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Study of Friction and Wear characteristics of ball bearing by Numerical and Experimental Techniques

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Abstract-Ball bearings are used to provide smooth, low friction motion in rotary applications. Ball bearings provide high performance and have a long lifetime in order to transfer the load from the balls to the inner races. The balls have minimal contact with the inner and outer races due to their spherical shape and this allows them to spin smoothly. A disadvantage of ball bearings is that the balls can become flattened over time with too much pressure on the outer races leading to eventual failure. Therefore it is very important that the load ratings and other parameters are monitored. The property of friction and wear is crucial in many areas of tribology, reason of friction and wear of ball bearing is its lubrication and application of load. Study of friction and wear characteristics of ball bearing considering various parameters such as Load, Speed, Temperature, and Time. The main aim of our project is to study friction and wear characteristics of ball bearing by using SEM (Scanning electron microscopy) and EDX (Energy Dispersive X-ray) analysis and also to determine coefficient of friction and wear rate to validate experimental results.

Index Terms- Ball bearings, Lubrication, Co-efficient of friction and wear.

1. INTRODUCTION

Friction and wear of bearings leads to failure of the component, it is important to study the friction and wear characteristics by varying parameters such as Load, Speed, Temperature and Time.

M.A. Fazal et al,(2013), [1] proposed that, the friction and wear characteristics of palm biodiesel at different concentration level by using four-ball tester. The investigation is done by biodiesel (B100), diesel (B0) and three different biodiesel blends such as B10, B20, B50. Tests are conducted at 75 C under a normal load of 40 kg for 1 h at four different speeds, 600, 900, 1200 and 1500 rpm. Worn surfaces of the balls are examined by SEM and worn surfaces of the steel balls demonstrate that deformation of the surface decreased with increasing biodiesel. Experimental results show that wear and friction decreased with the increase of biodiesel concentration.T. Kayaba,(1960) [2] considered that, to study the friction and wear mechanism of different material taking three kinds of tin base white metal and two kinds of aluminum based alloys. In testing, mild steel is taken as the test material against which the test specimens of different kinds are slid. The testing is done in dry and wet lubrication condition, in dry condition wear of tin base white metals increased with the load black wear particles were formed from the surface under light load as with the aluminum alloys no wear occurred. The experimental results shows that the friction and wear changes with the composition of the material at different speed and load.Hyunseok et al,(2015),[3] explained that, failure mechanisms of the ball bearings under lightly loaded and non-accelerated condition is due to deteriorate of grease at elevated temperature both physically and chemically, which decreases its lubricating ability and cause bearing failure. The study investigated a single row deep groove ball bearing; the axial and radial loads are applied. The test is carried by placing bearings on the shaft of the DC motor which rotates, accelerometer and acoustic emission transducer are placed on the metal brackets to get vibration and acoustic emission signals. The surface characterization analysis shows that the wear of the cage is the main cause of failure of the bearing and it is investigated that, if percentage of the grease is increased the life of the bearing increases.

2. METHODOLOGY

The proposed work will be carried out by conducting experiments using a four ball test rig and the following parameters are determined

- Coefficient of friction and wear rate by Four Ball Tester.
- Samples will be examined using SEM(scanning electron microscope) and EDX (Energy Dispersive X-ray) analysis
- Values obtained by experimental and numerical techniques will be compared

SAE 52100 Chrome steel balls are used in precision ball bearing applications, and are crafted to be very hard and have a high load capacity, similar material of balls are used in four ball tester to study the friction and wear characteristics.

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Lubricants used: Valvoline SAE 15W40, Gulf SAE 15W40, Gulfstar SAE 15W40.

Sample specification:

Material : AISI E-52100 alloy steel (SKF Ball bearing)

Grade : 25 EP

HRC : 64-66

Solvent used for cleaning: n- Heptane

3. EXPERIMENTAL WEAR RESULTS

Case (i): Coefficient of friction of ball bearings using Valvoline SAE 15W40

For the conduction of test on four ball tester the ASTM D 4172 conditions are followed, maintaining temperature 75℃ at speed of 1200 rpm and load 40kg for one hour. The experimental result of the ball bearings using Valvoline SAE 15W40 lubricant in the sliding condition is as shown in figure1.

