Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 8, August -2017

A REVIEW PAPER ON PERFORMANCE ANALYSIS OF HYDRODYNAMIC JOURNAL BEARING WITH VARIOUS TYPES OF LUBRICANT FOR PRESSURE DISTRIBUTION AND CAVITATION

Arti Singh[1], Prof.S.S.Waydande[2]

[1] Mechanical Engineering, DYPIET, Ambi. Pune,
[2]Mechanical Engineering, DYPIET, Ambi. Pune,

Abstract — *A Journal bearings are widely applied in different rotating machineries. These bearings allow for transmission of large loads at mean speed of rotation. There are several types of journal bearing designs commonly used in machineries such as Hydrodynamic Journal bearing, which is based on hydrodynamic lubrication. Hydrodynamic lubrication means that the load-carrying surfaces of the bearing are separated by a relatively thick film of lubricant, so as to prevent metal-to-metal contact. The most important objectives of bearing design are to extend bearing life in machines, reduce friction energy losses and wear, and minimize maintenance expenses and downtime of machinery due to frequent bearing failure. From the Literature review and previous investigation, it is found that the cavitation area in hydrodynamic journal bearing is very essential area of investigation because it reduces the load capacity and leads to a risk of material damages. 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. Different combination of nano particle concentration is studied and it had been found that by addition of nanopartical, results in high viscosity, high pressure distribution and ultimately high load carrying capacity of journal bearing. The determination of the cavitation boundaries are important to get a realistic model of a hydrodynamic journal bearing with various nanofluid lubricants such as CO2, TiO2, ZnO, SiC and Al2O3. Studied the performance of the hydrodynamic journal bearing for the cavitation and pressure distribution. For Theoretical Analysis mostly summerfeld equation is used for finding the pressure distributation and Reynolds equation is used to get the cavitation location. From the previous research paper it is studied that various Experimental Analysis is done For finding the pressure distributation, cavitation location and cavitation shape. A Comparatively studied is done for the Theoretical Analysis and Experimental Analysis for various types of lubrication such as SAE30,SAE40 ,engine oil ,TiO2,SiC and AL2O3.*

Keywords- AL2O3, *Cavitation, Hydrodynamic journal bearing, Nanolubricant, Pressure distributation, Reynolds equation*, Summerfeld *equation.*

I. INTRODUCTION

Moving parts in machinery involve relative sliding or rolling motion. Examples of relative motion are linear sliding motion, such as in machine tools, and rotation motion, such as in motor vehicle wheels. Most bearings are used to support rotating shafts in machines. Bearings can be classified according to their geometry related to the relative motion of elements in machinery. Examples are journal, plane-slider, and spherical bearings. A journal bearing, also referred to as a sleeve bearing, is widely used in machinery for rotating shafts. The term hydrodynamic bearing refers to a sleeve bearing or an inclined plane-slider where the sliding plane floats on a thin film of lubrication. The fluid film is maintained at a high pressure that supports the bearing load and completely separates the sliding surfaces. The lubricant can be fed into the bearing at atmospheric or higher pressure. The pressure wave in the lubrication film is generated by hydrodynamic action due to the rapid rotation of the journal. The fluid film acts like a viscous wedge and generates high pressure and load-carrying capacity.

Cavitation is the disruption of what would otherwise be a continuous liquid phase by the presence of a gas or vapour or both. Large negative pressures in the hydrodynamic film are predicted when surfaces move apart or mutually sliding surfaces move in a divergent direction . For gases, a negative pressure does not exist and for most liquids a phenomenon known as cavitation occurs when the pressure falls below atmospheric pressure. It has been shown that very clean fluids containing a minimum of dissolved gas can support negative pressures but this has limited relevance to lubricants which are usually rich in wear particles and are regularly aerated by churning. The critical difference between ‘gaseous cavitation’, i.e. cavitation involving bubbles of dissolved air, and ‘vaporous cavitation’ is that with the latter, sudden bubble collapse is possible. The phenomenon has been examined by scientists and engineers for a century or more, and although this review concentrates on cavitation in bearings, there have been many studies outside the field of lubrication. Components that have proved susceptible to cavitation erosion damage include pump impellers, valves, marine propellers, pipes, and cylinder liners. The formation of cavities and their disposition affects the pressure generated in a continuous thin film and hence the integrated quantities such as the load capacity of bearings. Work by tribologists in this century has resulted in the development of cavitation models that make it possible to predict the performance of liquid-film bearings with acceptable engineering accuracy for the majority of applications. However, it is true to say that the physical understanding of cavitation in bearings is still not satisfactory.

