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Determination of Nano Particle Performance Added in Lubricating Oil Used For Hydrodynamic Journal Bearing

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Abstract

The aim of this project is experimental investigation of hydrodynamic journal bearing using nano particle added lubricating oil. Adding nanoparticles is the basic requirement to increase the viscosity of commercial lubricants in order to improve their performance characteristics. In this paper, we will present the observation of pressure distribution at the clearance space of a journal bearing.

CuO + ZnO nanoparticles were used in this project. We prepared CuO +ZnO based nano particles and used them in a lubricant at various volume ratios. It has been found that these samples exhibit good dispersion stability. An experimental analysis is carried out using nanoparticle based lubricant samples with different CuO + ZnO volume fractions to study the pressure generation and distribution in a lubricating layer of hydrodynamic bearing with increasing CuO + ZnO nanoparticle concentrations and varying loads on bearing. Bearing testing device will be used to carry out pressure generation and distribution of pressure related measurements. Readings were taken. Moreover, at various loads, pressure related measurements were obtained.

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Conventional (non nano fluid added lubricant) bearing underwent the same testing procedure.

Keywords: *Hydrodynamic journal bearing, Nanolubricant, CuO nanoparticles, ZnO nanoparticles, Pressure distribution, Viscosity enhancement, Bearing performance, Load variation, Nano-additive lubricants*

INTRODUCTION

In a hydrodynamic journal bearing, the metal to metal contact between load-carrying surfaces of the bearing is prevented by a relatively thick film of lubricant. By applying the laws of fluid mechanics, the stability obtained can be explained. By introducing the lubricant into the load-carrying area at a pressure high enough to isolate the surfaces, a relatively thick layer of lubricant is obtained in conventional solid bearing lubrication. Unlike hydrodynamic lubrication, it is applicable when velocities are low or zero. If the frictional resistance is an absolute zero, lubrication does not require motion relative surfaces. But in almost all of the engineering practices, these are obsolete, because of the extreme conditions under which these are operated. They obtained viscosities with nanoparticles like titanium dioxide, copper oxide for engine oil (SAE30 LB51153). It was observed that the viscosity increases almost 40% higher than that of oil when nanoparticles of titanium dioxide are added to the oil. The viscosity of oil may enhance by introduction of nanoparticles in the commercial lubricants and hence, in turn, improve the load carrying capacity of the bearing. These solid particles increase the thickness of lubricants which affect the performance characteristics of journal bearing.

In this paper, the study of the influence of CuO+ ZnO nanoparticle lubricant additive on the load carrying capacity of a bearing is presented. Increase in viscosity of oil due to presence of SiO2 nanoparticles is modeled. Validity of investigational setup in the viscosity simulation of CuO+ZnO nanoparticle diffusions in engine oil is experimentally verified. Using a modified Reynolds equation, pressure distribution and load carrying capacity are theoretically evaluated for various CuO+ZnO nanoparticle concentrations. Results reveal an improvisation in load carrying capacity as compared to oils without additive.

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LITERATURE SURVEY

Due to the use of Titanium Oxide nanoparticle, additives can be used at volume fractions, ranging from 0.005 to 0.025. The load bearing capacity of journal bearings increases by 40% in comparison to general engine oil without nanoparticle additives. By using Titanium Oxide nanoparticles even at small concentration amount of 0.01 volume fraction, this can be achieved. The DLS particle size analysis showed that TiO2 additives of primary size <~100 nm spread in engine oil forms aggregates of average size 777 nm, resulting in a particle packing fraction of 7.77. The load carrying capacity of bearing operating on TiO2 based lubricant at a uniform volume segment is also observed to increase with greater nanoparticle aggregate packing ratios. Simulated results showed that rise in the particle packing fraction from 7.77 to 10 will lead to a 35 % improvisation in load carrying capacity for a TiO2 nanoparticle concentration of a volume fraction 0.015. However, further experimental analyses are necessary to prove the effects of nanoparticle aggregates on dispersion stability and load carrying capacity. The couple stress effects of nanoparticle additives on the load carrying capacity of bearings is also necessary to analyze.

Sriharsha T.S. et. al. [3] studied that the dynamic analysis of hydrodynamic solid journal bearing operating under nano particle added lubricants. The load carrying capacity of the bearing mainly depends upon the thickness of the oil being used. The introduction of nanoparticle in commercial lubricants may improve the viscosity of lubricant and in turn, changes the performance characteristics. In this work, to obtain pressure distribution in the space available between two adjacent surfaces of the solid journal bearing, modified Reynolds equation is used. The steady and dynamic behavior of bearing system have been studied and presented here. The result shows that oil with nano diamond have greater threshold speed that gets improved with gradual improvement in eccentricity ratio, whereas damped frequency decreases. The threshold speed and load capacity increases with introduction of nano particles at any eccentricity ratio.