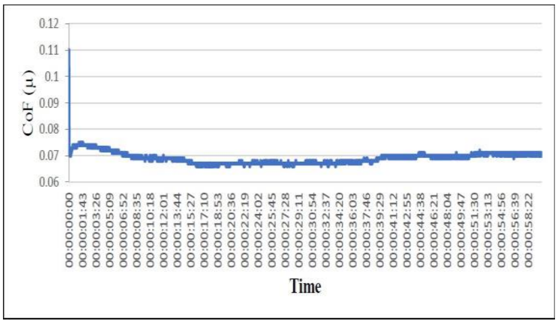


Fig.1. Coefficient of friction v/s time using Valvoline SAE 15W40

The graph is plotted coefficient of friction versus time, it is observed during the running in period at very beginning, the coefficient of friction has reached to 0.11 and sudden decrease in the value to 0.07, coefficient of friction is unstable with respect to time till 15 minute, this is due to high asperities have knocked off after it maintains the stable condition, it is observed that maximum temperature attained from 75℃ to 89℃ that is due to direct metal to metal contact when the lubricant gets squeezed out, the average coefficient of friction value is 0.069.

Case (ii): Coefficient of friction of ball bearings using Gulf SAE 15W40

The experimental result of the ball bearings using Gulf SAE 15W40 lubricant in the sliding condition is as shown in the figure 2.

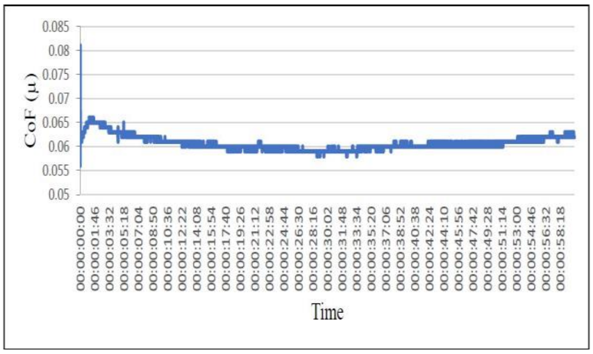


Fig.2. Coefficient of friction v/s time using Gulf SAE 15W40

The graph is plotted coefficient of friction versus time, it is observed during the running in period at very beginning, the coefficient of friction has reached to 0.08 and sudden decrease in the value, coefficient of friction is unstable with respect to time till 11 minute, this is due to high asperities have knocked off after it maintains the stable condition, again there is increase in coefficient of friction from 50 minutes and it increases to 0.063, it is observed that the there is no increase in temperature that indicates that there is no metal to metal contact in the presence of lubricant and lubricant film has not squeezed out. The average coefficient of friction value is 0.0694.

Case (iii): Coefficient of friction of ball bearings using Gulfstar SAE 15W40

The experimental result of the ball bearings using Gulfstar SAE 15W40 lubricant in the sliding condition is as shown in the figure 3.

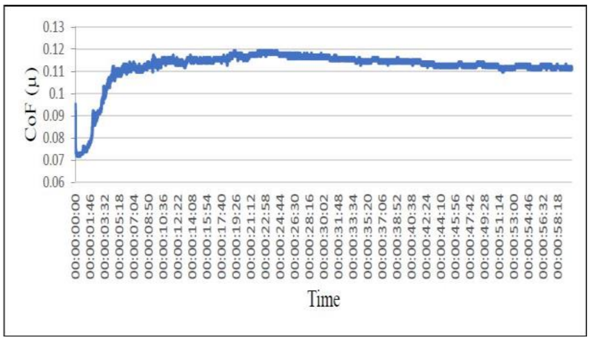


Fig.3. Coefficient of friction v/s time using Gulfstar SAE 15W40

The graph is plotted coefficient of friction versus time, it is observed during the running in period at very beginning, the coefficient of friction has reached to 0.095 and sudden decrease in the value to 0.07. Coefficient of friction is unstable with respect to time till 5 minute, this is due to high asperities have knocked off after it maintains the stable condition, again there is increase in coefficient of friction up to 0.11 and then gradual decrease, it is observed that there is increase in temperature that indicates, metal to metal contact in the presence of lubricant and lubricant film has squeezed out. The average coefficient of friction value is 0.112.