Addition of nanoparticles on the commercial lubricants may enhance the viscosity of lubricant and hence, in turn, load capacity of the bearing. These suspended solid particles increases thickness of lubricants, as a result which affect the various performance characteristics of journal bearing. The existing literature shows that the studies on static and dynamic performance characteristics of rigid and flexible circular journal-bearing operating under nanolubricant are scarce. 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. 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. The load bearing capacity of hydrodynamic journal bearing get enhanced by addition of nano particle because of enhancement of viscosity of lubricant and in turn affect various performance characteristics of hydrodynamic solid journal bearings. Various metals and metal oxide nanoparticles have been studied as lubricant additives in thin film lubrication. These studies have reported reduced friction and wear in tribo-surfaces with the use of nanoparticle lubricant additives. Nanoparticles have received considerable attention because of their special physical and chemical properties. In recent years, with the development of nanomaterials, many scientific researchers added nanoparticles into lubricating oils to improve extreme pressure, anti-wear and friction reducing properties, and the efficiency and service life of machinery were improved and prolonged. The application of advanced nanomaterials has played an active role in improving and reforming traditional lubrication technology.

II. Literature Review

Following are some of the important reviews of different researches and scientists.

Surojit Poddar,et.al studied the Detection of journal bearing vapour cavitation using vibration and acoustic emission technique with the aid of oil film photography. A journal bearing rig with transparent sleeve, a bronze bearing insert and an LED illuminator has been designed for rapid development of vapour cavitation and to carryout oil film photography.In addition to this, simultaneous photography of oil film has been carried out to evaluate changes in vapour bubbles under different stages of experiment. The captured photographs have been image-processed for better visualization of bubbles. The vapour cavitation of journal bearing has been experimentally studied using vibration,acoustic emission and oil film photography. Vibration has been measured in terms of RMS Velocity and Acoustic Emission involves measurement of parameters: RMS, energy and peak frequency. The captured photographs have been image-processed using Mathematica software package for clear visualization of vapour bubbles. The evolution of vapour bubbles and its collapse during cavitation increases with increase in speed of journal; and there is relative decrease in size of bubbles with elevation of speed. Vapour cavitation involves generation of acoustic emission due to evolution of vapour bubbles and their subsequent collapse. This is a high frequency activity and is registered in AE measurement as scattered events.

D.C.Sun, et.al. worked on the Simultaneous Pressure Measurement and High-Speed Photography Study of Cavitation in a Dynamically Loaded Journal Bearing Cavitation of the oil film in a dynamically loaded journal bearing was studied using high-speed photography and pressure measurement simultaneously. Comparison of the visual and pressure data provided considerable insight into the occurrence and non-occurrence of cavitation. It was found that (1), cavitation typically occurred in the form of one bubble with the pressure in the cavitation bubble close to the absolute zero; and (2), for cavitation-producing operating conditions, cavitation did not always occur; with the oil film then supporting a tensile stress. The appearance or absence of cavitation might be crucially dependent on the availability of cavitation nuclei in the oil. Where nuclei were not present, the oil could sustain tension without cavitation up to its tensile strength. Where nuclei were present, the tensile strength of the oil was annihilated and cavitation occured. The cavitation nuclei in the experiment were most likely the small air bubbles not thoroughly vented out of the test chamber.