Baskar S. et. al. (2014) [4] In this study, the friction and wear related behavior of bearing material (brass) was examined and the effect of nano particle CuO in the chemically improved rapeseed oil was studied. The bearing material (brass) lubricated with CMRO + 0.5 w. % nano particle CuO has the smallest friction

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coefficient of 0.073. The frictional coefficient of bearing material oiled with CMRO is 0.13 and SAE20W40 is 0.09. The frictional coefficient of CMRO + 0.5 w. % nano particle CuO is 49 % smaller as compared to CMRO and 18 % smaller than SAE20W40. The wear of bearing material oiled with SAE20W40, CMRO and CMRO + 0.5 w. % nano CuO of 86.77, 136.34 & 82.07 mg. The wear value of bearing material oiled with CMRO + 0.5 w. % nano particle CuO has smaller wear and 39 % smaller than CMRO. The wear value of bearing oiled with CMRO + 0.5 w% nano particle CuO is 5 % smaller than SAE20W40.

Yathish K et. al. (2014) [5] stated that load bearing capacity of an oil lubricated two-axial groove of bearing is simulated by taking into account the viscosity variations in lubricant due to the introduction of Titanium Oxide nanoparticles as an oil additive. Shear viscosities of Titanium Oxide nanoparticle dispersions in a lubricant are evaluated for various nanoparticle additive ratios. The viscosity model derived from the investigational viscosities are utilized in a modified Reynolds equation to get the pressure profiles and load bearing capacity of two-axial groove bearing. Results show an improvement in load bearing capacity of bearings operating on nanoparticle dispersions than on general oil. The addition of 0.01 volume fraction of Titanium Oxide nanoparticles in engine oil improves the load bearing capacity by 38%. However, this improvement in load capacity should be experimentally validated. The behavior of additive particle size on the bearing performance is also necessary to investigate.

B.S.Shenoy et Al. (2012) Friction force of an externally adjustable fluid-film bearing increases by 25% for the API-SF engine oil without nanoparticles, as compared to TiO2 nanoparticle additives. It is also predicted that API-SF engine oil neglecting nanoparticle additives and Base Oil, respectively, have 15% to 23% higher values of oil end leakage as compared to API-SF engine oil with added nanoparticles of titanium dioxide.

PROPOSED EXPERIMENTATION PROCEDURE OF BEARING TESTING

CuO+ZnO are additives used in this experimentation. CuO+ZnO based nanoparticle is added to oil at various volume fractions. The prepared samples should exhibit good dispersion stability. The nano particle added oil samples with varying CuO+ZnO volume samples are

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then subjected to an experimental analysis to study the pressure exertion and distribution in lubricating a layer of hydrodynamic bearing with increasing CuO+ZnO nanoparticle concentrations and load exerted on bearing. Readings will be taken at the same intervals. Pressure measurements will be carried out at various loads. Same testing procedure will be carried out for conventional (non nanofluid added lubricant) bearing.

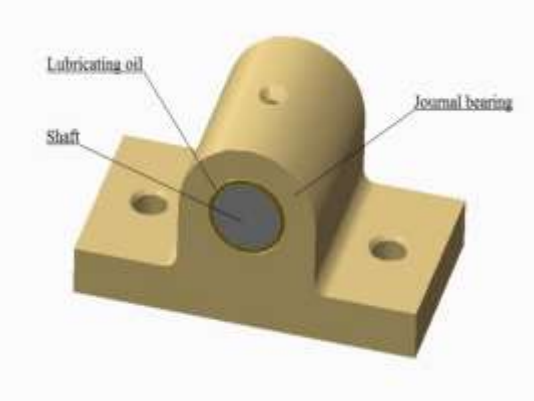

Fig 1: Testing Bearing

Equipment Specifications:

- Bearing diameter = 2.166 in
- Journal diameter = 1.984 in
- Effective bearing length = 2.766 in
- Bearing weight with attachments = 1.43 lb
- Weight of each movable load = 0.22 lb
- Lubricant = SAE 15 W 50
- Lubricant's density = 0.0282 lb/in3

Procedure

1. Select the direction of rotation of the motor by turning the switch provided for this purpose. Do not change the direction of rotation while the motor is running.

2. Start the motor and let it run for about half an hour for the temperature and the oil viscosity to reach the steady state condition.

3. Apply about a one-pound load on bearing, using the dead weights.

4. Increase the shaft speed gradually until you observe instability and vibration of the bearing. Measure the speed of rotation ω of the shaft. Observe and comment about pressure distribution around the bearing.

5. Using the strobe light, set the journal speed to 1200 RPM. (Periodically check this speed as it may increase during this experiment.) Allow enough time for the oil to level in the barometer tubes to stabilize (about 3 min.)