Comparison of Coefficient of friction:

Case (i): lubricated by engine oils

In the figure 4 it is clear that the running in period of the ball bearings using Valvoline and Gulf oil is less compared to that of Gulfstar, coefficient of friction value by using gulf, Valvoline and gulfstar is 0.065, 0.075 and 0.12 whereas running in period of ball bearings using the gulfstar oil is more.
It is observed that the worn surfaces of the ball bearings got dark in color at the point of contact even the lubricant got black in color. It is clear that from the above results and observation, selection of lubricant is also an important aspect as selection of materials.

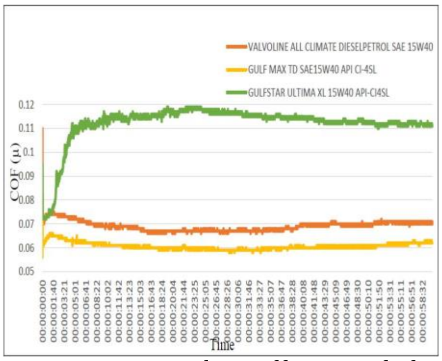


Fig.4.Comparison of Coefficient of friction using Engine oil

4. COMPARISON OF MEAN WEAR SCAR DIAMETER RESULTS BY USING ENGINE OILS

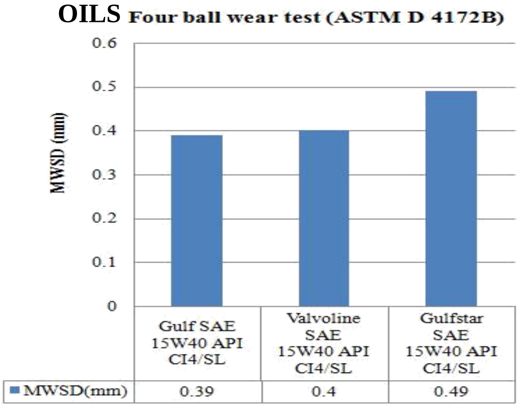
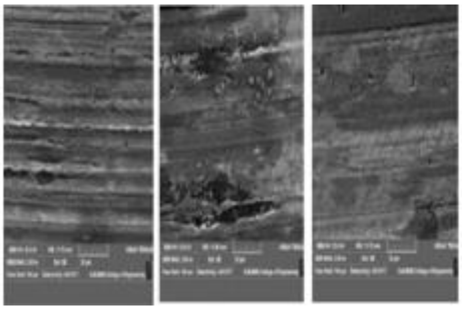


Fig.5. MWSD using Engine oils

Scanning Electron Microscopy results

Case (i) SEM micrographs of worn surfaces lubricated by Engine oils



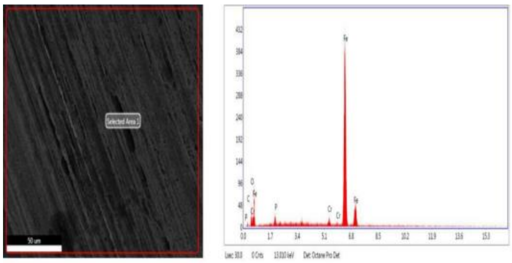
(a) (b) (c)

