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Theoretical Analysis of Journal Bearing With Nanolubricants

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ABSTRACT

Fluid bearings are frequently used in high load, high speed or high precision applications where ordinary ball bearings have short life or high noise and vibration. The investigation of nanotribology shows that the nanoparticles have unique property in lubrication and tribology, such as anti-wear, reducing friction, and high load capacity. There were some investigations on the tribological properties of lubricants with different nanoparticles added, and it was reported that the addition of nanoparticles to lubricant oil is effective anti-wear and reducing-friction performances. Recent experiments have revealed that addition of nanoparticles on lubricants results in better viscosity as compared to that of oils without addition of nanoparticles. Furthermore, these suspended solid particles in the commercial lubricants affect the load carrying capacity and other performance characteristics of journal bearings. In this paper Load Carrying capacity of Journal Bearing is studied by considering Sommerfeld and Reynolds boundary conditions. Solution of two dimensional Reynolds equation is done using Finite difference method and graph is obtained with help of MATLAB. Different combination of nanopartical concentration is taken and it had been found that by addition of nanopartical, higher the concentration of nanopartical results in high viscosity, High friction coefficient, high pressure distribution and ultimately high load carrying capacity of journal bearing.

Keywords: Journal Bearing, Nanolubricants, Load Carrying Capacity, Reynolds Equation, Sommerfeld & Reynolds Boundary Condition.

I. INTRODUCTION

The current trend of modern industry is to use machineries rotating at high speed and carrying heavy loads. In such applications hydrodynamic bearings are widely used. A journal bearing is a sliding contact bearing working on hydrodynamic lubrication and which support load in radial direction. Lubricating oil is likely to come in contact with water, by leakage or condensation, such a situation arises in case of Steam engine, turbine lubricant and marine application which decrease the viscosity of oil. Sometimes increase in temperature reduce viscosity like hot working of steel.

In case of high load condition there are chances of metal to metal contact in journal bearing. The viscosity decrease of the lubricant causes a lower extreme pressure of the lubricant, so the friction surface is damaged at high load, due to the metal contact, which makes reliability worse. There is an impetus for improving the performance of fluid-film journal bearings. Sulfur and phosphorus containing compounds themselves, in fact, are excellent extreme-pressure and friction-reducing additives but can cause environment pollution. They widely used as the oil additives in the past. As an environmental protection measure, the use of sulfur-, chlorine- and phosphorus-containing compounds as lubricant additives has been restricted, so developing new additives that pollute less has therefore become the target for researchers. Over the last two decades, tribologists have used nanoparticles as lubricant additives to reduce friction and wear between two contacting surfaces. A lot of inorganic and organic nanoparticles used as oil additives have been synthesized and investigated in recent years. It is found that they improved the tribological properties of the base oil and displayed good friction-reducing and anti-wear characteristics. The main advantages of using nanolubricants are that they are relatively insensitive to temperature and that tribochemical reactions are limited, compared to traditional additives. Recent experiments have revealed that addition of nanoparticles on lubricants results in better viscosity as compared to that of oils without addition of nanoparticles. Furthermore, these suspended solid particles in the commercial lubricants affect the load carrying capacity and other performance characteristics of journal bearings. From this nanoadditive can be pointed to antioxidant agent, corrosion inhibitors, extreme pressure agents, and dispersants, anti-foaming agents, anti-wear agent, detergents and the viscosity index improvers.

II. METHODS AND MATERIAL

A. Literature Review

Shenoy,Binu,Pai [1]have studied This paper presents the effect of CuO, TiO2 and Nano Diamond nanoparticles additives in engine oil, on static characteristics of an externally adjustable fluid-film bearing. Modified form of Reynolds equation is solved numerically for various simulated operating conditions.

