Review on "Performance of Nano Particle Added Lubricating Oil in Hydrodynamic Journal Bearing"

Shahaji Bhosale
Research Scholar (M.E- Design)
Department of Mechanical Engineering,
JSCOE, Hadapsar, Pune University, Pune
***E-mail**: shahaji30@gmail.com*

Abstract

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.

***Keywords:** Nanoparticles, Tribological Properties, Engine Oil, Friction Coefficient*

INTRODUCTION

Hydrodynamic Journal Bearing is the bearing in which the load supporting high pressure fluid film is created due to the shape and relative motion between two surfaces. The moving surfaces pull the lubricant into a wedge shaped zone, at a velocity sufficiently high to create the high pressure film necessary to separate the two surfaces against the load. It leads to Hydrodynamic Lubrication. The use of nanoparticles as lubricant additive has been a major subject of research in the past decade. 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.

However, application of nanoparticles in hydrodynamic lubrication is not clearly understood and represents a major gap in research. Nano-lubricants as well as any other colloidal solution are prone to a problem of suspension's stability. Some of the nanoparticles pose environmental issues and therefore, need to be reclaimed after use as oil additives. Some types of the particles are often expensive.

Nanoparticles have received considerable attention because of their special physical and chemical properties. The preparation of organic–inorganic complex nanoparticles was causing more interest in science and industry. Now, a number of these nanoparticles have been synthesized and many of them have been studied as lubrication oil additive. However, few of them were used and studied as water base lubrication additives. In recent years, with the development of some nanomaterials, many scientific researchers added nanoparticles into lubricating oils to improve extreme pressure, anti-wear and friction reducing properties, the result was that the efficiency of machinery was improved and service life prolonged. The application of advanced nanomaterials has played an active role in improving and reforming traditional lubrication technology.

LITERATURE REVIEW

Lee et al. [1] the thermophysical properties of SiC/DIW nanofluids for high temperature heat transfer application were investigated. Because the properties of the nanofluids depend on the morphologies of nanoparticles, the SiC nanofluids were prepared in-house while the shape and size of SiC nanoparticles were also checked. For the SiC dispersion stability, the IEP was identified as pH 6 and the pH control apart from the point was successful to maintain its stability. The measured maximum relative viscosity for the 3 vol% SiC/DIW nanofluids compared with DIW was 102%, while the measured maximum relative thermal conductivity data for the 3 vol% SiC/DIW nanofluids compared with DIW was approximately 7.2%.

Pisal et al. [2] in their research, studied adding copper oxide (CuO) nanoparticles to engine oil 20W40 and investigated their Tribological properties. Samples were prepared of varying percentage of CuO

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nanoparticles in engine oil (0.2, 0.5, 0.75 and 1 wt. %). The wear and friction experiment was carried on Pin on Disc Tribometer and the tests were performed with varying load, speed and varying concentration of nanoparticles in engine oil. The obtained results show that CuO nanoparticles added in engine oil exhibit good friction reduction and anti-wear properties and also decreased the coefficient of friction by 24% and 53% at 0.5wt% concentration respectively, as compared with standard engine oil without CuO nanoparticles. He found that as a lubricant, friction-reduction properties of base oil are enhanced by the addition of CuO nanoparticles to a moderate concentration. Base oil with CuO nanoparticles improved tribological properties in terms of load carrying capacity, anti-wear and friction reduction than base oil without nanoparticles. The results showed that 0.5 wt% concentration was an optimum concentration. For the friction reduction test, when CuO nanoparticles were added into base oil, the coefficient of friction reduced by 24% and 53% at 0.5 wt% concentration as compared to oil without nanoparticles.

Y.Y. Wu et al. [3] examined the tribological properties of two lubricating oils, API-SF engine oil and Base oil, with CuO, TiO2, and Nano-Diamond nanoparticles used as additives. The experimental results show that nanoparticles, especially CuO, added to standard oils exhibit good friction-reduction and anti-wear properties. 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, as compared to the standard oils without CuO nanoparticles. In addition, investigations were performed using TEM, OM, SEM, and EDX to interpret the possible mechanisms of antifriction and anti-wear with nanoparticles.