Fig. 6 SEM micrographs of worn surfaces lubricated by Gear oils

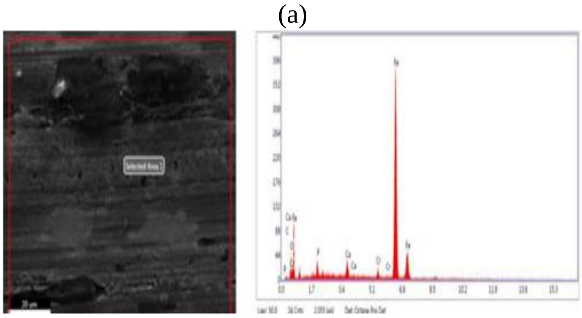
The figure 6 (a) shows SEM micrographs at 2000X resolution at center. In Figure 8 (a) there are wedges and pits parallel to the direction of sliding, surface morphology shows that the worn metal surface exhibit the surface striation in the direction of sliding that are formed in the adhesive and erosive condition, the surface is rough and dark in color due to the effect of temperature on the ball bearings. The surface damage is greater than 20µm for all lubricants indicates the adhesive wear; particles are generated as direct consequence of loading causing pitting and wedges on the surface.In figure 6 (b) it is clear that the depth of ploughing and pits is more, that is due to mechanism of slight abrasive wear in the direction of sliding indicates the greater amount of wear, few small wear debris with a particle like shape is seen on the worn surface. Interface temperature produced at asperity contacts during sliding of metallic pairs under nominally lubricated conditions results in the tribological oxidative wear under conditions of oxidative boundary lubrication that is seen in the form of dark spot of the worn surfaces. At low temperature oxidation occurs at asperity contacts from frictional heating, at higher ambient temperature, general oxidation of entire surface occurs and affects wear.
In figure 6 (c) small pits are observed that is due to mechanism of abrasive wear in the direction of sliding, at interface temperature the oxidative wear results asperity contact during sliding of metallic pair under lubricated conditions.

Electron Dispersive X- ray Analysis

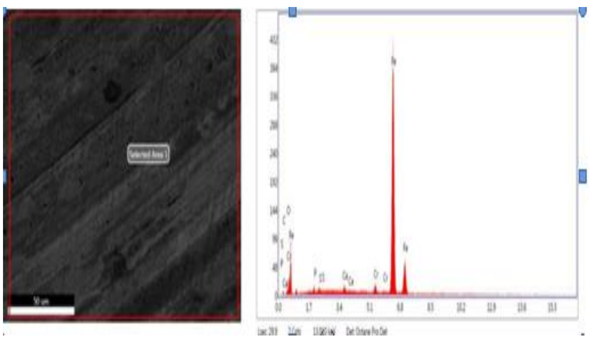
Case (i) EDX of worn surface lubricated by Engine oils



(a)



(b)



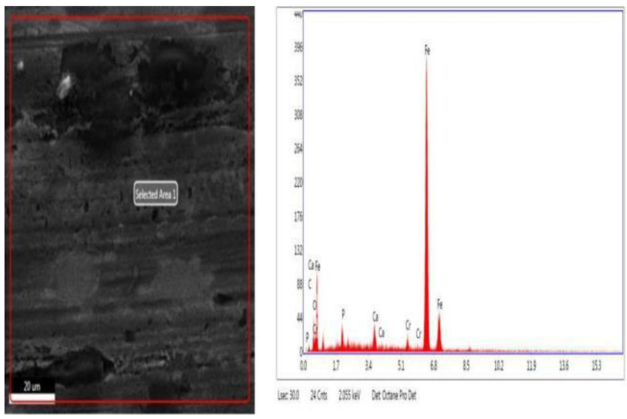
(c)

Fig. 7. EDX of worn surface lubricated by engine oil

The Energy Dispersive X-ray spectroscopies of the worn surfaces are shown in Figure 9. Particular area is selected for analysis and the graph is obtained, Count v/s Energy. In Figure 7 (a), (b) and (c) at 384,396 and 432 no. of counts Fe peak is highest, indicates the amount of Fe at 13.010 kev of energy. Very small peaks of chromium, carbon, oxygen, and phosphorous are seen. The EDX results of elemental content in weight % of worn surfaces lubricated by different engine oil is tabulated in Table 1.