Static characteristics evaluated are in terms of load carrying capacity, end leakage and friction. This study predicts that, a bearing operating with engine oil blended particularly with TiO2 a noparticles, results in better load capacity with reduced end leakage and increased friction, as compared to engine oil and base oil without nanoparticle additives. This study predicts that a bearing having engine oil added especially with TiO2 nanoparticles, results in approximately 23%and35% higher load capacity than that obtained for engine oil without nanoparticles additives and Base Oil, respectively. Ghola-mreza, Dorany [2] have studied Kinematic viscosity of single walled carbon nanotubes (SWCNTs)/ lube oil cuts nanofluids containing 0.01-0.2 wt% single walled carbon nanotube (SWCNTs) was investigated at 25°C-100°C.Viscosity was measured by rheometer. Kinematic viscosity of nanofluids increases with increasing particle weight fraction and decreasing temperature. The viscosity index of oil-based SWCNT nanofluids is increased up to 32.94% at a weight fraction of 0.2%. Perikinalil, Nair , Kalakada[3] have studied static and dynamic performance characteristics of journal bearing in terms of load capacity, attitude angle, end leakage, frictional force, threshold speed and damped frequency are presented when the bearing operating under lubricants, which contain nanoparticles. The nanoparticles used for the present work are copper oxide (CuO), cerium oxide (CeO2) and aluminum oxide (Al2O3) 0.5% weight concentration of nanoparticles increases the load capacity by 14.45% (CuO), 13.98% (CeO2) and 12.53% (Al2O3) on thermo viscous case when bearing operates at e=0.9.The friction force of bearing increases with the increase in concentration of nanoparticles. Perikinalil, Nair , Kalakada[4] have modeled Viscosity models for the lubricants are developed with the available experimental data. Reynolds and energy equations are used to obtain pressure and temperature distribution across the lubricant film and these equations are solved by using the finite element method and a direct iteration scheme. At any eccentricity ratio, both end leakage and attitude angle decreases with the increase in concentration of nanoparticles. The stability parameters in terms of threshold speed increases by the addition of nanoparticles at any eccentricity ratio and the damped frequency decreases with addition of nanoparticles. Cheong, Lee, Hwang [5] The purpose of this study is to apply oil, which has lower viscosity and is mixed with nanoparticles, to the compressor used in a refrigerator to decrease the friction coefficient with the same or superior load-carrying capacity. Mineral oil of 8 mm^2/s was used and mixed with fullerene nanoparticles of 0.1 vol%. Friction coefficient was evaluated by a disk-on-disk The friction coefficient of the nano-oil decreased by 90% in comparison with raw oil. These results lead us to the conclusion that nano-oil can contribute to improving the efficiency and reliability of the compressor. Lee, Cho, Hwang, [7]have present This paper presents the friction and anti-wear characteristics of nano-oil composed of refrigerant oil and fullerene nanoparticles in the sliding thrust bearing of scroll compressors. The nano-oil was evaluated using a sliding thrust bearing tester .The friction coefficient and friction surface temperature for using both nano-oil and pure oil have been evaluated by varying the sliding thrust bearing operating parameters, including the normal forces and the orbiting speed of the friction plate. The friction coefficient of fullerene nano-oil at the lower normal loads (1200 N) under the fixed orbiting speed (1800 rpm) was 0.02, while that of pure oil was 0.03, indicating that the fullerene nanoparticles dispersed in the base refrigerant oil improved the lubrication property by coating the friction surfaces. Zhao, Bai, Fu[8]have tested the tribological properties of different samples and compared by Multi-functional friction abrasion tester and MHK-500 Ring-block wear testing machine. The results of the friction tests indicate that serpentine, La (OH)3 and serpentine/La(OH)3 composite particles all exhibit friction-reducing and anti-wear properties compared to the base oil. The oil containing the composite particles have the best friction- reducing, anti-wear and self-repairing properties. The friction coefficients are reduced by 24.63% and the diameters of friction spots are reduced by 41.88% compared to the base oil. Viesca, Battez,[9] This work presents and discusses the friction behavior of a NiCrBSi coating lubricated by CuO nanoparticle suspension in a polyalphaolefin (PAO6). CuO nanoparticles were separately dispersed at 0.5 and 2.0 wt% in PAO6. Friction reduction properties were obtained using a block-on-ring tribometer, where blocks were coated with a NiCrBSi alloy using the laser cladding technique. Tests were made under loads of 165 and 214 N, sliding speed of 0.5 m/s and a total distance of 1800 m. The study led to the following conclusions: all nanolubricants tested exhibited reductions in friction compared to the base oil; the antifriction behavior of the nanoparticles on the wear surfaces can be attributed to third body and tribosinterisation mechanism. Rukuiza, Padgurskas [11] have studied Tribological investigations were performed on mineral oil containing Fe, Cu and Co nanoparticles and their combinations. The friction coefficient was measured by a four ball tribotester. The wear was evaluated according to the wear scar diameter on the steel ball surfaces. The mixtures of nanoparticles were investigated to identify the materials that are most effective for the reduction of the friction coefficient. The tribological tests showed that each set of nanoparticles significantly reduced the friction coefficient and wear (up to 1.5 times) of friction pairs. The Fe nanoparticles reduce the friction coefficient by 39%, and the copper nanoparticles produce as much as a 49% reduction. This drop, fluctuation and later stabilization of the friction torque can be explained by the formation of a metallic nanoparticle layer on the friction surface that operates at lower friction levels. Jiao, Zheng[13]The as-prepared alumina/silica (Al2O3/SiO2) composite nanoparticles were synthesized with a hydrothermal method and modified by silane coupling agent. The tribological properties of the modified Al2O3/SiO2 composite nanoparticles as lubricating oil additives were investigated by four- ball and thrust-ring tests in terms of wear scar diameter, friction coefficient, and the morphology of thrust-ring. It is found that their anti-wear and anti-friction performances are better than those of pure Al2O3 or SiO2 nanoparticles. When the optimized concentration of nanoparticle additive is 0.5 wt.%, the diameters of wear scar and friction coefficients are both smallest. Such modified composite nanoparticles can adsorb onto the friction surfaces, which results in rolling friction. Therefore, the friction coefficient is reduced. Kasolang, Ahmada [15] In the present study, an experimental work was conducted to determine the pressure distribution around the circumference of a journal bearing and fluid frictional force of the bearing caused by shearing actions. A journal diameter of 100mm with length-to-diameter ratio was used Pressure results for 600 RPM speed at different radial loads was obtained. From the experimental results, it was found that the experimental maximum pressure values were higher than the theoretical maximum pressure values. It was also observed that the position (i.e. angle) of the maximum pressure has not changed significantly with loads. However the position of the minimum film thickness varied clearly with changes in loads. Friction coefficients of oil lubricant in this experiment decrease when the loads increase. Lots of work has been carried out to use nano particles as lubricant additives to reduce friction and wear. Even though the influence of nanoparticle lubricant additives on boundary lubrication regime is well documented, there is a definite lack of published data regarding their influence on hydrodynamic lubrication regime. Theoretical studies have been carried out to find effect of nanoparticles additives on performance of journal bearing but there is still scope on experimental investigation.