S. Natsumeda,et al. studied Negative pressures in statically and dynamically loaded journal bearings The circumferential pressure distribution in a journal bearing is measured under static and dynamic loading. Compared with conventional pressure transducers a pressure pickup mounted in the journal has given more accurate results and yielded negative pressure o r tension as much as -1.2MPa (absolute) in the oil film. Two patterns are found in the pressure distribution: the one similar to the pressure curves calculated under separation boundary condition, and the other similar to the Sommerfeld's one. In order to expound the negative pressure o r tension, a hydrodynamic theory is developed regarding the lubricant as two-phase liquid of oil and small bubbles. Equation of motion for small spherical bubbles is solved taking into account surface-dilational viscosity.

M. Riedel, et.al done the Numerical investigation of cavitation flow in journal bearing geometry .The appearance of cavitation is still a problem in technical and industrial applications. Especially in automotive internal combustion engines, hydrodynamic journal bearings are used due to their favourable wearing quality and operating characteristics. Cavitation flows inside the bearings reduces the load capacity and leads to a risk of material damages. Therefore an understanding of the complex flow phenomena inside the bearing is necessary for the design development of hydrodynamic journal bearings. Experimental investigations in the fluid domain of the journal bearing are difficult to realize founded by the small dimensions of the bearing. In the recent years more and more the advantages of the computational fluid dynamics (CFD) are used to investigate the detail of the cavitation flows. The analysis in the paper is carried out in a two-step approach. At first an experimental investigation of journal bearing including cavitation is selected from the literature. The complex numerical model validated with the experimental measured data. In a second step, typically design parameters, such as a groove and feed hole, which are necessary to distribute the oil supply across the gap were added into the model. The paper reflects on the influence of the used design parameters and the variation of the additional supply flow rate through the feed hole regarding to cavitation effects in the bearing.

Feng Cheng,et.al.studied A Velocity-Slip Model for Analysis of the Fluid Film in the Cavitation Region of a Journal Bearing. The Reynolds equation is derived by using the continuity equation, Navier-Stokes equation and slip length equation within cavitation region. A finite difference method are used to obtain the static and dynamic parameters of journal bearing. A comparison with the available experimental results reveals that the load capacity is well predicted by the present model. The results also show that slip effects in the cavitation region have an influence on the oil film pressure, the load capacity, the dynamic characteristics coefficients and the stability of journal bearing. The good behavior of the proposed algorithm is further illustrated in one example of a dynamically loaded journal bearing, and evolution with time of the journal center is well obtained. A velocity-slip model for analysis of the fluid film in a journal bearing, including slip length within the cavitation region and slip boundary conditions at the gas-liquid interfaces, has been developed, and well predicts the load capacity by the available experiment results.

Roberto Ausas, et.al. done Study the Impact of the Cavitation Model in the Analysis of Microtextured Lubricated Journal Bearings. In this paper, they analyze the impact of the cavitation model on the numerical assessment of lubricated journal bearings. We compare results using the classical Reynolds model and the so-called p- model proposed by Elrod and Adams to fix the lack of mass conservation of Reynolds' model. Both models are known to give quite similar predictions of load-carrying capacity and friction torque in nonstarved conditions, making Reynolds' model the preferred model for its better numerical behavior. Here, we report on numerical comparisons of both models in the presence of microtextured bearing surfaces. We show that in the microtextured situation, Reynolds' model largely underestimates the cavitated area, leading to inaccuracies in the estimation of several variables, such as the friction torque. This dictates that only mass-conserving models should be used when dealing with microtextured bearings.

Gustavo G.Vignolo, et.al.done Approximate analytical solution to Reynolds equation for finite length journal bearings. The understanding of the behavior of hydrodynamic bearings requires the analysis of the fluid film between two solid surfaces in relative motion.The differential equation that governs them ovement of this fluid,called the Reynolds equation,arises from the integration over the film thickness of the continuity equation,previously combined with the Navier–Stokes equation. An order of magnitude analysis,which is based on the relative value of the dimensions of the bearing, produces two dimensionless numbers that govern the behavior of the system:the square of the aspect ratio, length over diameter $(L/D)^2$, and the eccentricity ratio(Z). An analytical solution of the Reynolds equation can only be obtained for particular situations as, for example, the isothermal flow of Newtonian fluids and values of L/D-0 or L/D-N. For other conditions, the equation must be solved numerically. The present work proposes an analytical approximate solution of the Reynolds equation for isothermal finite length journal bearings by means of the regular perturbation method. $(L/D)^2$ is used as the perturbation parameter.

