Performance Investigation of Hydrodynamic Journal Bearing with Nano- additives in Lubricating Oil

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Abstract*- The aim of this project is the experimental analysis of the Hydrodynamic journal bearing with Nano particle added lubricating oil. The dynamic analysis of the hydrodynamic solid journal bearing operating under nano lubricants will be presented in this paper. The load carrying capacity of the solid journal bearing mainly depends upon the viscosity of the Lubricant being used. The addition of the nano particles on commercial lubricants may enhance the viscosity of lubricant and in turn changes the performance characteristics. In the proposed work is about to obtain pressure distribution in the clearance space of the solid journal bearing.*

Keywords- Bearing pressure distribution, Load Carrying Capacity, Hydrodynamic journal bearing, lubricating oil, Nanoparticle.

I. INTRODUCTION

here is an impetus for enhancing the performance of fluid-film journal bearings. Now recent years, many researchers have shown clear that the Newtonian viscous lubricants blended with small amounts of long-chained additives can increase the performance characteristics of traditional hydrodynamic lubricating system. Bearings are necessary when one part of a machine slides against the, and they can be classified as either providing sliding or rolling contact bearing. A sliding bearing typically uses a lubricant to decrease friction between the sliding surfaces. The fluid lubricant develope a film between the sliding surfaces, so there is no contact between solid components. Rolling bearings has balls or rollers to minimize rubbing, and lubricant Can also be used. The useful life of the engineered bearing surfaces depends on frictional compatibility with their counter surfaces. Controlling friction by lubrication is one way to increase the service life. The current trend of modern industry is to use machineries rotating at high speed and handle the heavy loads. In such type of applications hydrodynamic bearings are widely used. When a bearing operates at maximum speed, the heat generated due to large shear rates in the lubricant film increase its temperature, which decrease the viscosity of the lubricant and it affects the performance of journal bearing. Addition of nanoparticles in the lubricant may increases the viscosity of the lubricant and in changes the static and dynamic performance characteristics of the bearing. So the thermo hydrodynamic analysis is important to predict the performance characteristics of the journal bearing. (lubricants, which include nanoparticles). Solid journal bearings are used in heavy machineries to support high loads. The load carrying capacity of hydrodynamic journal bearing get increase by addition of nano particle because of enhancement of viscosity of lubricant and it affects various performance characteristics of hydrodynamic solid journal bearings. Profit of nanoparticles as lubricant additive has been a major subject of research in the past decade. Now Recent experimental study of Static and Dynamic Performance Characteristics of THD Journal Bearing Operating Under Lubricants Including Nanoparticles study by Sridhar Babe Kalakada (2012) . They have obtained For thermoviscous case addition of nanoparticles enhance the load capacity of journal bearing at any eccentricity ratio, and this increase is significant at high number of eccentricity ratio. For example, 0.5% weight concentration nanoparticles increases the load carrying capacity by 14.45% (CuO) and 12.53% (Al_2O_3) on thermoviscous case when bearing operates at ε=0.9. The friction force of bearing increase with the increase in concentration of nanoparticles for both isoviscous and thermoviscous cases. In addition of nanoparticles on the commercial lubricants may enhance the viscosity of lubricants may enhance the viscosity of lubricants and therefore, load capacity of bearing. Hydrodynamic journal bearings are extensively used in large speed rotating machinery. When a bearing rotates at large speed and heavy load, the heat generated due to more shear rates in the lubricant increase its temperature which lowers the viscosity of the lubricant and in turn affects the performance characteristic of journal bearing.

A. OBJECTIVE

The objective of this experiment is to :

- Measure hydrodynamic pressure variation in a journal bearing at different speeds with conventional lubricant.
- Measure hydrodynamic pressure variation in a journal bearing at different speeds with Nanolubricant..
- Find out the pressure profile between nanolubricant and conventional oil.