B. Theoretical Analysis

The Reynolds equation is given by

$$\frac{\partial}{\partial x}\left(h^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(h^3\frac{\partial p}{\partial y}\right) = 6U\eta\frac{dh}{dx}$$

This equation can be used for finding the pressure distribution in journal bearing. The next things are to find out the load acting on journal and resultant load carrying capacity. If W_X is the total integrated force acting in the X direction and W_Y is the force in the normal, Y, direction then

$$W_X = L\int_0^{2\pi} pR\, d\theta \cos\theta \text{ and}$$
$$W_Y = L\int_0^{2\pi} pR\, d\theta \sin\theta$$
$$W = \sqrt{(W_Y^2 + W_X^2)}$$

This equation can be used for finding the load carrying capacity of journal bearing.

Estimation of Nanofluid Viscosity: There exist few theoretical formulas that can be used to estimate particle suspension viscosities.

Almost all such formulas have been derived from the Einstein's linear formula

$$\mu_{nf} = \mu_{bf}\,(1 + 2.5\phi)$$

Where, μ_{nf} is the viscosity of nanofluid and μ_{bf} is the base fluid viscosity.
ϕ is volumetric concentration of nanoparticles.

This formula was found to be valid for relatively low volume fractions $\phi < 0.02$.

Brinkman has extended Einstein's formula to the following form useful to moderate particle suspension

$$\mu_{nf} = \mu_{bf}\,(1/(1- \phi)^{2.5})$$

Batchelor in his model considered the effect due to brownian motion of the particles on the bulk stress of the fluid and suggested following formula

$$\mu_{nf} = \mu_{bf}\,(1 + 2.5\,\phi + 6.5\,\phi^2)$$

Cheng -Law suggested the following expression for nanofluids consisting of spherical particles

$$\mu_{nf} = \mu_{bf}\,(1 + (2.5\,\phi) + (2.5\,\phi)^2 + (2.5\,\phi)^3 + ...)$$

Recently modified Krieger-Dougherty equation was expressed as

$$\mu_{nf} = \mu_{bf}\,(1- \phi/ \phi_m)^{-}\, \phi_m[n]$$

where [n] is intrinsic viscosity.
By putting different volume fraction of nanopartical as 0.5, 1,1.5, 2, & 2.5 volume fraction following graph of non-dimensional relative viscosity is obtained.

