Friction and Wear Behaviour Analysis of Different Journal Bearing Materials

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ABSTRACT

It is well known fact that connecting rod is the important intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. Existing Bearing of connecting rod is manufactured by using non ferrous materials like Gunmetal, Phosphor Bronze etc.. This paper describes the tribological behavior analysis for the conventional materials i.e. Brass and Gunmetal as well as New non metallic material Cast Nylon. Friction and Wear are the most important parameters to decide the performance of any bearing. In this paper attempt is made to check major tribological parameters for three material and try to suggest better new material compared to conventional existing material. It could help us to minimize the problem of handling materials like Lead , Tin, Zinc etc.After Test on wear machine we found that Cast Nylon compared to Brass and Gunmetal for the same operating and lubricating condition, have less value of coefficient of friction which help us to minimize power lost due to friction and assist in increasing overall engine efficiency of the engine.

KEY WORDS: Tribology, Friction, Wear, Cast Nylon, Artificial cooling, engine efficiency

I. INTRODUCTION

Friction and wear always occur at machine parts which run together. This affects the efficiency of machines negatively. Today, many industrial applications use vacuum conditions. Therefore, it became essential to determine the tribological behavior of the machine components running under these conditions. In this paper, friction and wear behavior of BRONZE and BRASS alloy which is used commonly in the industry as a bearing material. Nowadays, especially with the growth of the plastics industry and the development of high-strength fibers, vast range combinations of materials are available for use in engineering fields. To take the advantages of new material developed, in this paper attempt is made to offer Cast Nylon 6 as the non metallic material in place of conventional material.

Journal bearing materials are expected to have several properties such as low friction coefficient, high load capacity, high heat conductivity, compatibility, high wear and corrosion resistance. These properties directly affect the fatigue and wear life of the bearing [1].

There are several theories which were found to explain the phenomenon of adhesion wear, and from that the simple adhesion wear theory. The adhesive wear occurs when two surfaces are moving relatively one over the other, and this relative movement is in one direction or a successive movement under the effect of the load so that the pressure on the adjacent projections is big enough to make a load plastic deformation and adhesion. This adhesion will be at a high grade of efficiency and capability in relative to the clean surfaces, and adhesion will take place between a number of these projections whose sizes will be bigger and the area will be increased during movement [2].

Wear resistance is one of the most important properties that journal bearings should possess. Several studies and investigations have been made in order to improve the wear resistance. The researchers investigate friction and wear behavior of materials because of the adverse effect observed in the performance and life of machinery components. Much of the research reported in the literature was carried out under the atmospheric conditions. However, some tribological behaviors have been recently investigated under the vacuum conditions. Especially, as a result of some new developments in aeronautic, space, electronic, material, metallurgy, chemistry, coating and manufacturing industrial areas necessitate the machinery components to be investigated under the different conditions. Therefore there is great interest among the researcher to estimate to the effect of the loads and speeds on the material's friction and wear behavior.

In the recent years studying the metallurgy science gave to humanity an ever growing range of useful alloys. Whilst many of these alloys are put to purposes of destruction, we must not forget that others have contributed to the material progress of mankind and to his domestic comfort. This understanding of the materials resources and nature enable the engineers to select the most appropriate materials and to use them with greatest efficiency in minimum quantities whilst causing minimum pollution in their extraction, refinement and manufacture.

In the past few years, wood, iron and skin have been used as journal bearing materials. Later, brass, bronze and white metal have also found some applications. Currently, in addition to these bearing materials, aluminum and zinc based materials are used as journal bearing materials. With technological improvements, self-lubricated sintered bearings and plastic materials are used where continuous lubricating is impossible. Therefore, it is essential that the bearing material be chosen depending upon area of application. Wear resistance is one of the most important properties that journal bearings should possess. Copper based materials are widely used as bearing materials because they have high thermal and electrical conductivity, self-lubrication property, good corrosion and wear resistance [3].The effect of tin on wear in copper based materials is important. Copper based tin bronzes are used as bearing materials to have a high wear resistance [4]. Friction and wear properties of these materials can be improved by adding tin [5] Tin bronze (90% Cu and 10% Sn) is the most suitable bearing material under corrosive conditions, at high temperatures and high loads.