- Find out the pressure with increasing speed at any type of oil.
- Calculate the average pressure and maximum pressure with and without nanofluids.
- Calculate load carrying capacity of the journal bearing and compare it with theory

II. LITERATURE REVIEV

C. C. Narayana et al. studied the static and dynamic characteristics of the finite hydrodynamic journal bearing with micropolar lubricant are analyzed. The Effects of mass transfer of solid additives and contaminants in the lubricant oil, on the bearing characteristics are involved in this study. A generalized form of Reynolds equation is derived from fluid flow equations of mass transfer across the fluid film considered. The generalized Reynolds equation is solved by using Galerkin's weighted-residual finite element method to get the fluid pressure distribution in the bearing. The different static and dynamic characteristics are obtained and presented. Various additives are mixed to the lubricant oil to increase certain characteristics of the lubricant. These additives along with the contaminants from a dilute suspension of solid particles in oil. These suspended solid particles produce the thickening of the lubricant oil, which in turn affects the various performance characteristics of the journal bearing.

Rajesh C. Shah et al . Ferro fluid squeeze film in an axially undefined porous journal bearing was analyzed to determine its performance consider the anisotropic permeability of the porous facing and slip velocity at the interface of porous matrix and film region with use of Jenkins flow model. Expressions were obtained for the dimensionless pressure, load capacity and response time of squeeze film. How to reduce results for the no-slip case, isotropic porous case and for Neuringer–Rosensweig model case were indicated. The computed values of the dimensionless load capacity and response time were displayed in graphical form. They enhance with increasing the values of eccentricity ratio and anisotropic parameter while they decreased with increasing the values of slip parameter or material parameter of Jenkins model.

M Zare Mehrjardi et al. study steady-state and stability performance characteristics of circular and noncircular two-, three-, and four-lobe journal bearings involving micropolar fluids are presented. For this purpose, lubricating oil contain the additives and contaminants are modeled as micropolar fluid. The modified Reynolds equation in dynamical state is obtained with use of the micropolar lubrication theory, and it is solved by using finite element method. The bearing performance characteristics in terms of load bearing capacity, whirl frequency ratio, and critical mass parameter of journal are determined for various values of design parameters such as eccentricity and aspect ratio, preload factor, and micropolarity characteristics of lubricant and coupling number. Results show that in the case of noncircular bearings, the critical mass to load carrying capacity ratio decreases with enhancing of preload factor, so for a constant vertical external load, the stability performance of the rotating system can be improved by replacing the circular journal bearing with same noncircular types. The results compared with Newtonian fluids state that micropolar lubricant include better steady state and dynamic performance. Also, results conclude that upgrading the micropolarity characteristics of lubricant causes enhance in critical mass, load carrying capacity but minimizes in the whirl frequency ratio. It is also concluded that effect of the micropolar fluids are more pronounced at more coupling numbers.

R. Sinhasan presents a theoretical study of the performance characteristics of hydrostatic rigid orifice compensated multirecess journal bearings with use of non-Newtonian lubricants. The generalized Reynolds equation governing the flow of lubricant having variable viscosity has been solved by using the finite element method and iterative procedure. The static and dynamic performance characteristics for non-Newtonian lubricants are presented of which constitutive equation has been represented with use of cubic shear stress law. The non-linearity factor (K) in the cubic shear stress law significantly increases the bearing performance characteristics, especially the dynamic characteristics.

K. Prabhakaran Nair et al. stated the effect of deformation of the bearing liner on the static and dynamic performance characteristics of an elliptical journal bearing operate with micropolar lubricant is presented. Lubricating oil including additives and contaminants is modeled as micropolar fluid. A generalized form of Reynold’s equation is derivated from fluid flow and diffusion equations. Finite element technique is used to solve the modified Reynold’s equation governing the flow of the micropolar lubricant in the clearance space of the journal bearing and the three-dimensional elasticity equations governing displacement field in the bearing shell. The static and dynamic characteristics of the bearing are computed for a small range of the deformation coefficient which takes into accountant the flexibility of bearing liner by treating operating lubricant as (1) Newtonian and (2) micropolar. The computed results show that the enhancing volume concentration of additives and the mass transfer of additives produce significant changes on the performance characteristics. For any type eccentricity ratio and deformation coefficient, load carrying capacity of a twolobe journal bearing increases with increasing in volume of concentration of additives. For a fixed value of mass transfer rate the load-bearing capacity increases with increase in the volume concentration of additives at any value of the deformation coefficient and eccentricity ratio. The end leakage and the attitude angle do not depend on the volume concentration of additives when the mass transfer rate is zero for any type of value of deformation coefficient and eccentricity ratio.

