Experimental Analysis of Pressure Distribution in Hydrodynamic Journal Bearing Under Sae40 Lubrication Oil With Nano Graphite Additives

Santhosh kumar. E.[1], Parimala murugaveni. S.[2].
[1] Dept of Mechanical Engineering
[2]Assistant professor, Dept of Mechanical Engineering
[1, 2] Government College of Technology, Coimbatore, Tamilnadu, India -641013.

Abstract- *The aim of this study is to analyse the pressure distribution on hydrodynamic journal bearing under SAE 40 lubricant oil with and without nano graphite additives for various loading conditions and various operating speeds. The gap between the journal and the bearing surface is filled with SAE40 lubricant oil. Journal bearing test rig (JBTR) is used to test the 50 mm diameter and 50 mm long bearing. Test bearing is loaded mechanically. At first the bearing is tested in JBTR under SAE40 oil of various load conditions such as 5N and 75N and speed ranges such as 250 rpm and 350 rpm and the pressure distribution results were observed and recorded. The SAE40 lubricant oil mixed with nano graphite at 1% weight composition were tested under the same operating conditions in the JBTR and the results are compared with the SAE40 base oil.*

Keywords- Pressure distribution, Hydrodynamic journal bearings, Nanolubrication, Nano graphite.

I. INTRODUCTION

Large rotating modern machineries uses oil lubricated hydrodynamic journal bearings because of its easy application, long life, low cost, high radial precession and silent operation. The usage of lubrication oil is completely depend upon the loading condition and operating speed of journal. Makoto Tomimoto determined the particle induced friction (friction caused by impurities in lubricant oil) between sliding surfaces [1]. Gy. Szota B. Kovács and F. J. Szabó have calculated the Optimized Gap Shapes and lubricant film shape between lubricated surface of sliding pairs by using the previously developed and published results of the various authors [2]. S.M.Alvesn, et.al, were studied that the Newtonian viscous lubricants blended with small amounts of long chained additives can improve operational characteristics of the lubricating condition. Addition of nano particles on lubricants enhances the viscosity as compound to that of oil without addition of nano particles [3]. Ma and Taylor studied the thermal effects in a plain journal bearing under steady loading condition [4]. Cem Sinanoglu, et.al, investigated the performance characteristics of journal bearings under various operating conditions and found that the narrowing oil wedge mechanism is the significant reason of formation of load supporting pressure area [5]. Prof. Dr.-Ing. Monika Ivantysynova, Dipl.-Ing. Rolf Lasaar has found that the importance of Gap Geometry Variations in Displacement Machines. The design of individual lubricating gaps between parts influences the energy dissipation of linear displacement systems, having relative motion between them [6]. A.D.Dongare, and Amit D.Kachare, studied the distribution of pressure on steel journals over hydrodynamic plain bearings at different speed, load, and working temperature by simulation and experimental approach. They used MATLAB programming to predict pressure distribution values by using neural network technique and compared with experimental outcomes [7]. Gethin investigated the thermal behaviour of different types journal bearings in high speed, low load application and determined the theoretical and the experimental results [8]. Mahesh Aher, et.al, experimented on the pressure distribution of lobe journal bearing and estimated that the stability of bearings can be increased by the use of lobe bearing. The comparative study was carried out for determining the load carrying capacity of plain and lobe bearing at different loading conditions and operating speeds. The results showed the higher stability of lobe bearing with good load carrying capacity [9]. The effects of change in specific heat and change in viscosity on maximum temperature, maximum pressure, load bearing capacity, and side leakage in journal bearing under high operational speeds were examined [10]. Chaitanya K Desai, et.al, analysed the distribution of pressure in hydrodynamic plain journal bearings at various operating parameters. The bearing is tested under different conditions like various lubricants, loading conditions and speeds and results compared with the theoretical outcomes and found satisfactory [11]. The effects of couple stress due to lubricant blended with additives were examined in the rough bearing surfaces [12]. Bekir Sadik Ünlü (2009,) were investigated tribological properties of reinforced aluminium alloy prepared by stir casting method and concluded that the hardness is increased with adding particle reinforcement. The surface roughness values decreased in particle reinforced bearings after wear test [13]. It was concluded that the couple stress effects can increase the film pressure of the oil lubricant, improve the load bearing capacity and reduce the friction parameter at high eccentricity ratio [14]. Bekir Sadik Ünlü, et.al have conducted the experiments on boron and ferrous based plain bearings. In this study boronizing process increasing wear resistance and Wear rate decreased in SAE lubricants. Wear surfaces of non boronized samples were found to be rough [15]. Film pressure, end leakage flow rate, load-carrying capacity, misalignment moment and frictional coefficient were studied for various conditions of misalignment degree and eccentricity ratio. It was found that there are changes in film pressure distribution, film thickness distribution and the misalignment moment when the misalignment takes place [16]. S. Baskar, et al, studied the pressure distribution on hydrodynamic bearing under various loading and operating conditions using different lubricants. The vegetable oils such as rapeseed oil and soya bean oil were tested in the JBTR and the results were compared with the SAE20W40 [17]. It was found that a two-component surface layer journals resulted in reduction in the weight carrying capacity for elevated eccentricity ratios. Velocity distributions in fluid flow in circumferential, radial and axial directions were observed. Effects of various operating conditions on the tribological properties of a zinc based hydrodynamic bearings were investigated [18]. S. Arumugam, et.al, experimented the vegetable oils instead of mineral based SAE lubricants. The rapeseed oil based bio-lubricant with low pour point was chemically modified using epoxidation and esterification process. Epoxidized rapeseed oil showed significant oxidative stability and frictional coefficients compared to base oil [19]. It was found that the bearings appear to have a smoother operation at higher rotation speeds and when tested at the same load, reduction of the speed resulted in higher friction and more wear of the bearings. Herringbone grooved journal bearings (HGJB) under thermal analysis showed that the temperature of the fluid film rises due to the frictional heat. hence, the viscosity of the fluid and the load bearing capacity decreases [20]. .M J Goodwin et.al, gave fluid film thickness measurements using capacitive transducers supported by a mechanical linkage. They used thermocouples for measuring temperature in the crank journals, via slip rings [21].