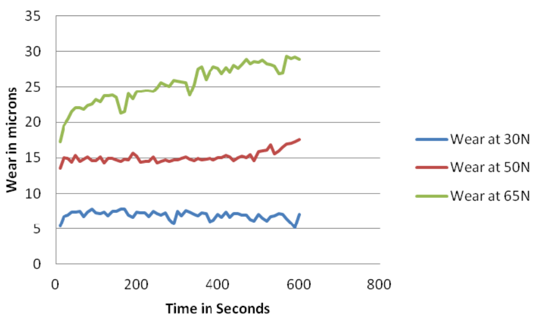

Figure 1: Wear in micron with base oil without nanoparticles

Binu K.G. et al. [4] studied the influence of shear viscosity variation of engine oil, due to the presence of TiO2 nanoparticle additives at volume fractions ranging from 0.005 to 0.025, on the load carrying capacity of a journal bearing. The presence of TiO2 nanoparticles, even at low concentrations of 0.01 volume fraction, is found to increase the load carrying capacity of journal bearings by 40% in comparison to plain engine oil without nanoparticle additives. The DLS particle size analysis reveals that TiO2 nanoparticles of primary size <~100 nm dispersed in engine oil forms aggregates of average size 777 nm, resulting in a particle packing fraction of 7.77. The load carrying capacity of the journal bearing operating on TiO2 based nanolubricant at a constant volume fraction is also found to increase with higher nanoparticle aggregate packing ratios. Simulated results reveal that increasing the particle packing fraction from 7.77 to 10 will lead to a 35 % increase in load carrying capacity for a TiO2 nanoparticle concentration of 0.015 volume fraction. However, further experimental studies are necessary to prove the influence of nanoparticle aggregates on dispersion stability and load carrying capacity. The influence of couple stress effects of nanoparticle additives on the load carrying capacity of journal bearings also need to be studied.

Kalakada et. al. [5] studied the mathematical model developed for relationship between viscosity and temperature for the lubricant SAE 15W40 multi grade engine oil with Al2O3 and ZnO nanoparticles. The developed mathematical model for viscosity and 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 on commercially 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. In non-thermo viscous case, increase of weight concentration of nanoparticles changes the performance characteristics of the bearing slightly. But in this case, addition of nanoparticles increase the load capacity of journal bearing at any eccentricity ratio, and this increase is significant at high values of the eccentricity ratio. 0.5% weight concentration of nanoparticles increases the load capacity by 12.53% (Al_2O_3) and 11.16% (ZnO) in thermo viscous case when bearing operates at ε=0.9. The friction force of bearing increases with the increase in concentration of nanoparticles for both non-thermo viscous and thermo viscous cases. At any eccentricity ratio, both end leakage and attitude angle decrease with the increase in concentration of nanoparticles in both non thermo viscous and thermo viscous cases, and these decreases are considerable in thermo viscous case and occur at higher eccentricity ratios.

Baskar S. et. al. (2014) [6], in their study, stated that the friction and wear behaviour of journal bearing material (brass) was evaluated by focusing on the effect of Nano CuO in the chemically modified rapeseed oil. The bearing material (brass) lubricated with CMRO + 0.5 w.% nano CuO has the lowest friction coefficient of 0.073. The frictional coefficient of bearing material lubricated with CMRO is 0.13 and SAE20W40 is 0.09. The frictional coefficient of CMRO + 0.5 w% nano CuO is 49 % lesser than CMRO and 18 % lower than SAE20W40. The wear of bearing material lubricated with SAE20W40, CMRO and CMRO + 0.5 w% nano CuO of 86.77, 136.34 & 82.07 mg. The wear value of bearing material lubricated with CMRO + 0.5 w% nano CuO has lowest wear and 39 % lesser than CMRO. The wear value of bearing lubricated with CMRO + 0.5 w% nano CuO is 5 % lesser than SAE20W40. It also possesses superior tribological behavior in chemically modified rapeseed oil with nano CuO than the other two lubricating oils. By evaluating the above mentioned discussions, it can be stated that among the three lubricating oils, nano CuO can be preferred for the lubrication purpose in Journal bearing application.

Yathish K et. al. (2014) [7] stated that Load carrying capacity of an oil lubricated two-axial groove journal bearing is simulated by taking into account the viscosity variations in lubricant due to the addition of TiO_2 nanoparticles as lubricant additive. Shear viscosities of TiO_2 nanoparticle dispersions in oil are measured for various nanoparticle additive concentrations. The viscosity model derived from the experimental viscosities is employed in a modified Reynolds equation to obtain the pressure profiles and load carrying capacity of two-axial groove journal bearing. Results reveal an increase in load carrying capacity of bearings operating on nanoparticle dispersions as compared to plain oil. The presence of 0.01 volume fraction of TiO2 nanoparticles in engine oil was found to increase the load carrying capacity by 38%. However, this increase in load capacity should be experimentally validated. The effect of additive particle size on the bearing performance also needs to be investigated.

B.S. Shenoy et. al. (2012) [8] studied static performance characteristics of an externally adjustable fluid-film bearing operating with CuO, TiO2 and Nano-Diamond nanoparticles additives in API-SF engine oil that were simulated theoretically. This study predicts that a bearing having negative radial and negative tilt adjustments and operating with API-SF engine oil added, especially withTiO2 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. Furthermore, friction force of an externally adjustable fluid-film bearing increases by 25% for the API-SF engine oil without nanoparticles compared with TiO2 nanoparticle additives. It is also predicted that API-SF engine oil without nanoparticles additives and Base Oil, respectively, have 15% to 23% higher values of lubricant end leakage as compared to API-SF engine oil with nanoparticles of titanium dioxide.