Hershberger et al. study that most theories on the initiation of scuffing have been based on the assumption of the development of the adhesion between sliding surfaces. Since diamond nano-particles can reduce the sliding friction coefficient and wear, it is beneficial to study the anti-scuffing performance of nanodiamonddispersed oil. The aim of our study is to experimentally study the anti-scuffing performance of Nano diamond dispersed oil. Lubricating oil containing diamond particles with various concentrations was used in that study to evaluate the tribological performances and scuffing resistance. In order to simulate scuffing of the piston ring and the cylinder wall pair in an engine, the experiments were performed on a Falex wear test machine with the three-block-on-ring configuration operating at different conditions. The contact behavior between a block and rings similar to the piston ring and cylinder wall pair. The Friction coefficient, electrical contact resistance, and temperature of oil were measured to evaluate the effects of operating conditions and nano diamond additive concentration on tribological performances adding scuffing resistance, mean friction coefficient, wear loss, and friction power.

Greco et al. studied that to evaluate the tribological performance of boron based surface treatment and lubricant additive in consideration for the application in a wind turbine drive train to accommodate severe operating conditions and mitigate surface failure. Electrochemical boride surface treatment is considered in comparison to traditional case carburization as an alternative or an additive method to significantly increase the surface hardness and wear resistance. The Nano-colloidal boron-nitride based lubricant additives are considered as a complementary technology to react with the borides surface to develope a wear protective tribo film. Experimental evaluation confirmed the following conclusions: Electrochemical boriding provided an increased hardness (1500–2200 HV) to the surface of 9310 gear steel, in the form of a uniform thick two phase boron diffused layer (FeB and Fe_2B). The thermal processing time was less than 1 h.XPS analysis showed that the nano-colloidal boron nitride additive in a commercial gear oil chemically reacted with the borided surface to form a wear protective tribo film. High contact load (2.5 GPa) sliding tests showed that the electrochemical borided surface was significantly large wear resistant than the carburized surface by more than an order of magnitude. Further work is necessary to evaluate the performance of this boron based surface treatment and lubricant additive for a wide range of contact conditions (i.e. rolling contact) with corresponding optimization of the treatment, in order to fully evaluate the advantages of that technology in wind turbine drive train applications and beyond.

Swamy study et al the effect of the non-Newtonian behaviour of lubricants, resulting from the addition of polymers, on the performance of the hydrodynamic journal bearings was investigated. An empirical fluid flow equation which adequately represents the flow behaviour of the lubricant was used to get a modified form of Reynolds' equation. Finite difference numerical solutions were obtained for the steady state conditions at various width-to-diameter ratios. The results show a the strong influence of width-to-diameter ratio on the load capacity of the journal bearings. Linearised stiffness and damping coefficients was evaluated from the fluid film force equations for the unsteady motion of the journal centre and were used to predict stability limits of a simple rigid rotor- bearing system which showed a reduction in the threshold speeds. The steady state load capacity and the stability limits were verified experimentally for finite width bearings.

Shiuh-Hwa Shyu et al. study Static performance characteristics were comprehensively investigatedfor adiabatic finite-width turbulent journal bearings. A numerical method formed using the Legendre collocation technique was used to simulate liquid lubricant flows in different geometric conditions over a wide range of the mean Reynolds number. Both isoviscous and thermohydrodynamics (THD) were studied. The least-squares method was applied to groups of parameters, yielding formulas for the load capacity, friction coefficient, attitude angle, and side leakage. With the formulas derived in this study, designers can suddenly determine static parameters of turbulent full journal bearings without the burden of labor-intensive numerical computation for governing differential equations. The formulas of static performance parameters (namely, load capacity, attitude angle, and side leakage) were established for finite-width full journal bearings for a full range of the mean Reynolds number with the THD effects. The correlation database was compiled from the numerical solutions of the Navier-Stokes equations over wide ranges of possible operating conditions. Then easy-to-use empirical formulas were found using least-squares correlation with the nondimensional parameters of the Navier-Stokes equations.