II. PRINCIPLE OF JOURNAL BEARING

In hydrodynamic lubrication, the load bearing contact surfaces of the bearing and the shaft are separated by a thick fluid film of lubricant, to prevent the metal with metal contact, and a stability obtained in bearing is due to the general laws of fluid mechanics. Hydrodynamic lubrication depends on availability of significant supply of lubrication rather than having an externally pressurized lubrication. The film pressure is generated by the hydrodynamic drag created by relatively moving surfaces is sufficient for pulling the lubricant into creating a wedge-shaped zone, with a velocity high enough to generate the pressure required to separate the contacting surfaces against the load direction on the journal bearing. In this region, heavy hydrodynamic forces are created within the fluid film and these forces when integrated over the total bearing surface will efficiently support the load acting on the bearing. If bearing conditions changes at an instance, the load may fluctuate, the eccentricity between the centre of the journal shaft and the bearing material changes, so that the increased pressure distribution is sufficient to counter the additional load and figure 1 illustrates the basic principles of hydrodynamic bearings. The bearing parameters are formed from characteristics such as the viscosity of lubricant and the applied load and operating speed of the bearing. Due to adhesion on surfaces of the journal and its resistance to flow, the lubricant is dragged by the angular displacement of the shaft. Hence forms the wedge-shaped thick fluid film between the journal shaft and bearing material is created. Figure 2, represents the fluid film formation inside the bearing.