6. Read the pressures for locations 1 through 16 and convert the readings to psi.

7. Change the shaft speed to 1400 and 1600 and repeat steps 5 through 7 for the new RPMs.

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8. Plot the variation of pressure along the bearing axis (pressure taps 1 through 5) and obtain the average pressure along axis as well as the ratio (R) of average pressure to the maximum pressure along axis (pressure tap No. 3).

9. Multiply the reading at pressure tap 3 by the ratio R obtained in Step 8 to obtain axially averaged pressure. Repeat the same multiplication procedure for the readings at pressure taps 6 through 16. Plot the axially averaged pressure vs. theta in Cartesian as well as polar coordinates.

10. Find 2 points A and B on the experimental pressure curve that are 180° apart but having equal pressure. Note that for any pressure curve, there will be only one such pair of points possible. These two points, A and B, form the axis P - P0 = 0 for the Sommerfeld curve.

11. Out of these two points, choose one as a origin, the point with a greater viscosity of oil film and take the axis $\theta = 0$ to pass through this point.

12. From your pressure distribution graph, determine the location (θ_1) of maximum pressure and then from Eq. (6), find the eccentricity ratio.

13. Using Eq. (2) to calculate the constant K, and then plot the Sommerfeld curve (theoretical pressure distribution), using Eq. (1). A typical curve is shown in Fig.4.

14. Calculate the load carrying capacity of the bearing from:

$$W = \sum_{i=1}^{12} \left(\frac{\pi L d}{12} \right) (P - P_0)_i \cos \beta_i$$

Where, (P-P0)i is the pressure at the midpoint between any two consecutive pressure tap points and βi is the angle between that mid-point and the line of action of load (pressure tap point no. 3). Compare this load with the actual load on the bearing.

15. Calculate the Sommerfeld number from:

$$S = \left(\frac{r}{c} \right)^2 \left(\mu \frac{N}{P} \right) = \frac{K\left(2 + \varepsilon^2\right)}{12 \pi \varepsilon P}$$

and then the friction coefficient from Fig. 3.

16. Calculate and plot theoretical HP lost in the bearing based on the friction coefficient obtained in the previous step.

17. Discuss your results and comment on them.

RESULTS AND DISCUSSION

After examining the result of load, speed and bearing texture on the bearing, the

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profile pressure has been calculated, and then it has been compared with each other with regards to the pressure profile generated. Methods to improve the load carrying capacity of the bearing while generating less pressure are also recognized.

Comparison of pressure profile for no load condition at 1300 rpm.

Figure 4.1 shows the comparison of radial pressure profile graphed for all the bearing at no load condition and running the shafts at 1300 rpm.

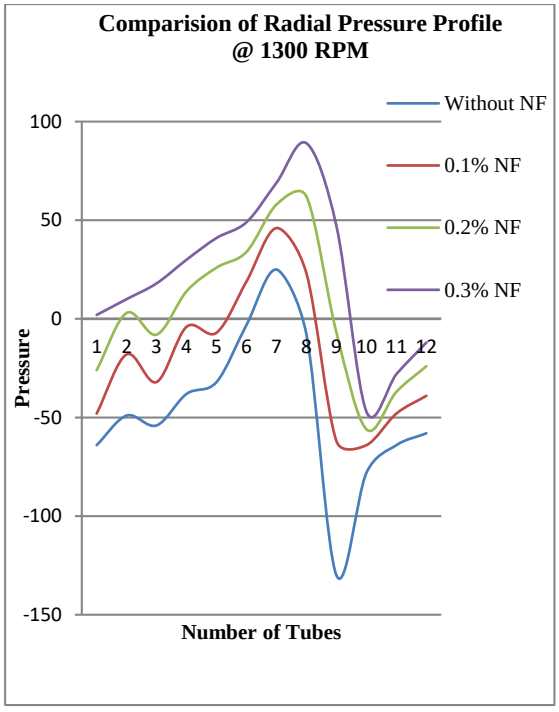
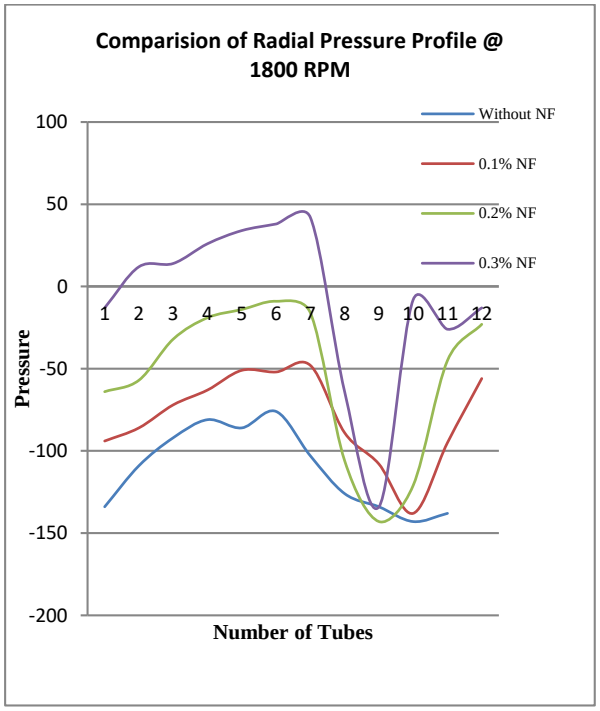