D.Y. Dhande,et al.studied Multiphase flow analysis of hydrodynamic journal bearing using CFD coupled Fluid Structure Interaction considering cavitation. In this study, a fully three-dimensional CFD analysis and multi-phase flow phenomena, has been successfully implemented for simulation of hydrodynamic journal bearing considering the realistic deformations of the bearing with Fluid–Structure Interactions (FSI) along with cavitation.Mixture model is used into model cavitation in the bearing and parametric modelling for modifying the flow domain due to deformation. Both systems are coupled and design optimization based on multi objective genetic algorithm (MOGA), is used to obtain optimized solution of the attitude angle and eccentricity for the combination of operating speed and load. In the study of bearings with and without effects of cavitation, it is observed that maximum pressure values drop when cavitation is considered in the bearing. Al there is decrease in maximum pressure when elastic deformation in the bearing is considered. The oil vapour distribution goes on increasing with the increase in shaft speed, thus lowering the magnitude of the pressure build up in the bearing. Multiphase study of bearings with cavitation hence becomes extremely important in case of bearings operating with higher speeds. The experimental data obtained showed very good agreements with numerical results and considerable reduction in computation time is observed.

WANG Li-li, et.al. studied the effect of viscosity on the cavitation characteristics of a high speed sleeve bearing is investigated theoretically and experimentally. The cavitation characteristics, the cavitation shape and the cavitation location of a spiral oil wedge hydrodynamic bearing are investigated experimentally by using the transparent bearing and the high-speed camera. The generalized Reynolds equation is established with considerations of the cavitation mechanism based on the modified Elrod method in theory, and the cavitations of different viscosity sleeve bearings are analyzed and compared. It is shown that the cavitations are strip-shaped for both the high viscosity lubricant and the low viscosity lubricant, and in the rupture region of the oil film at a high speed, the oil vapour or bubbles are produced. With the decrease of the supply pressure and the increase of the rotating speed, the rupture area of the oil film increases distinctly. The cavitation area decreases distinctly and the quality of lubrication is better for the low viscosity lubricant than for the high viscosity lubricant. The experiment results in general are consistent with the theoretical results.

Tushar P. Gundarneeya done the Theoretical Analysis of Journal Bearing With Nanolubricants.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. 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.

Kalakada.S.Babu, et.al explained Computational analysis of journal bearing operating under lubricant containing Al2O3 and ZnO nanoparticles. In this paper, the mathematical model developed for relationship between viscosity and temperature for the lubricant SAE 15W40 multi grade engine oil with Al2O3 and ZnO nanoparticles is presented. The developed mathematical model for viscosityand temperature of lubricant containing nanoparticles is used for the computation of static performance characteristics of the bearing. These performance characteristics mainly depend on the viscosity of the lubricant. The addition of nanoparticles oncommercially available lubricant considerably enhances the viscosity of lubricant and in turn changes the performance characteristics. To obtain pressure and temperature distribution, modified Reynolds and energy equations are used, and these equations are solved by using Finite Element Method. An iterative procedure is used to establish the film extent. The performance characteristics are calculated from the obtained pressure field. The computed results show that addition of nano-particles increase the viscosity of lubricant and in turn change the performance characteristics of journal bearing.