Wang-Long Li et al. studied the static performance of the finite journal bearings lubricated with non-Newtonian poruer law fluids is analyzed by the use of control volume method ruith an 1:'lrod algorithm to solve the average Reynolds equation and determine the cavitation region properly. The results show that the flow behavior index of power law fluids has an insignificant aflect on the load ratios, side Jloru ratios and cavitation regions, while it significantly aflects load capacities and the side flow rates. Furthermore, the 4fict.s of film thickness ratios, pressure flow factors, shear flow factors, eccentricities and inlet pressures on the variations of cavitation regions are also discussed.

Chou and Lee et al . investigated the rheological behavior and tribological performance of the Nano diamond-dispersed oil. The Bingham plastic model was considered for this Nano-diamond-dispersed oil. They used aluminum alloy and steel to study the tribological performance and get that the nano-diamond particles made the wear tracks of aluminum alloy smoother by polishing the contact asperities and thus enhancing the friction and wear. However, for carbon steel pairs, this additive reduced friction force and the wear but made the wear tracks rougher.

III. PROPOSED EXPERIMENTAL LAYOUT

The major objective of lubrication of journal bearings is to induce and maintain a film of lubricant between the journal and the bearing. The purpose of this film of lubricant is to keep the two surfaces separate at all times and thus prevent metal to metal or dry contact which otherwise will create bearing failure. Hydrodynamic lubrication is the most common method of lubrication of journal bearings. In this method, as the shaft rotates it will, due to the load applied to it (as well as its own weight), take a slightly eccentric position relative to the bearing. The eccentric rotation of the shaft in the bearing acts some-what like a rotary pump and generates a relatively high hydrodynamic pressure in the con-verging zone. The hydrodynamic pressure for a properly designed bearing is responsible for supporting the shaft without allowing it to come in contact with the bearing.

Dimensions of Journal Bearing:

- Bearing Radius = R= 0.025m
- Radial Clearance = C = 0.0025m
- Distance Between Journal & Bearing Centers = e = 0.0005m
- Speed Of The Jornal = N=650RPM
- Viscosity Of The Oil = 0.068 Nsec/m^2
- Eccentricity Ratio = 0.2
- Angular Velocity = U = [{ 2*3.14*R*N}/60]

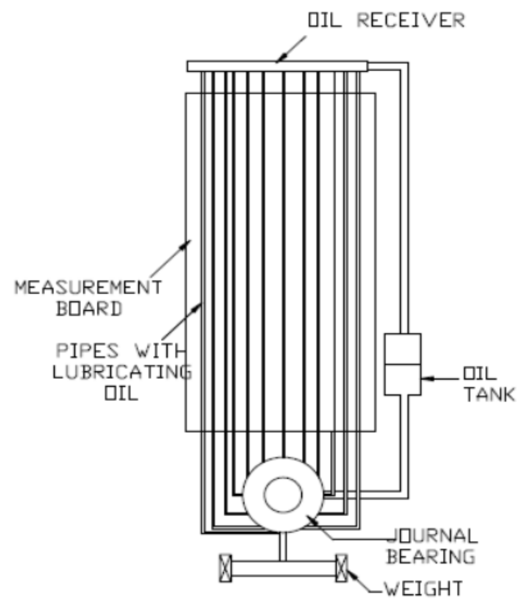

Fig 1. Layout of Experimental system

Hydrodynamic pressure distribution around the bearing is related to other parameters by:

$$P = \frac{6*U*\eta*R}{C^2} * \frac{\varepsilon*\sin\theta(2+\varepsilon\cos\theta)}{(2+\varepsilon)^2(1+\varepsilon\cos\theta)^2} \text{ N}/m^3$$