(15W40)	**Fe**	**Cr**	**P**	**O**	**C**	**Ca**
Gulfstar	85.68	1.61	1.56	5.24	5.62	0.21
Valvoline	83.45	1.46	2.15	6.01	4.28	2.65
Gulf	90.42	1.63	0.46	2.93	3.29	0.99

Table. 1 EDX result of elemental content in weight% lubricated by engine oil



5. CONCLUSION

For Valvoline SAE 15W40 Engine oil it is observed that during the running in period at very beginning, the coefficient of friction has reached to 0.11 and sudden decrease in the value to 0.07. The coefficient of friction is unstable with respect to time till 15 minute; this is due to high asperities which have knocked off after it maintains the stable condition. It is observed that maximum temperature attained from 75°C to 89°C that is due to direct metal to metal contact when the lubricant gets squeezed out, the average coefficient of friction value is 0.069 is achieved.For Gulf SAE 15W40 API CI4/SL that the graph is plotted coefficient of friction versus time, it is observed during the running in period at very beginning, the coefficient of friction has reached to 0.08 and sudden decrease in the value, coefficient of friction is unstable with respect to time till 11 minute, this is due to high asperities have knocked off after it maintains the stable condition, again there is increase in coefficient of friction from 50 minutes and it increases to 0.063, it is observed that the there is no increase in temperature that indicates that there is no metal to metal contact in the presence of lubricant and lubricant film has not squeezed out. The average coefficient of friction value is 0.0694 For Gulf star SAE 15W40 API CI4/SL that the graph is plotted coefficient of friction versus time, it is observed during the running in period at very beginning, the coefficient of friction has reached to 0.095 and sudden decrease in the value to 0.07. Coefficient of friction is unstable with respect to time till 5 minute, this is due to high asperities have knocked off after it maintains the stable condition, again there is increase in coefficient of friction up to 0.11 and then gradual decrease, it is observed that there is increase in temperature that indicates, metal to metal contact in the presence of lubricant and lubricant film has squeezed out. The average coefficient of friction value is 0.112.On observing the wear Scar on ball bearings it is attributed that on using Gulf star ultima XL SAE 15W40 API CI-4/SL has higher wear than Valvoline all climate Diesel/petrol SAE 15W40 API CI-4/SL and Gulf SAE 15W40 API CI4/SLThe SEM micrographs at 2000X resolution at center, is seen and is observed that there are wedges and pits parallel to the direction of sliding, surface morphology shows that the worn metal surface exhibit the surface striation in the direction of sliding that are formed in the adhesive and erosive condition, the surface is rough and dark in color due to the effect of temperature on the ball bearings. The surface damage is greater than 20μm for all lubricants indicates the adhesive wear; particles are generated as direct consequence of loading causing pitting and wedges on the surface.In figure 6 (b) it is clear that the depth of ploughing and pits is more, that is due to mechanism of slight abrasive wear in the direction of sliding indicates the greater amount of wear, few small wear debris with a particle like shape is seen on the worn surface. Interface temperature produced at asperity contacts during sliding of metallic pairs under nominally lubricated conditions results in the tribological oxidative wear under conditions of oxidative boundary lubrication that is seen in the form of dark spot of the worn surfaces. At low temperature oxidation occurs at asperity contacts from frictional heating, at higher ambient temperature, general oxidation of entire surface occurs and affects wear.

In figure 6 (c) small pits are observed that is due to mechanism of abrasive wear in the direction of sliding, at interface temperature the oxidative wear results asperity contact during sliding of metallic pair under lubricated conditions.The Energy Dispersive X-ray spectroscopy of the worn out surfaces is shown in Figure 7. Particular area is selected for analysis and the graph is obtained, Count v/s Energy. In Figure 7 (a), (b) and (c) at 384,396 and 432 no. of counts Fe peak is highest, indicates the amount of Fe at 13.010 kev of energy. Very small peaks of chromium, carbon, oxygen, and phosphorous are seen. The EDX results of elemental content in weight % of worn surfaces lubricated by different engine oil is tabulated in Table 1.

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