close which goes on increasing up to sensor P4 and then the difference going on decreasing.

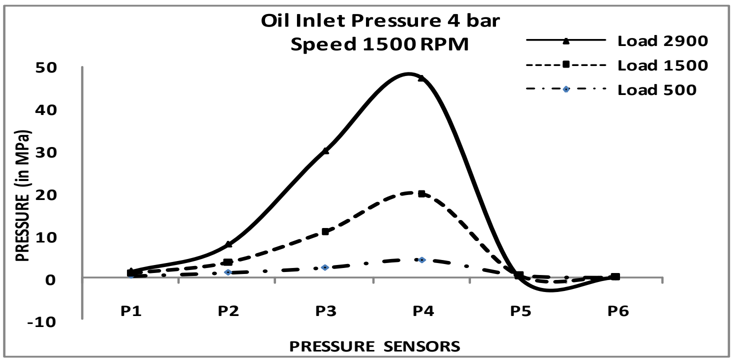


Fig.9: Pressure distribution along circumferential direction

Similarly as shown in Fig.9, the pressure distribution of lower half of the bearing along circumferential direction is made again. It is observed that the pressure development decreases with the increase in speed. The pressure developed for different loads in P1 sensor are very close which goes on increasing up to sensor P4 and then the difference going on decreasing.It is observed that with the increase in load the maximum pressure also increases this is due decrease in film thickness and due to this the maximum pressure will develop more.

V. CONCLUSIONS

So from the above study it is clear that the fluid film thickness decreases with the increase in load. With the increase in load the pressure development of oil pressure also increases. Also with the increase in inlet oil pressure the minimum film thickness increases and maximum pressure decreases. Similarly that the fluid film thickness increases with the increase in speed. Further the film thickness decreases with the increase in load. With the increase in speeds the pressure development of oil pressure decreases. So the bearing performance is severely affected by the load and speed and hence requires attention.

REFERENCES

[1]. W. Hughes and F. Osterle, “Temperature Effects in Journal Bearing Lubrication,” ASLE Transactions, Vol. 1, no.1, pp 210-212, 1958
[2]. S. Basri and D.T. Gethin, “A Comparative Study of The Thermal Behaviour of Profile Bore Bearings,” Tribology International, Vol. 23, pp 265-276, 1990
[3]. S. Cupillard, S. Glavatskih, M.J.Cervantes, “Computational Fluid Dynamics Analysis of A Journal Bearing with Surface Texturing,” Proc. IMechE, Engineering Tribology, Vol. 222, no.2, pp 97-107, 2008
[4]. K.P. Gertzos, P.G. Nikolakopoulos, C.A. Papadopoulos, “CFD Analysis of Journal Bearing Hydrodynamic Lubrication by Bingham Lubricant,” Tribology International, Vol. 41, no.12, pp 1190-1204, 2008
[5]. H. Liu, H. Xu , P. J. Ellison ,Z. Jin, “Application of Computational Fluid Dynamics And Fluid–Structure Interaction Method to The Lubrication Study of A Rotor–Bearing System,” Tribology Letters, Vol. 38, pp 325-336, 2010
[6]. J. Lin, C. Hwang and R. Yang, “Hydrodynamic Lubrication of Long, Flexible, Porous Journal Bearings Using The Brinkman Model,” Wear, Vol. 198, pp 156-164, 1996
[7]. M.B.W. Nabhan, G.A. Ibrahim and M.Z. Anabtawi, “Analysis of Hydrodynamic Journal Bearings Lubricated With A Binary Water-Based Lubricant,” Wear, Vol. 209, pp 13-20, 1997
[8]. H. E. Rasheed, “Effect of Surface Waviness on The Hydrodynamic Lubrication of A Plain Cylindrical Sliding Element Bearing,” Wear, Vol. 223, pp 1-6, 1998
[9]. S.K. Guha, “Analysis of Steady-State Characteristics of Misaligned Hydrodynamic Journal Bearings with Isotropic Roughness Effects,” Tribology International, Vol. 33, pp 1-12, 2000
[10]. M. Cho, H. Shin and D. Han, “A Study on The Circumferential Groove Effects on The Minimum Oil Film Thickness in Engine Bearings,” KSME International Journal, Vol. 14, pp 737-743, 2000
[11]. N. Biswas and P. Chakraborti, “Transient Analysis Of 3 Lobe Bearing Considering Surface Roughness Effect For Gas Turbine,” 6th BSME International Conference On Thermal Engineering (ICTE), 2014
[12]. J. Sep, A. Kucaba-Pietal, “Experimental Testing of Journal Bearings With Two-Component Surface Layer in The Presence of An Oil Abrasive Contaminant,” Wear, Vol. 249, pp 1090-1095, 2001
[13]. B. H. Rho, K.W. Kim, “Acoustical Properties of Hydrodynamic Journal Bearings,” Tribology International, Vol. 36, pp 61-66, 2003
[14]. B. H. Rho, D.G. Kim and K.W. Kim, “Effects of Design Parameters on The Noise of Rotor-Bearing Systems,” Tribology International, Vol.37, pp 599-605, 2004
[15]. P. G. Nikolakopoulos, C. A. Papadopoulos, “A Study of Friction in Worm Misaligned Journal Bearings Under Severe Hydrodynamic Lubrication,” Tribology International, Vol.41, pp 461-472, 2008
[16]. U. Singh, L. Roy and M. Sahu, “Steady-State Thermo-Hydrodynamic Analysis of Cylindrical Fluid Film Journal Bearing with An Axial Groove,” Tribology International, Vol. 41, pp 1135-1144, 2008
[17]. R.A.V.Ostayen, “Film Height Optimization of Dynamically Loaded Hydrodynamic Slider Bearings,” Tribology International, Vol. 43, pp 1786-1793, 2010

[18]. A.Z. Szeri, "Composite-film Hydrodynamic Bearings," International Journal of Engineering Science, Vol. 48, pp 1622-1632, 2010

[19]. K. M. Panday, P. L. Choudhury and N. P. Kumar, "Numerical Unsteady Analysis of Thin Film Lubricated Journal Bearing," International Journal of Engineering And Technology, Vol. 4, No. 2, 2012

[20]. N. Tala-Ighil, M. Fillon and P. Maspeyrot, "Effect of Textured Area on The Performances of A Hydrodynamic Journal Bearing," Tribology International, Vol. 44, pp 211-219, 2011

[21]. A. K. Meybodi, A. Assempourand and S. Farahani, "A General Methodology for Bearing Design in Non-Symmetric T-Shaped Sections in Extrusion Process," Journal of Materials Processing Technology, Vol. 212, pp 249- 261, 2011

[22]. G.T. McAllister and S.M. Rohde, "Optimum Design of One-Dimensional Journal Bearings," J. Optimization Theory and Application, Vol.41, no. 4, pp 599-617, 1983

[23]. H. Hashimoto, "Optimization of Oil Flow Rate and Oil Film Temperature Rise in High Speed Hydrodynamic Journal Bearings," Journal of Tribology Series, Vol. 34, pp 205-210, 1998

[24]. P. Vats, B.C. Sharma, S. Sharma, "Heat Transfer Through Journal Bearing: A Case Study," International Journal of Research in Engineering and Technology, Vol.3, no.10, pp 216-221, 2014