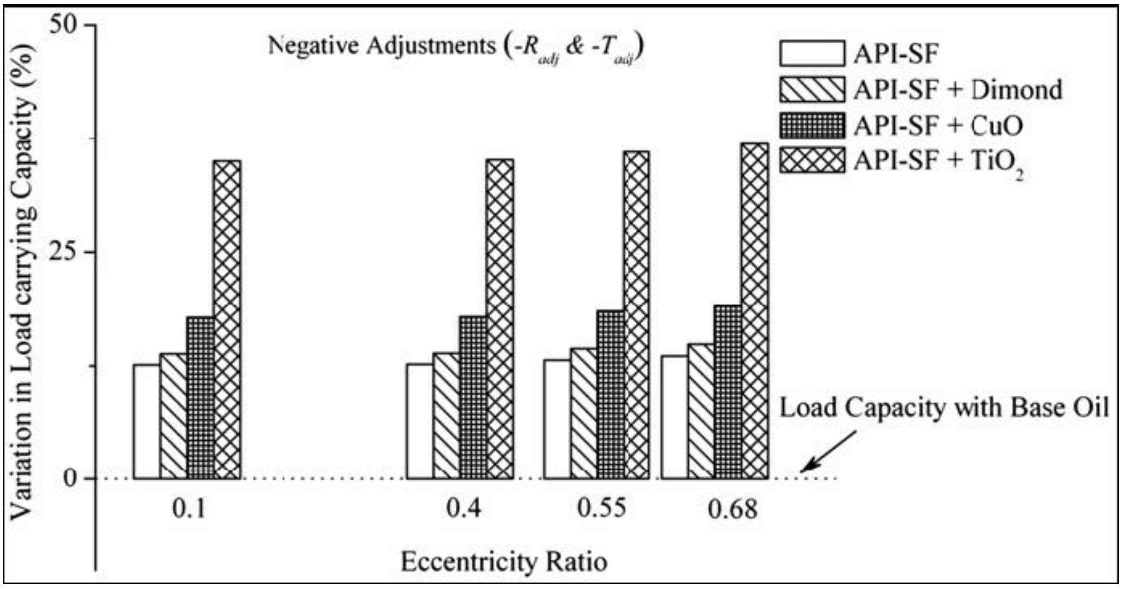

Figure2: Variation in Load Carrying Capacity with the addition of nanoparticles additives.

Gabi N. et. al. (2012) [9] studied the friction and wear performance of ZDDP plain oil additives (0.1% phosphorus) with (iron fluoride FeF3 + titanium fluoride TiF3) catalysts and polytetrafluoro ethylene PTFE using thermal and tribological analysis. Thermal tests and tribological tests were performed using thermo gravimetric analysis (TGA), X-ray Photoelectron Spectroscopy (XPS), and ball on cylinder wear apparatus. The influence of TiF3 + FeF3 on the formation and properties of anti wear films was examined. Results indicated that the surface of metals can be significantly modified using fluorinated anti wear additives at 100 ◦C temperatures, as the decomposition temperature of ZDDP was decreased. This surface modification provides tightly bound fluorocarbon and metal fluoride materials that bring about significant changes in properties, especially enhancing wear protection and reducing surface tension.

RELEVANT RESEARCH STUDY OF NANOFLUIDS IN PLAIN OIL LUBRICANT

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% and
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, TiO_2, 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	TiO_2/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	1. The frictional coefficient of CMRO + 0.5 w.% nano CuO is 49 % lesser than

	rapeseed oil).	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.	TiO_2/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.

CONCLUSION

The study reveals that by adding nanoparticles in lubricating oil, an increase in load carrying capacity in comparison to plain engine oil is evident. The analysis also reveals there is a decrease in friction force for lubricating oil of journal bearings using Nano lubricants, as compared to plain lubricating oil. The effect of variation in nanoparticles volume fraction on load carrying capacity is found to be more significant when compared to couple stress parameter. The aim of this current study is to evaluate the tribological performance of lubricant with nano additive in consideration for different applications to survive severe operating conditions and mitigate surface originated failure. The effects of variable density and variable specific heat on maximum pressure, maximum temperature, load bearing, frictional loss and side leakage in high-speed journal bearing operation are examined. The calculation results are compared with the results calculated under various properties of lubricating oil. These include nano additives used in hydrodynamic bearing like load carrying capacity, friction loss, and wear resistance.

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