Shahaji Bhosale explained Review on “Performance of Nano Particle Added Lubricating Oil in Hydrodynamic Journal Bearing”. This paper presents the literature review of hydrodynamic journal bearing. Hydrodynamic Journal bearing is a power transmission component that carries high load in different machineries. It is essential to study the performance characteristics under different loading and operating conditions. The behavior of Hydrodynamic Journal Bearing is also dependent on lubricant used. Lubricant additives play a major role in improving the tribological properties of modern day lubricants. Considering present day energy scenario and the ever increasing severity in operating conditions of machineries, it is imperative that we develop better tribological practices leading to reduced losses due to friction and wear. Journal bearings, being the more popular support mechanism in high speed applications, have been the focus of research of many tribologists.

Table 1:The relevant research Tribological properties of lubricating oil with nanofluids

Name of Author	**Pair used of Base Fluid-Nanofluid**	**Results obtained**
Lee et al	SiC/deionized water (DIW)	Thermal conductivity increases with 7.2%
Pisal et al	CuO/engine oil 20W40	the coefficient of friction reduced by 24% and 53% at 0.5wt% concentration
Y.Y. Wu et al.	CuO, TiO2, and Nano-Diamond nanoparticles/API-SF engine oil	The addition of CuO nanoparticles in the API-SF engine oil and the Base oil decreased the friction coefficient by 18.4 and 5.8%, respectively, and reduced the worn scar depth by 16.7 and 78.8%, respectively.
BinuK.G. et. al	TiO2/engine oil	35 % increase in load carrying capacity
Kalakada et. al.	Al2O3 and ZnO/SAE 15W40 multi grade engine oil	Increases the load capacity by 12.53% (Al2O3) and 11.16% (ZnO)
Baskar S. et. al.	CuO/CMRO (chemically modified rapeseed oil).	1. The frictional coefficient of CMRO + 0.5 w.% nano CuO is 49 % lesser than CMRO and 18 % lower than SAE20W40. 2. The wear value of bearing lubricated with CMRO + 0.5 w% nano CuO has 5 % lesser than SAE20W40.
Yathish K et. al.	TiO2/engine oil	Increase the load carrying capacity by 38%.
B.S.Shenoy et.al.	TiO2/API-SF engine oil	With TiO2 nanoparticles, results in approximately 23% and 35% higher load capacity than that obtained for API-SF engine oil without nanoparticles additives and Base Oil, respectively
Gabi N. et. al.	FeF3,TiF3/ZDDP plain oil	Improvement in wear protection and reducing surface tension

III. Problem Statement

From the Literature review and previous investigation the cavitation area in hydrodynamic journal bearing is very essential area of investigation because it reduces the load capacity and leads to a risk of material damages. The studied of nanotribology shows that the nanoparticles have unique property in lubrication and tribology. The load carrying capacity of solid journal bearing mainly depends upon the viscosity of the Lubricant being used. The addition of nano particles on commercial lubricants may enhance the viscosity of lubricant and in turn changes the performance characteristics. Hence it is important to study the cavitation and pressure distribution in the analysis of hydrodynamic journal bearing with various types of lubricant.

IV. Analytical Method

A. Sommerfeld equation

It assumes that $P = 0$ at $\theta = 0$ and 2π. Pressure distribution is calculated without considering oil film rupture, and the positive and negative pressures obtained are taken into consideration as they are. This is applicable when the bearing pressure is low.The Sommerfeld Solution allows convenient implementation of this cyclic condition. In dimensionless form, oil pressure distribution around the bearing circumference is a function of eccentricity ratio ε. Hence, eccentricity ratio is a parameter which directly influences the bearing load carrying capacity.