U= Surface speed of the shaft (Angular velocity),m/s

= 3.14 DN/60 where, D= shaft diameter=2*R

$\boldsymbol{\eta}$ = Viscosity of oil,Nsec/m^2 = Centipoise reading/1000

R = Radius of bearing= 0.025mtr

C = Radial Clearance = 0.0025mtr

Eccentricity ratio = 0.2

Supply Head = P_0 = 880mm

Load carrying capacity of bearing :

$$W = 12\pi L\mu V *\left(\frac{r}{c}\right)^2 * \frac{\varepsilon}{(2+\varepsilon^2)\sqrt{1-\varepsilon^2}} \qquad \text{(IV)}$$

Selection and Preparation of Nanolubricant :

Nanoparticles of ZnO are selected and are added to refrigeration system by adding them into the lubricant SAE 30/20. The preparation and stability of this mixture is very important. The lubricant SAE 30/20 is in a liquid state so it is difficult to mix the nanoparticles in lubricant. The nanoparticle is added in the lubricant by the following procedure:

1. Find out the amount of lubricant SAE 30/20 is circulated in the bearing.
2. Weigh the mass of ZnO nanoparticles on a digital electronic balance for 0.1% of weight of refrigerant.
3. Vibrate the mixture by using an ultrasonic vibrator for 3 hrs and get the well-dispersed ZnO nanolubricants.
4. Repeat the above steps for preparing the dispersion of 0.2%, 0.3%, nanoparticles in lubricant SAE 30/20.

IV. RESULTS AND DISCUSSION

Comparison of Expreimental Pressure Distribution of Base Oil at various RPM

The fig. shows pressure distribution in journal bearing operated without Nano lubricants; it has been observed that the value of theoretical pressure obtained at any angle θ is increases as rotational speed (RPM) is increases.

		600RPM	800RPM	1000RPM	1200RPM
Tube No.	Angle	Hydrolic pressure distribution			
	θ	P_i-P_o			
1	30	120	170	222.5	277
2	60	290	264.5	270	300
3	90	240	296	355	417
4	120	50	96	146	197
5	150	-275	-239.5	-207.5	-174
6	180	-388	-364	-338.2	-311
7	210	-350	-323.5	-295.6	-266
8	240	-260	-231	-198.5	-164.425
9	270	-170	-145	-108.25	-69.7
10	300	-120	-72	-31	12
11	330	-40	2	46	93
12	360	40	86	134	200

Table 1.Observation table for Comparison of Theoretical Hydrodynamic Pressure Distribution of without Nanolubricant at various RPM

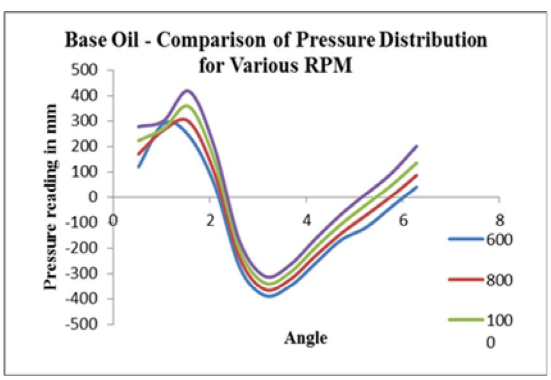

Fig 2.Comparison of Theoretical Hydrodynamic Pressure Distribution of Base Oil NanoLubricant at various RPM

Comparison of Experimental Pressure Distribution of 0.1% NanoLubricantat various RPM.

The fig. shows pressure distribution in journal bearing operated with 0.1% nanolubricants; it has been observed that the value of experimental pressure obtained at any angle θ is increases as rotational speed (RPM) is increases.