Fig1. Comparison of pressure profile for no load condition at 1370 rpm

Comparison of pressure profile for no load condition at 1800 rpm.

Now the bearing is being compared at the same loading condition but raising the speed of the shaft to 1800 rpm and the radial pressure profile of each bearing is being compared as shown in Figure 4.2.



Comparison of pressure profile with loading condition at 1300 rpm.

The bearing with different context texture and the bearing with no texture was compared with each other while running the shaft at 1300 rpm and subjected to load of 8kg.

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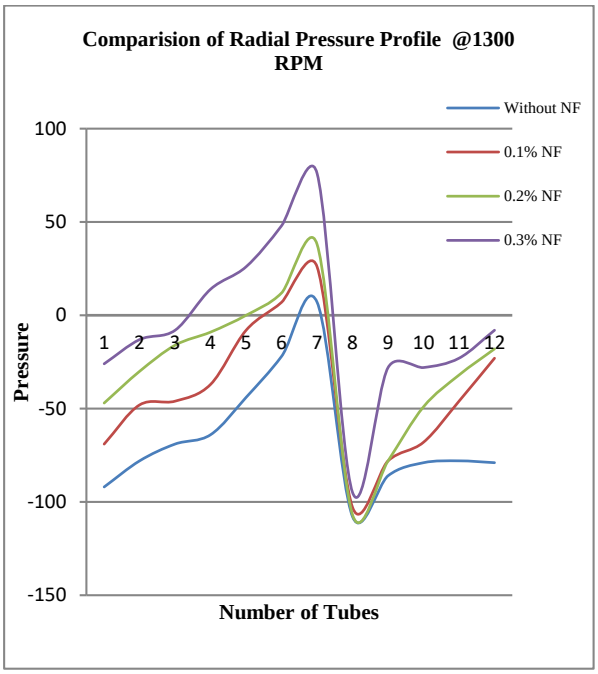
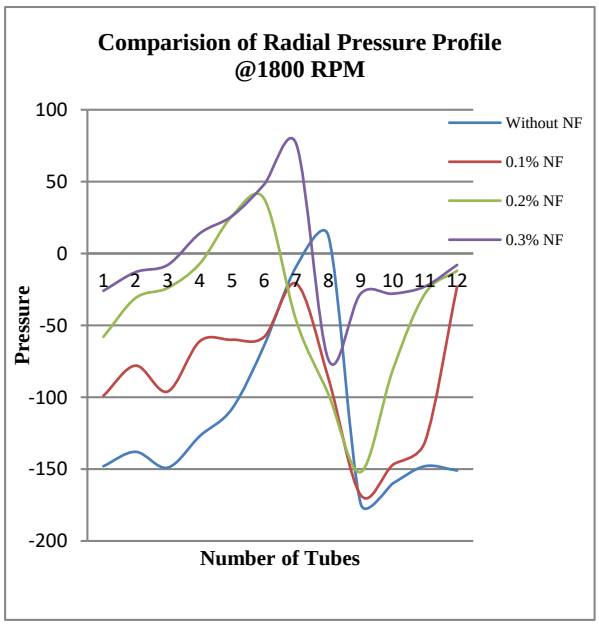


Comparison of pressure profile with loading conditions at 1890 rpm.

The bearings now compared with each other while running the shaft at 1800 rpm and subjected to a load of 7kg.



CONCLUSION

Experiment concludes that nano particles added lubricant affected the journal bearing performance. It is observed that pressure sustaining capacity of journal bearing increases more when nano particles are added to the oil than without such an addition.

- From graphs, it can be stated that nano particle added bearing can bear greater loads and it has the optimum pressure profile compared to a bearing with conventional (SAE 15W40) lubricant.
- As the load increases at constant speed, percentage of maximum pressure bearing capacity increases in nano particle journal bearing w.r.t general journal.
- It is concluded that influences of surface nano particle added lubricant are affected by speed variation.
- From the above readings for a specific application of greater or lesser loading condition, higher or lower speed levels, the optimum shaft perspective of nano particle added lubricant can be applied for a better performance of the Journal bearing and a larger lifespan.

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