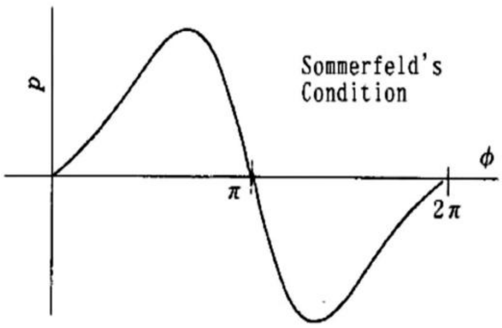

Figure 1: Full sommerfeld boundary condition

Fig. 1 shows that pressure distribution looks like a sine curve. Physically large negative pressure can be encountered only in the presence of high ambient pressure such as those in a nuclear pressurized water system or a deep submerged submarine. Conventional lubrication cannot withstand negative pressure, and liquid oil in the divergent region will cavitate with gases dissolved in the oil coming out of solution. While the full Sommerfeld boundary condition does not takes cavitation effect into consideration. According to equation the summerfeld pressure function is given by :

$$P_i - P_o = \frac{6U\mu r}{C^2} \times \frac{\varepsilon \sin\theta\,(2+\varepsilon\cos\theta)}{(2+\varepsilon^2)(1+\varepsilon\cos\theta)^2}$$

Where:
ε – Eccentricity Ratio ,
r – Bearing radius,
μ – dynamic viscosity of oil,
P– local oil film pressure,
U – linear velocity of journal,
C - Radial Clearance

B. Reynolds equation

The basic problem of hydrodynamic bearing analysis is the determination of the fluid film pressure for a given bearing geometry. A solution to this problem can be found by solving the Reynolds equation of the case under investigation. In the following, the pressure distribution of the journal bearing is introduced. In Reynolds' boundary condition the oil film is assumed to terminate at a certain position at ($\theta cav = \pi+\delta$) which both the pressure and pressure gradient are zero, simultaneously. The Reynolds boundary condition is most realistic boundary condition.

The boundary condition used in the previous Sommerfeld relation had two shortcoming one is full Sommerfeld boundary condition neglected cavitation. Reynold in 1886, he was apparently aware of problems associated with the trailing boundary condition and suggested that pressure should smoothly approach zero in the manner that the position where cavitation begin $\theta = \theta cav$. This condition requires that

$$P = 0 \text{ at } \theta = 0$$

$$P = \frac{dp}{d\theta} = 0 \text{ at } \Theta = \theta cav$$

Where θcav is the cavitation angle and the location of cavitation angle is unknown.

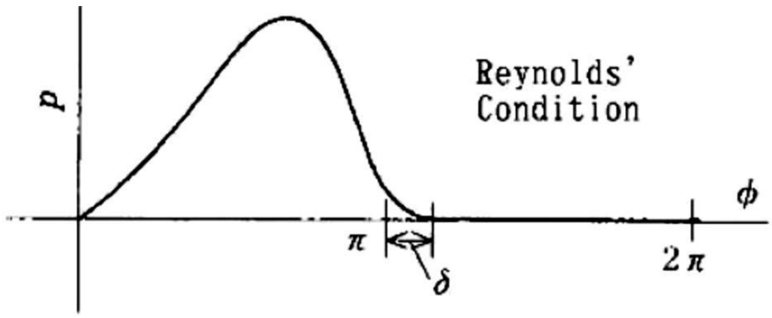

Figure 2: Reynolds boundary condition

Fig.2 shows the pressure distribution using the Reynolds boundary condition. Schematically, the pressure smoothly approaches towards zero at the cavitation start point, and film rupture commences at θcav. Lubricant pressure distribution as a function of journal speed, bearing geometry, oil clearance and lubricant viscosity is described by Reynolds equation and these equations are solved by using Finite Element Method. The pressure distribution in hydrodynamic journal bearing is governed by Reynolds equation which is derived from Navier Stokes continuity and momentum equations Reynolds equation is numerically solved to obtain the pressure distribution within the oil film developed in the clearance between bearing and journal. The Reynolds equation is given by

$\partial/\partial x(h^3 \partial p/\partial x)+ \partial/\partial z(h^3 \partial p/\partial z) = 6\ \mu U \partial h/\partial x$

Where:

h – local oil film thickness,

μ – dynamic viscosity of oil,

p – local oil film pressure,

U – linear velocity of journal,

V. Experimental Setup

Experimental setup consists of a shaft of 50 mm diameter and bearing of 55mm to be tested is floats on the shaft as shown in Figure 3. The system also consists of an oil receiver, measurement Board, oil tank, journal bearing, dead weight and connecting pipes. For this system SAE 30 is used to measure pressure distribution.