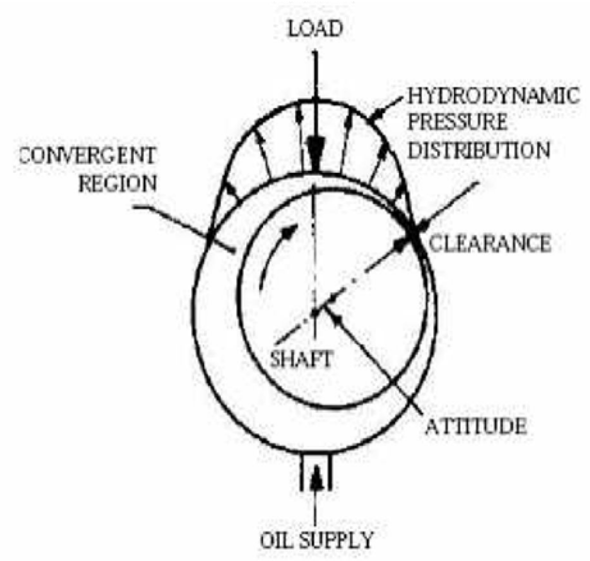

Fig.1. Pressure Distribution over Convergent Region

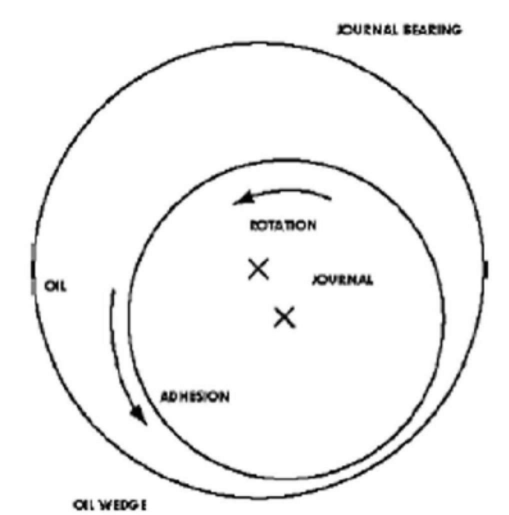

Fig. 2. Principle of Hydrodynamic journal bearing

III. EXPERIMENTAL ANALYSIS

3.1. Oil preparation

By using ball mill, the micro sized graphite particle of size 50 µm can be resized into nano sized particle of ranging approximately 100 nm. In the hexagonal structure of graphite, the bonds between the carbon atoms within a layer are strong chemical (covalent) bonds, so that the layers are strong and the crystals strongly resist bending or breaking of the layers. The bonds between the layers are weak (van der Waals) forces, so that the crystals can be made to split easily between layers, and the layers will slide readily one over the other. SAE40 lubrication oil is selected due to its high oxidation resistance and high velocity, which is suitable for high load and high speed machine components. The nanolubricant was prepared by adding graphite nanoparticle obtained from ball milling process in SAE 40 lubricant oil in a composition of 1% weight of nano graphite particles in base oil and by thoroughly mixing (severe hand stirring using a glass rod for 2 hours) graphite nanoparticles in SAE 40 base oil.

3.2. Experimental procedure

The pressure distribution of journal bearing is determined with help of Journal Bearing Test Rig (custom manufactured for academic purposes, shown in figure 3) in different lubricants under various loading condition. The JBTR equipment consists of a horizontally mounted steel shaft and driven by a variable speed motor. The speed of the shaft motor is controlled by the resistance regulator attached with AC power supply. The bearing surface is made of ZA27 (zinc aluminium alloy) and has 12 holes along the circumferential direction equally displaced by 30 degree angles. These holes are connected to manometers to measure the pressure heads in each holes. The lever arm fixed with bearing is used to apply radial load by dead weights and also has the counter weights to maintain the stability of bearing surface. The oil tank is placed at certain height to give the initial pressure inside the bearing. When the journal starts rotating, the lubricant forms a drag force which lifts the bearing surface away from the journal. Due to this a low pressure is created in the area of maximum radial clearance and a high pressure created in the area of minimum clearance. The oil level in the manometers will vary according to the pressure created inside the bearing. Using the pressure head values in the manometers the pressure distribution over the circumferential direction can be calculated by using the expression that the pressure at any point is given by the product of density of fluid, acceleration due to gravity and the pressure head value from manometer.