		600RPM	800RPM	1000RPM	1200RPM
Tube No.	Angle	Hydrolic pressure distribution			
	θ	Pi-Po			
1	30	145.2	205.7	269.225	336.017
2	60	350.9	320.045	326.7	396.275
3	90	290.4	358.16	530	604
4	120	60.5	116.16	176.66	238.37
5	150	-332.75	-289.795	-251.075	-210.54
6	180	-469.48	-440.44	-409.222	-376.31
7	210	-423.5	-391.435	-357.676	-321.86
8	240	-314.6	-279.51	-240.185	-198.954
9	270	-205.7	-175.45	-130.983	-84.337
10	300	-145.2	-87.12	-37.51	14.52
11	330	-48.4	2.42	55.66	112.53
12	360	48.4	104.06	162.14	222.64

Table 3.Observation table for Comparison of Theoretical Hydrodynamic Pressure Distribution of with 0.2% Nanolubricant at various RPM

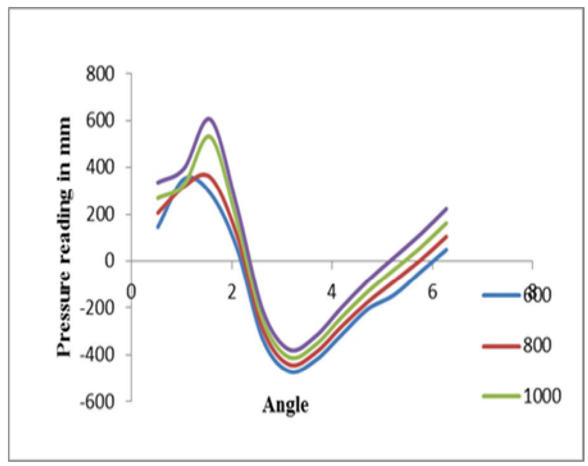

Fig 4.Comparison of Theoretical Hydrodynamic Pressure Distribution of 0.2% NanoLubricant at various RPM

Comparison of Theoretical Pressure Distribution of 0.3% NanoLubricant at various RPM.

The fig. shows pressure distribution in journal bearing operated with 0.3% nanolubricants; it has been observed that the value of theoretical pressure obtained at any angle θ is increases as rotational speed (RPM) is increases.

		600RPM	800RPM	1000RPM	1200RPM
Tube No.	Angle	Hydrolic pressure distribution			
	q	Pi-Po			
1	30	159.72	226.27	296.1475	369.6187
2	60	385.99	352.0495	359.37	497.9
3	90	319.44	393.976	472.505	600.037
4	120	66.55	127.776	194.326	262.207
5	150	-366.025	-318.775	-276.183	-231.594
6	180	-516.428	-484.484	-450.144	-413.941
7	210	-465.85	-430.579	-393.444	-354.046
8	240	-346.06	-307.461	-264.204	-218.85
9	270	-226.27	-192.995	-144.081	-92.7707
10	300	-159.72	-95.832	-41.261	15.972
11	330	-53.24	2.662	61.226	123.783
12	360	53.24	114.466	178.354	244.904

Table 4.Observation table for Comparison of Theoretical Hydrodynamic Pressure Distribution of with 0.3% Nanolubricant at various RPM.

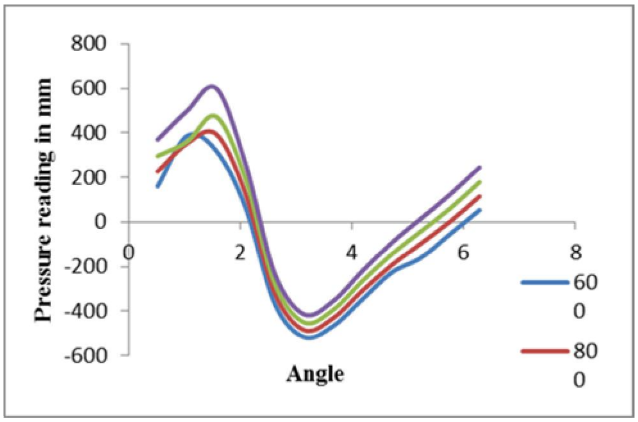

Fig 5. Comparison of Theoretical Hydrodynamic Pressure Distribution of 0.3% NanoLubricant at various RPM.