Using FDM 1-D approach two boundry condition are considered one is sommerfeld condition and other is reynolds boundary condition. As 2-D Analytical solution of reynolds equation is not exist FDM (2-D) approach used to get pressure distribution and load carrying capacity. Now using this FDM (2-D) equation, I made the MATLAB program to study pressure distribution of journal bearing by putting different boundary condition like Half Sommerfeld, Full Sommerfeld and Reynolds condition.

III. RESULTS AND DISCUSSION

Fig. 1 shows full sommerfeld condition where curve is anti-symmetry about y axis. This condition is not valid because it shows heavy negative pressure in other half which is not possible because of cavitations phenomenon. So we safely assume the negative pressure as zero in other half resulted in half sommerfeld boundary condition which is shown in fig.2. Fig.3 represents the correct boundary condition which is Reynolds condition where pressure is zero beyond half part of it.

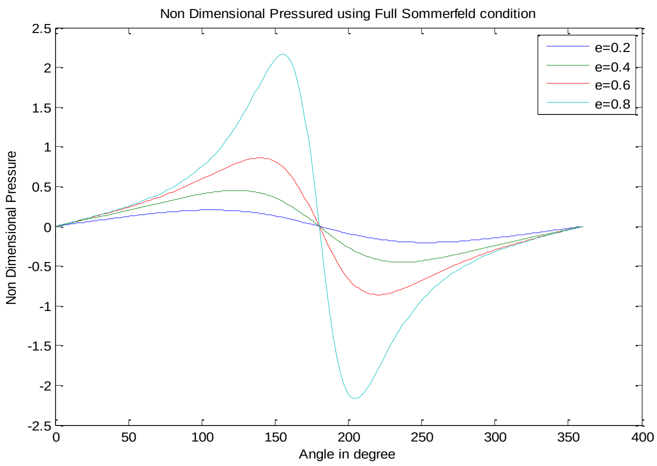

Figure 1. 1-D Non Dimensional Pressure Using Full Sommerfeld Boundary Condition

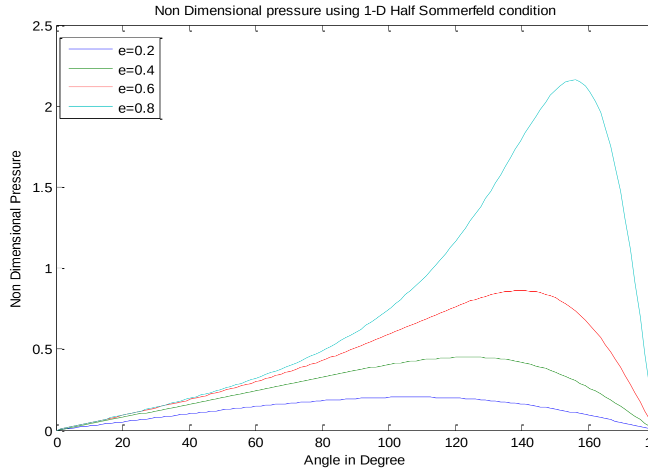

Figure 2. 1-D Non Dimensional Pressure Using Half Sommerfeld Boundary Condition

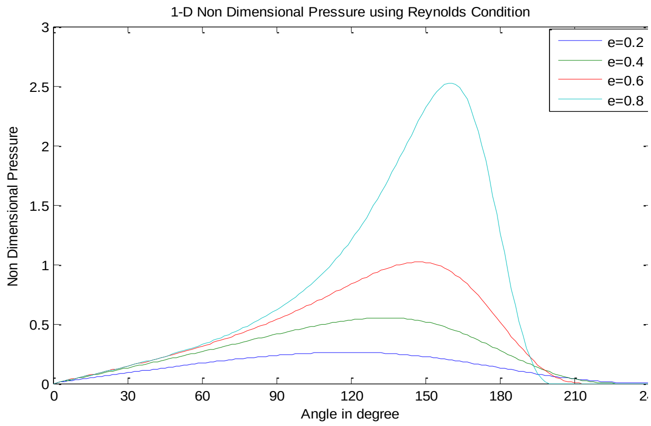

Figure 5. 1-D Non Dimensional Pressure Using Reynolds Boundary Condition

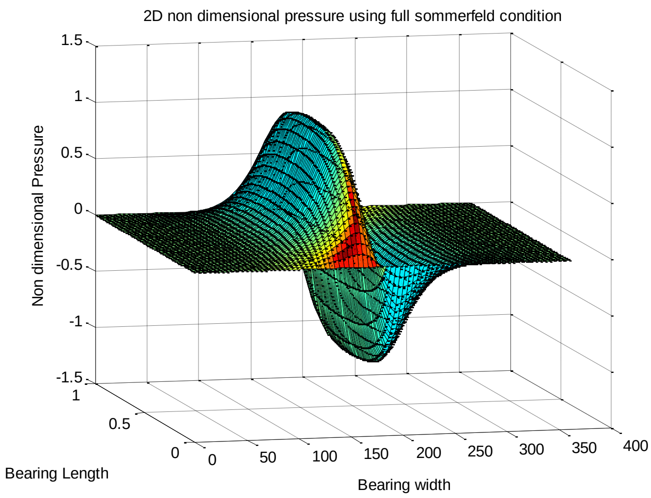

Figure 4. 2-D Non Dimensional Pressure Using Full Sommerfeld Condition

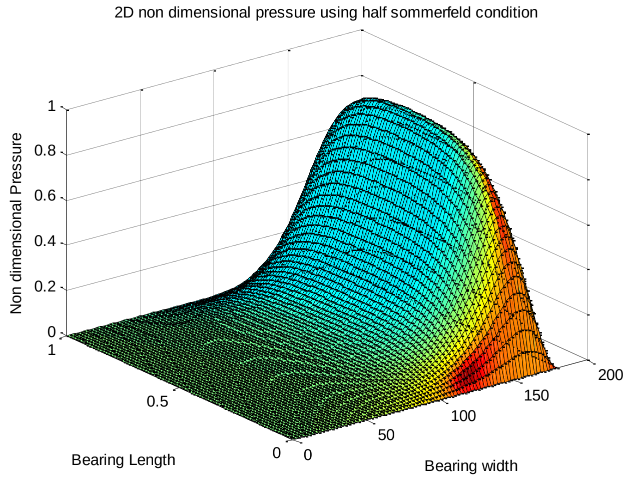

Figure 5. 2-D Non Dimensional Pressure Using Half Sommerfeld Condition

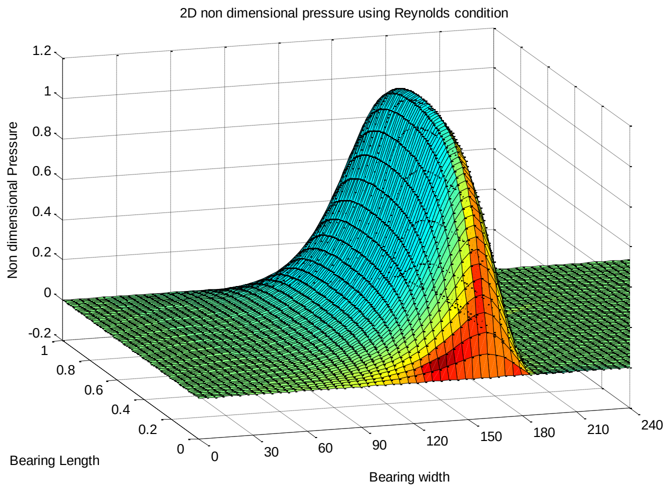

Figure 6. 2-D Non Dimensional Pressure Using Reynolds Condition

Fig.4,5,6 represent different boundary condition in 2-D case.