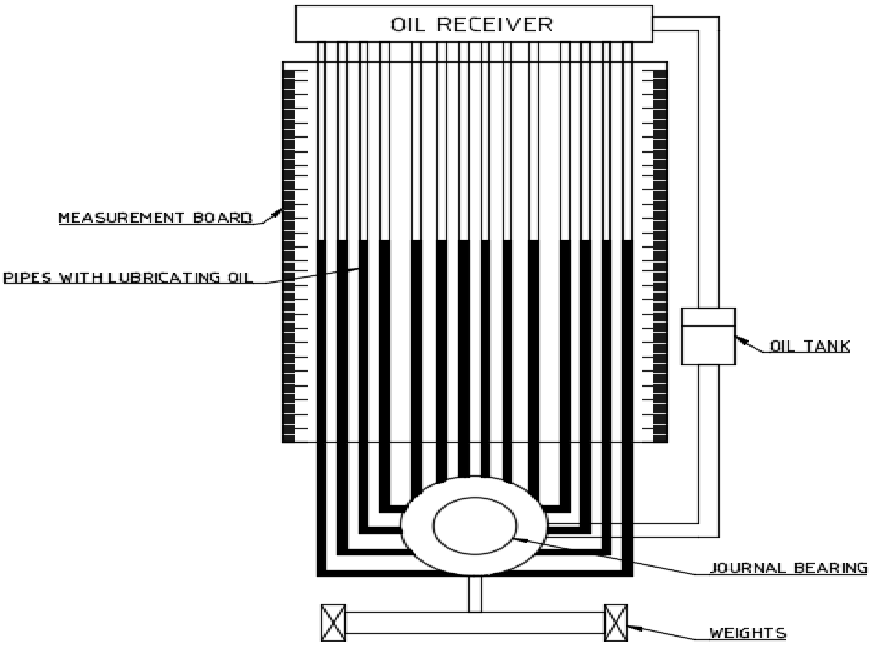

Figure 3: Experimental layout

A. Experimental procedure

1. Fill the oil tank using SAE30 lubricating oil under test & position at desired height.
2. Drain out air from all tubes on manometer & check balance with supply level.
3. Check that some oil leakage is there. Some leakage of oil is necessary for the cooling purpose.
4. Check the direction of rotation and increase the speed of motor slowly.

5. Set the speed and let the journal run for about half an hour until the oil in bearing is warmed up and check the steady oil levels at various toppings.
6. Add required loads and keep the balancing rod in horizontal position by moving balancing weight on the rod and observe the steady levels.
7. When the manometer levels have settled down, take the pressure reading on 1-12 manometer tubes.
8. Repeat the experiment for various speeds.

B. Specifications of bearing and oil

Table 2: Specifications of Bearing and oil

Bearing Specifications	
Bearing Diameter D	0.055m
Shaft Diameter	0.05m
Radial Clearance C	0.0025m
Length of the bearing, L	0.1m
Speed Of The Journal, N	500, 800, 1000, 1200 RPM
Eccentricity Ratio (ε)	0.8
Lubricating Oil (SAE30) Specifications	
Viscosity Of The Oil (η)	0.0635 Nsec/m^2
Density Of The Oil (ρ)	869.3 Kg/m^3
Lubricating Oil (AL2O3) Specifications	
Viscosity Of The Oil (η)	0.0688Nsec/m^2

VI. SUMMARY

From the Literature review and previous investigation, it is found that the cavitation area in hydrodynamic journal bearing is very essential area of investigation because it reduces the load capacity and leads to a risk of material damages. Addition of nanoparticles in the lubricant may enhance the viscosity of the lubricant and in turn changes the static and dynamic performance characteristics of the bearing. However, the application of nanoparticles in hydrodynamic lubrication is not clearly understood and represents a major gap in research such as on cavitation area. Nanolubrication such as AL2O3 is the future area of investigation in hydrodynamic journal bearing for pressure distributation and cavitation because of its property like stability and dispersion are better than other nanolubricant.