Fig.3. Journal bearing test rig

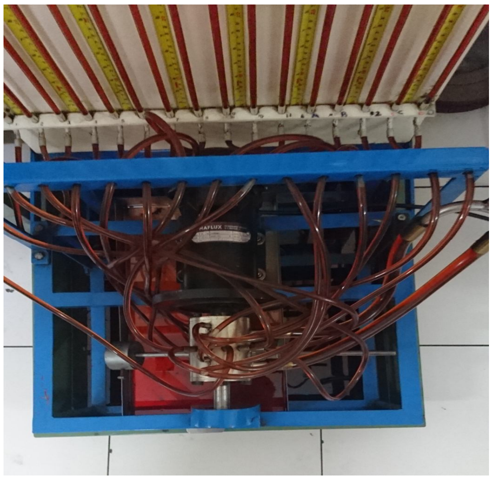
Fig.4. Journal and bearing setup

IV. RESULTS AND DISCUSSION

Investigations on the hydrodynamic journal bearing with various lubricants has carried out experimentally. The results obtained for a journal bearing with the following parameters are presented here: Journal material = ZA27: bearing material = steel: journal diameter = 50 mm; bearing length =50 mm; length and diameter ratio = 1.0; radial clearance = 0.25 mm; journal speed (N) = 250, 350 RPM load (W) = 4.9N and 9.8N. In figure 5 and 6, it shows that the maximum pressure in SAE40 oil at 250 and 350 rpm are 6819 N/m^2 and 6982 N/m^2 respectively. In nano graphite mixed SAE40 oil, the maximum pressure at 250 and 350 rpm are 6596 $N/m^2$and 6804 N/m^2 respectively.

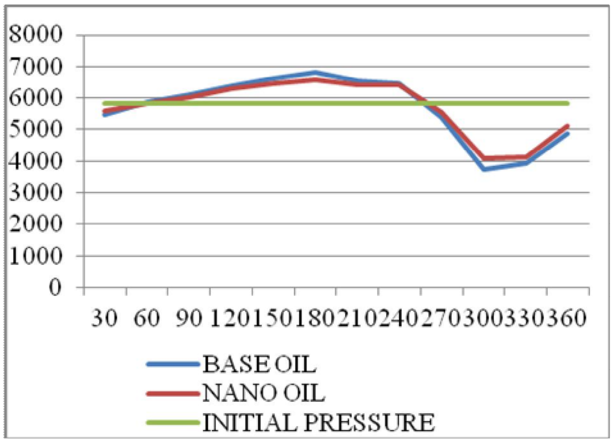

Fig.5. Pressure distribution at 4.9N and 250 rpm.

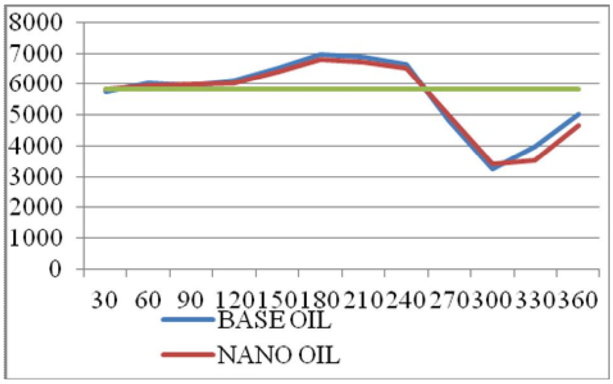

Fig.6. Pressure distribution at 9.8N and 350 rpm.

V. CONCLUSION

In this study the pressure distribution of the hydrodynamic journal bearing at various loading conditions, operating speed and under different lubricants. The study concludes that the maximum pressure under SAE40 lubricant oil mixed with nano graphite is reduced when compared to the SAE40 base oil lubrication. This is due to the increase in viscosity of oil by nano additives, which creates high hydrodynamic drag and increased load bearing capacity, thus results in less pressure developed on the bearing. The addition of nano graphite to SAE40 lubrication oil will give a smooth operation in high load and low speed applications.

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