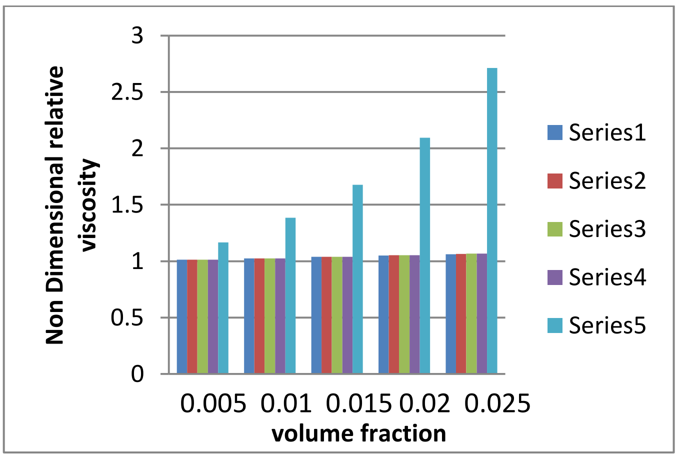

Figure 7. Estimation of Nanofluid Viscosity

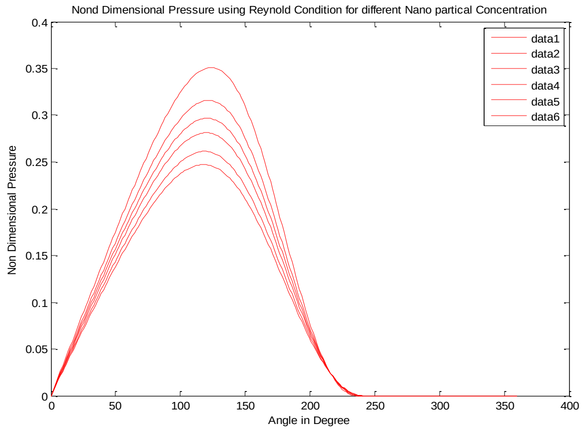

Figure 8. Comparison of Pressure for Different Nanopartical concentration for Reynolds Condition

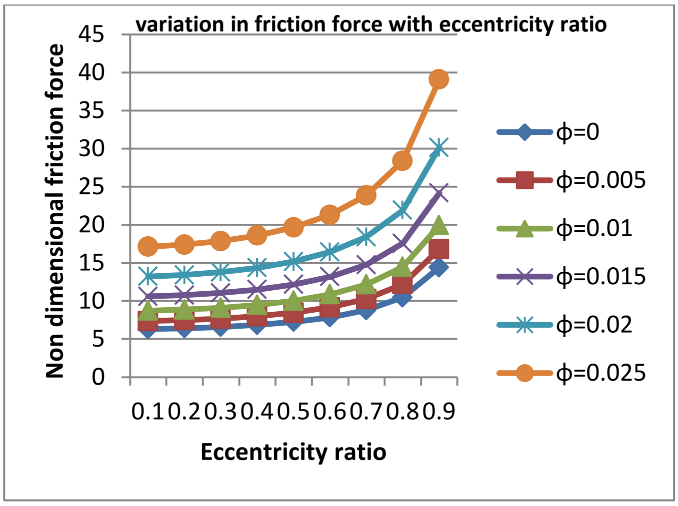

Figure 9. Variation of friction force with different eccentricity ratio.

Fig.7 Shows estimation of nano fluid viscosity for various nanopartical concentration. Fig.8 Shows various pressure distribution for different concentration of nanoparticle and Fig.9 represent variation in friction force with different nanopartical volume fraction.

IV. CONCLUSION

In the literature review Full Sommerfeld, Half Sommerfeld and Reynold condition with graph represented by different author is studied. Then effect of viscosity on pressure and load capacity is studied.

The one dimensional solution method is extended to get the two dimensional solution for the pressure distribution in the Journal Bearing. Peak pressure obtained in two dimensional case is less than the one dimensional case, which is true because we neglect the side leakages in one dimensional analysis.
Reynolds Boundary condition will give correct information about pressure distribution.

With increase in nanopartical percentage concentration relative viscosity is increases and compared to other model modified Krieger-Dougherty is giving very high value and which can be verified by comparing it with experimental value.

With increase in nanopartical concentration percentage pressure distribution shows high value with it. Similarly it also increases load carrying capacity of journal bearing.

Non dimensional friction force is also increased with increase in nanopartical concentration which lead to high value of viscosity and high load carrying capacity.

V. REFERENCES

[1] Hernandez Battez, J.L. Viesca, Friction reduction properties of a CuO nanolubricant used as lubricant for a NiCrBSi coating, Wear 268 (2010) 325-328

[2] Binu K.G., Shenoy B.S., Rao D.S.,A variable Viscosity Approach for the Evaluation of load Carrying Capacity of oil lubricated Journal Bearing with TiO2 Nanoparticles as lubricant Additives, Procedia Materials Science 6 (2014) 1051 - 1067

[3] S. Shenoy, K.G. Binu, R. Pai, D.S. Rao, Effect of nanoparticles additives on the performance of an externally adjustable fluid film bearing, Tribology International 45 (2012) 38-42

