Review Paper on Performance of Hydrodynamic Journal Bearing with Nano Particles in Lubricating Oil

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Abstract— *This paper presents the literature review of hydrodynamic journal bearing. Hydrodynamic journal bearings are used in heavy machineries to support high loads .It is essential to study the performance characteristics under different loading and operating conditions. The 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. Lubricant additives play a major role in improving the tribological properties of modern day lubricants. The study reveals that by adding in nanoparticle in lubricating oil, it is found that increase in load carrying capacity in comparison to plain engine oil. The analysis also reveals there is decrease in friction force for lubricating oil of journal bearings using nano lubricants as compared to plain lubricating oil.*

Keywords— Hydrodynamic Journal Bearing, Nanoparticle, Lubricant, Load Carrying Capacity

I. 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.

II. Literature Review

A brief review of some selected references on this topic is presented here.

Wu et al. (2007) [1] obtained viscosities for engine oil (SAE30 LB51153) with nanoparticles like copper oxide, titanium dioxide. It has been found that when nanoparticles of titanium dioxide are added to the above oil, the viscosity increases 40% higher than that of oil without nanoparticles addition. 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.

Binu K.G. et al. [2] studied the influence of shear viscosity variation of engine oil, due to the presence of TiO_2 nanoparticle additives at volume fractions ranging from 0.005 to 0.025, on the load carrying capacity of a journal bearing. The presence of TiO_2 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 TiO_2 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 TiO_2 based Nano lubricant 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 TiO_2 nanoparticle concentration of 0.015volume 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 needs to be studied.

Sriharsha T.S. et al. [3] studied that the dynamic analysis of hydrodynamic solid journal bearing operating under nano lubricants is presented in this paper. The load carrying capacity of solid journal bearing mainly depends upon the viscosity of the lubricant being used. The addition of nanoparticle on commercial lubricants may enhance the viscosity of lubricant and in turns changes the performance characteristics. In the proposed work, to obtain pressure distribution in the clearance space of the solid journal bearing, modified Reynolds equation is used. The steady and dynamic behaviour of hydrodynamic journal bearing system have been studied and presented in this paper. The result reveals that lubricant with nano diamond have higher threshold speed which increase with gradual increase in eccentricity ratio whereas damped frequency decreases. The threshold speed and load capacity increases with addition of nano particles at any eccentricity ratio.

Kalakada et al. [4] studied the mathematical model developed for relationship between viscosity and temperature for the lubricant SAE15W40 multi grade engine oil with Al_2O_3 and ZnO nanoparticles is presented. 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-thermoviscous case increase of weight concentration of nanoparticles change the performance characteristics of bearing slightly. But in thermoviscous 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% (Al2O3) and 11.16% (ZnO) in thermoviscous case when bearing operates at ε=0.9. The friction force of bearing increases with the increase in concentration of nanoparticles for both non-thermoviscous and thermoviscous cases. At any eccentricity ratio, both end leakage and attitude angle decrease with the increase in concentration of nanoparticles in both non thermoviscous and thermoviscous cases, and these decreases are considerable in thermoviscous case and at higher eccentricity ratios.

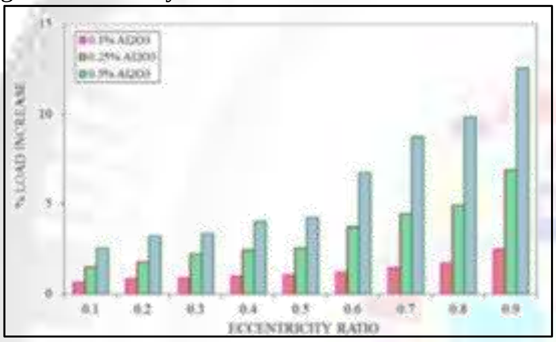

Fig. 1: Effect of % wt. concentration of Al2O3 nanoparticles in SAE 15W40 multi-grade engine oil on % Load increase of journal bearing

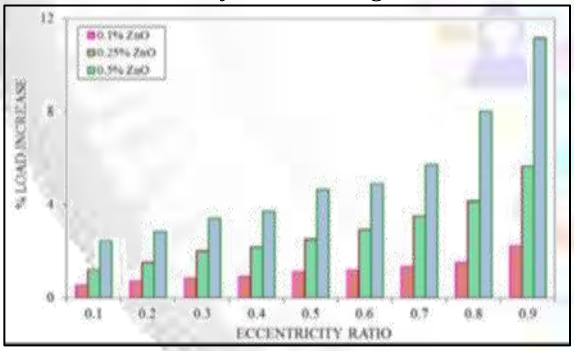

Fig. 2: Effect of % wt. concentration of ZnO nanoparticles in SAE 15W40 multi-grade engine oil on %Load increase of journal bearing

Baskar S. et al. (2014) [5] stated that, the friction and wear behavior of journal bearing material (brass) was evaluated and 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 SAE 20W40 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 withSAE20W40, 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 + 0.5w. % nanoCuO has lowest wear and 39 % less than CMRO. The wear value of bearing lubricated with CMRO + 0.5 w% nano CuO has 5 % lesser than SAE 20W40. It is also possesses superior tribological behavior in chemically modified rapeseed oil with nano CuO than the other two lubricating oils. The above mentioned discussions are evaluated, it can be stated that among the three lubricating oils, one can contain nano CuO can be preferred for the lubrication purpose in Journal bearing application.