Calculation of Load Carrying Capacity:

Load carrying capacity is calculated by using Harrison-Sommerfeld equation for an ideal journal bearing.

$$W= 12\pi L\mu V * \left(\frac{r}{c}\right)^2 * \frac{\varepsilon}{(2+\varepsilon^2)\sqrt{1-\varepsilon^2}}$$

Where

W = Load carrying Capacity in N

L = Length of Journal, (m)

r = Journal radius, (m)

c = Radial clearance, (m)

μ = Oil viscosity at operating temperature, (Ns/m2)

ε = Eccentricity ratio (= e/c)

V = Velocity of Bearing in m/s

Comparison of Load Carrying capacity at various Bearing RPM.

The fig. shows load carrying capacity in journal bearing operated at various fractions of nanolubricants, it has been observed that the value of load carrying capacity is increases as bearing speed goes on increase.

RPM	Base Fluid	0.1% NF	0.2% NF	0.3%NF
600	2.775675	3.1908	3.3202	3.77614
800	3.695006	4.24763	4.41988	5.02684
1000	4.614338	5.30445	5.51956	6.27754
1200	5.551349	6.3816	6.64039	7.55228

Table 5.Comparison of Load Carrying capacity at various Bearing RPM

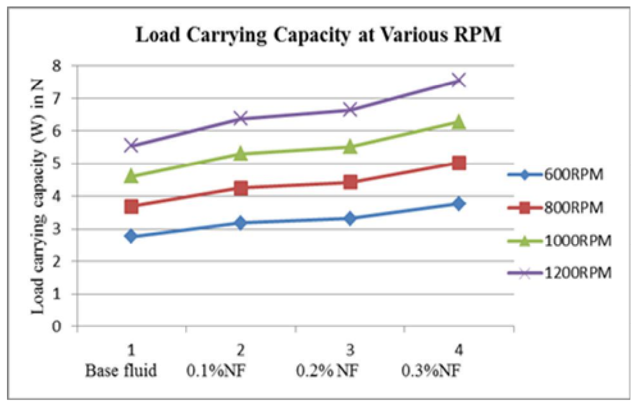

Fig 6.Load Carrying Capacity (W) for various bearing speed (RPM).

Comparison of Load Carrying capacity at various Nanolubricants.

Lubricant Type	600RPM	800RPM	1000RPM	1200RPM
BF	2.775675	3.695006	4.614338	5.5513492
0.1%NF	3.1908	4.24763	5.30445	6.381602
0.2%NF	3.3202	4.41988	5.51956	6.640393
0.3%NF	3.77614	5.02684	6.27754	7.552284

Table 6. Comparison of Load Carrying capacity at various Bearing RPM

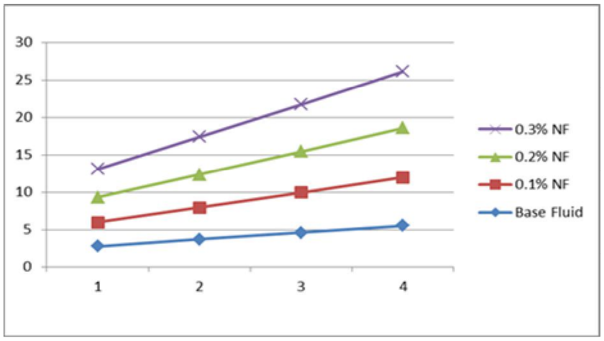

Fig 7. Load Carrying Capacity (W) for various Nano lubricants

V. CONCLUSION

Experiment shows that the ZnO Nano particle added lubricant affected the journal bearing performance. It is observed that hydraulic pressure increases more in nano particle added journal bearing as compared to conventional or lubricant without added nanoparticle journal bearing.

- From Results and discussion it can be concluded that nano particle added bearing has the optimum pressure profile as compared to bearing with conventional (SAE 30/20) lubricant.
- With increase of percentage of nanofractionate constant speed maximum pressure is increases.
- With increase of bearing speed at any type of oil (with and without Nano lubricants) maximum pressure is increases.Nano fluid volume fraction increases.

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