[4] Chau-Chang Chou, Szu-Hsien Lee, Tribological behavior of nanodiamond-dispersed lubricants on carbon steels and aluminum alloy, Wear 269 (2010) 757-762 Da Jiao, Shaohua Zheng, The tribology properties of alumina/silica composite nanoparticles as lubricant Additives, Applied Surface Science 257 5720-5725

[5] Dalai Jin, Linhai Yue, Tribological properties study of spherical calcium carbonate composite as lubricant additive, Materials Letters 62 (2008) 1565-1568 Fuyan Zhao, Zhimin Bai, Ying Fu, Tribological properties of serpentine, La(OH)3

and their composite particles as lubricant additives, Wear 288 (2012) 72- 77
[6] Gholamreza Vakili-Nezhaad, Akram Dorany, Effect of Single-Walled Carbon Nanotube on the Viscosity of Lubricants, Energy Procedia 14 (2012) 512 - 517 H.L. Yu, Y. Xu, Tribological behaviors of surface-coated serpentine ultrafine powders as lubricant additive, Tribology International 43 (2010) 667-675
[7] Hsiao Yeh Chu, Wen Chen Hsu, The anti-scuffing performance of diamond nano-particles as an oil additive, Wear 268 (2010) 960-967
[8] Jaekeun Lee, Sangwon Cho, Yujin Hwang, Application of fullerene-added nano-oil for lubrication enhancement in friction surfaces, Tribology International 42 (2009) 440-447
[9] Juozas Padgurskas, Raimundas Rukuiza, Tribological properties of lubricant additives of
[10] Fe, Cu and Co nanoparticles, Tribology International 60 (2013) 224-232
[11] Kwangho Lee, Yujin Hwang, Seongir Cheong, Performance evaluation of nano-lubricants
[12] of fullerene nanoparticles in refrigeration mineral oil, Current Applied Physics 9 (2009)
[13] e128-e131
[14] Chang, Z. Zhang, Y. Xu, PJ. Shi, Tribological behaviors of surface-coated serpentine ultrafine powders as lubricant additive, Tribology International 43 (2010) 667-675
[15] M. Kalin, J. Kogovsek, M. Remskar, Mechanisms and improvements in the friction and wear behavior using MoS2 nanotubes as potential oil additives, Wear 280- 281 (2012) 3645
[16] M.A. Maleque, H.H. Masjuki, Effect of mechanical factors on tribological properties of palm oil methyl ester blended lubricant, Wear 239 _2000. 117-125
[17] Sreedhar Babu Kalakada, Prabhakaran Nair Kumarapillai, Rajendrakumar Krishnan Perikinalil, Analysis of Static and Dynamic Performance Characteristics of THD Journal Bearing Operating Under lubricants Containing Nanoparticles, International Journal of Precision Engineering and Manufacturing Vol. 13, No. 10, pp. 1869-1876, October **2012**
[18] Salmiah Kasolang, Mohamad Ali Ahmada, Preliminary study of Pressure Profile in Hydrodynamic Lubrication Journal Bearing, Procedia Engineering 41 (2012) 1743 - 1749 Yanli Yao, Xiaomin Wang, Junjie Guo, Tribological property of onion-like fullerenes as lubricant additive, Materials Letters 62 (2008) 2524-2527
[19] Y.Y. Wu, W.C. Tsui, T.C., Experimental analysis of tribological properties of lubricating oils with nanoparticle additives, Wear 262 (2007) 819-825
[20] Yoshitsugu Kimura, H.H. Masjuki, Effect of mechanical factors on tribological properties of palm oil methyl ester blended lubricant, Wear 239 _2000. 117-125 Yanli Yao, Xiaomin Wang, Junjie Guo, Tribological property of onion-like fullerenes as lubricant additive, Materials Letters 62 (2008) 2524-2527
[21] Zhang Bao-Sen, Xu Bin-Shi, Xu Yi, CU nanoparticles effect on the tribological properties of hydrosilicate powders as lubricant additive for steel-steel contacts, Tribology International 44(2011)878-886
[22] The Principle of Lubrication" by A Cameron, Longman Green & Co.Ltd. 1966 Basic Lubrication Theory" by Alstair Cameron, Longman Green &Co.Ltd.1981 Principle of Tribology" by J Halling, 1978
[23] Engineering Tribology" by G.W. Stachowiak & A.W.Batchlor, Elsevier Science Publsiher ,1993
[24] Engineering Tribology" by J.A. Williams ,1994