Yathish K et al. (2014) [6] 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 TiO2 nanoparticles as lubricant additive. Shear viscosities of TiO2nanoparticle 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.

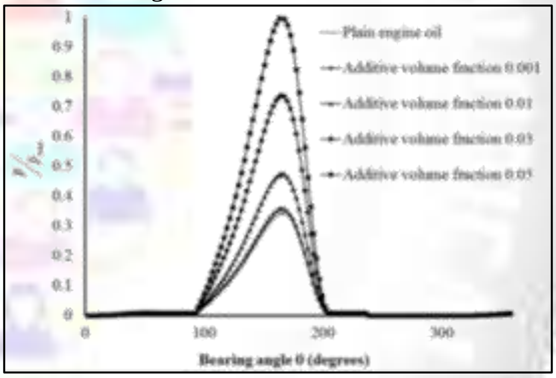

Fig. 3: Comparison pressures for different TiO2 nanoparticle concentrations at an eccentricity ratio of 0.7.

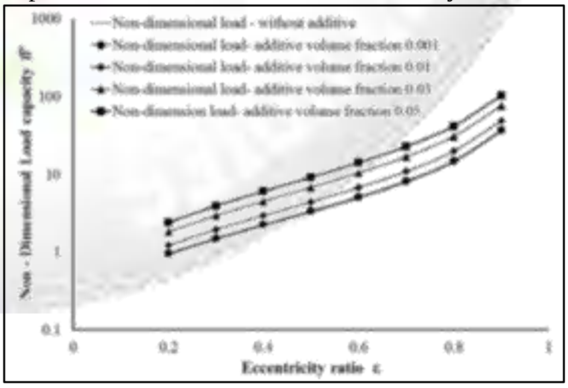

Fig. 4: Comparison of load carrying capacities at different TiO2 nanoparticle concentrations

B.S. Shenoy et Al. (2012) [7] studied that static performance characteristics of an externally adjustable fluid-film bearing operating with CuO, TiO2 and Nano-Diamond nanoparticles additives in API-SF engine oil are simulated theoretically. This study predicts that a bearing having negative radial and negative adjustments and operating with API-SF engine oil added specially 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.. 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 leakages compared to API-SF engine oil with nanoparticles of titanium dioxide.

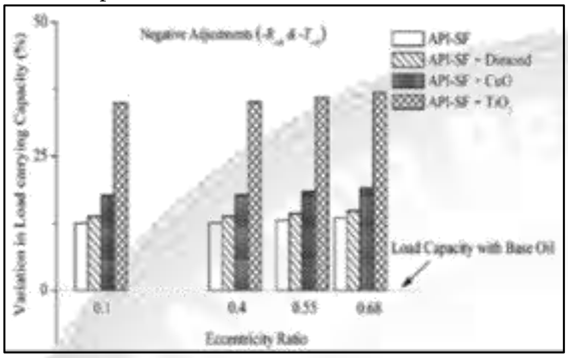

Fig. 5: Variation in Load Carrying Capacity with the addition of nanoparticles additives.

Greco et al. (2011) [8] studied that to evaluate the tribological performance of boron based surface treatment and lubricant additive in consideration for application in a wind turbine drive train to accommodate severe operating conditions and mitigate surface originated failure. Electrochemical boride surface treatment is considered in comparison to traditional case carburization as an alternative or additive method to significantly increase the surface hardness and wear resistance. Nano-colloidal boron-nitride based lubricant additives are considered as a complementary technology to react with the borides surface to form a wear protective tribofilm. Experimental evaluation confirmed the following conclusions: Electrochemical boriding provided an enhanced hardness (1500–2200 HV) to the surface of 9310 gear steel, in the form of a uniform thick two phase boron diffused layer (Fe Band Fe2B). The thermal processing time was less than 1 h.XPS analysis showed that a Nano-colloidal boron nitride additive in a commercial gear oil chemically reacted with the boride surface to form a wear protective tribofilm. High contact load (2.5 GPa) sliding tests showed that the electrochemical boride surface was significantly more wear resistant than the carburized surface by more than an order of magnitude. Further work is need to evaluate the performance of this boron based surface treatment and lubricant additive for a wider range of contact conditions (i.e. rolling contact) with corresponding optimization of the treatment, in order to fully evaluate the advantages of this technology in wind turbine drive train applications and beyond.

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 balloon cylinder wear apparatus. The tribological data were collected and Design of Experiment (DOE) was used to optimize the load and oil quantity with respect to surface finish the advantage of catalysts/PTFE coating on polished surfaces has been demonstrated through thermal decomposition of ZDDP plain oil and tribological behavior under different speeds condition sand Design of Experiment. The influence of TiF3 + FeF3 on the formation and properties of antiwear films was examined. Results indicated that the surface of metals can be significantly modified using fluorinated antiwear additives at 100 ◦C temperatures, and the decomposition temperature of ZDDP was decreased. This surface modification provides tightly bound fluorocarbon and meta fluoride materials that impart significant changes in properties, especially enhancing wear protection and reducing surface tension.

III. Conclusion

From literature survey it can be say that it is a novel method for evaluating the load carrying capacity of journal bearings operating on lubricants containing nanoparticle additives. The load carrying capacity of solid journal bearing mainly depends upon viscosity of lubricating oil. When lubricating oil is supplied to bearing then heat generated and viscosity decreases and load carrying capacity decreases. The addition of nanoparticle on commercial lubricants may enhance the viscosity and load carrying capacity increases.

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