REFERENCES

[1] Dowson D, Taylor CM.(1979), Cavitation in bearings. Annu Rev Fluid Mech 1979;11:35–65.
[2] Surojit Poddar,N. Tandon.(2016),The vapour cavitation of journal bearing has been experimentally studied using vibration, acoustic emission and oil film photography. Tribiology International S0301-679X (16)30210-9.
[3] Belova V, Krasowska M, Wang D, Ralston J, Shchukin DG, Möhwald H.(2013) ,Influence of adsorbed gas at liquid/solid interfaces on heterogeneous cavitation. Chem Sci 2013;4:248–56.
[4] Sun DC, Brewe DE, Abel PB.(1993) Simultaneous pressure measurement and high-speed photography study of cavitation in a dynamically loaded journal bearing. J Tribol 115:88–95.
[5] Natsumeda S, Someya T. Paper III (1987) Negative pressures in statically and dynamically loaded journal bearings. Tribol Ser;11:65–72.
[6] Braun MJ, Hannon WM. Cavitation formation and modelling for fluid film bearings: a review. Proc Inst Mech Eng Part J J Eng Tribol 2010;224:839–63.
[7] Khonsari MM, Booser ER. Applied tribology: bearing design and lubrication. vol. . John Wiley & Sons; 2008.
[8] M. Riedel, M. Schmid ,P. Stucke. (2013),Numerical investigation of cavitation flow in journal bearing geometry. published by EDP Sciences.
[9] Feng Cheng, Weixi Ji. (2016).A Velocity-Slip Model for Analysis of the Fluid Film in the Cavitation Region of a Journal Bearing. Tribiology International http://dx.doi.org/10.1016/j.triboint..01.025.
[10] Roberto Ausas, Patrick Ragot, Jorge Leiva , Mohammed Jai, Guy Bayada and Gustavo C. Buscaglia(2007). Study The Impact of the Cavitation Model in the Analysis of Microtextured Lubricated Journal Bearings. 868 / Vol. 129.
[11] Jinyu Zhang,Yonggang Meng. (2012) Direct Observation of Cavitation Phenomenon and Hydrodynamic Lubrication Analysis of Textured Surfaces Tribol Lett 46:147–158.
[12] B. Vincent,P. Maspeyrot , J.Frene(1997). Study the Cavitation in noncircular journal bearings. Wear 207 122–127 France.
[13] Gustavo G.Vignolo, Daniel O.Barila ,Lidia M.Quinzani(2011).Approximate analytical solution to Reynolds equation for finite length journal bearings. Tribology International 44 1089–1099.

[14] H. G. Elrod. Study on a Cavitation Algorithm. Journal of Lubrication Technology July 1981,Vol. 103/351.
[15] D.Y. Dhande, D.W. Pande (2016)..Multiphase flow analysis of hydrodynamic journal bearing using CFD coupled Fluid Structure Interaction considering cavitation. Journal of King Saud University Engineering Sciences.
[16] WANG Li-li, LU Chang-hou (2015). The effect of viscosity on the cavitation characteristics of a high speed sleeve bearing is investigated theoretically and experimentally.27(3):367-372.
[17]Tushar .P.Gundarneeya (2015).Theoretical Analysis of Journal Bearing With Nanolubricants. IJSRSET | Volume 1 | Issue 3 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099.
[18] Kalakada Sreedhar Babu,K. Prabhakaran Nair,P.K. Rajendrakumar (2014). Computational analysis of journal bearing operating under lubricantcontaining Al2O3 and ZnO nanoparticles. International Journal of Engineering, Science and Technology Vol. 6, No. 1, 2014, pp. 34-42.
[19] Shahaji Bhosale Review on “Performance of Nano Particle Added Lubricating Oil in Hydrodynamic Journal Bearing”. Advances of Production Engineering and System Technology Volume 1 Issue 1.