Lead and tin based white metal alloys are used due to their antifriction property as bearing materials. These alloys are produced by casting and spray deposition method. These casting alloys contain inter metallic phase. The process variables during spray forming of Babbitt bearing metal alloy strongly influence the microstructure and porosity of the spray deposits. The wear rate of the spray-formed alloy is lower than that of the as-cast alloy. Wear properties of the spray-formed alloy are attributed to the decreased inter metallic phases and modification in the microstructure of the eutectic phases [6]. SnPbCuSb (white metal) alloys are important due to non-seizure and good wear resistance as journal bearing material [7].

Wear and wear mechanisms depend on a lot of factors at journal bearings. These factors and their effects can be examined in a tribological system. These factors include base friction element, opposite friction element, interim matter, ecology, loading and movement [8]. Of these wear mechanisms, adhesion wear is affected by pressure and velocity concerning load and movement. This p.v. value (load capacity) is important for wear analysis. If bearings are used appropriately on p.v. values, wear quantity can be decreased [9].

There are non – metallic materials that do not exist in nature, although they are manufactured from natural substances such as oil, coal and clay. They combine good corrosion resistance with ease of manufacture by molding to shape and relatively low cost. Synthetic adhesives are also being used for the joining of metallic.

Journal bearing materials are expected to have several properties such as low friction coefficient, high load capacity, high heat conductivity, compatibility, high wear and corrosion resistance. These properties directly affect the fatigue and wear life [10,11–12]. Wear and wear mechanisms depend on a lot of factors at journal bearings. These factors and their effects can be examined in a tribological system. These factor include base friction element, opposite friction element, interim matter, ecology, loading and movement [13]. Of these wear mechanisms, adhesion wear is affected by pressure and velocity concerning load and movement. This p.v. value (load capacity) is important for wear analysis. If bearings are used appropriately on p.v. values, wear quantity can be decreased [14].

Natural cast nylon has the ability to operate effectively without the need for lubricants and has an increased resistance to wear of over 5 times that for plain bearings manufactured from non-ferrous metals. As is the case with virtually all nylons it is easy to machine, pleasant to work with and relatively light weight - one eighth that of brass - making the handling and fitting of large components manufactured in cast nylon a relatively easy matter.[15]

Wear Theories:

The adhesive wear occurs when two surfaces are moving relatively one over the other, and this relative movement is in one direction or a successive movement under the effect of the load so that the pressure on the adjacent projections is big enough to make a load plastic deformation and adhesion. This adhesion will be at a high grade of efficiency and capability in relative to the clean surfaces, and adhesion will take place between a number of these projections whose sizes will be bigger and the area will be increased during movement [16] .

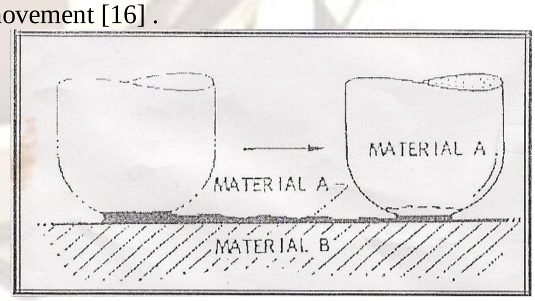

Fig.1 The mechanism illustration of adhesion wear

This adhesion wear is proportional directly to the load applied and the sliding distance and indirectly with the hardness of the metal. The adhesion wear is one of the most prevailing wears, it forms 15% of the industrial wear [17] , which happens when the surfaces are sliding one over the other, so that the pressure between the adjacent projections is enough to produce some local formation adhesion and plastic [16]. The mechanism of the formation of the adhesion wear could be explained as follows:

Every surface, however, smoothly appears, it will be rough in the microscopic scale and contains a range of tops and lows, and when two surfaces meet then this contact takes place at these projections which are little and relatively isolated; thus when applying a load on these surfaces, then locally there will be a high pressure and heat which will cause overtaking the elastic limits of one surface or both surfaces and the deformation of the projections in a plastic way, so that, the real contacting areas are increased to a limit to support the applied load. The contacting areas are inclined to be damaged under the effect of the relative movements between the two surfaces. The weariness occurs usually at one surface, because of the resistance of the in between surface to breaking and weariness due to the reaction of strain hardness during the adhesion of projections [18]. The removed substance (due to the shearing of projections) will take the shape of small foils which is usually transferred to the opposite surface or it is found separately between the two surfaces. The improvement of wear and corrosion resistance of RPS Ti-TiN coating by mean of thermal oxidation, and they found that the wear and its rate will be less in the specimens which were painted and oxidized and this will increase in the metals already coated without its oxidization also with the chemical corrosion[19]. In the current research the effect of loads, sliding speeds and times on the wear rate for three different materials were investigated.

The modeling of friction and wear is an important engineering problem. In the process of design of machine elements and tools operating in contact conditions, engineers need to know areas of contact, contact stresses, and they need to predict wear of rubbing elements. Friction, wear and contact problems are subjects of numerous experimental and theoretical studies. The very complex nature of tribological phenomena is a reason that many problems of contact mechanics are still not solved. The modeling of friction and wear can be carried out not only with the aid of laboratory tests but using also mathematical models and computer simulations. Due to computer simulation techniques, physical and mechanical phenomena in real objects can be reconstructed with a high degree of precision [20].

II. EXPERIMENT SETUP AND PROCEDURE

In this study, the bearing materials like BRONZE, BRASS, and CAST NYLON 6 which are widely used in industry were investigated in order to see the possible effects of wear and friction. The Copper, Brass and Cast Nylon were purchased from the market to prepare a test sample. The diameter and the length of the pins were 10 mm and 30 mm respectively. Before the experiments, the top surfaces of each pins were finished with CC-1500 abrasive paper so that they had the same surface conditions with the abrasive disk surface (surface roughness 0,35μm).The all three pins are shown in the figure–2.In the figure first pin is made from Gun metal. Second is made from Cast Nylon and last is made from the Brass.

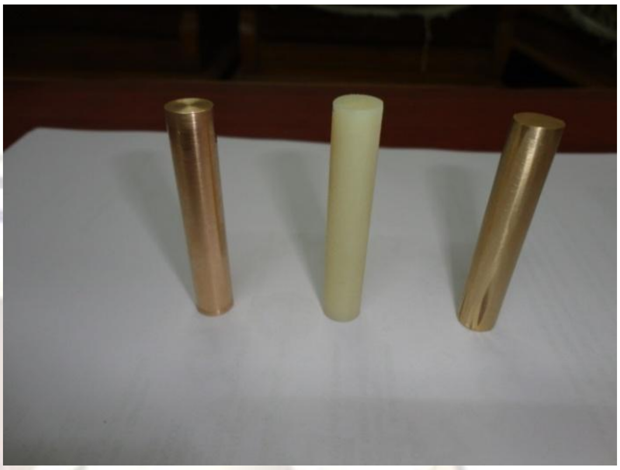

Figure – 2 Three different investigated pins

Experimental Setup:

The rate of wear will be relatively small in most of the machinery and engineering tool, and mostly the value of the change in dimensions is only few microns every year , and for measuring wear they are using some apparatuses and instruments which give results about the rate of wear happening in the tools and machinery.

OBJECTIVES OF EXPERIMENTS:

1. To Study the wear behavior of the selected materials and the effect of various speeds, loads and time on wear.
2. To study the relationship between coefficient of friction, frictional force, speed and load.
3. To find the effect of lubricant on wear rate and coefficient of friction.

Figure 3A Experimental complete setup

Figure 3B Top view of wear test

Table 1: Specification of pin-on Disc friction and Wear Monitor TR-20

Make	Ducom Ltd., Bangalore, India
Pin Diameter Range	Φ3mm to 12mm
Disc Size	Φ160mm × 8mm thick
Wear Track Diameter	Φ5mm to150mm
Sliding speed Range	0.25 to 12 m/s
Disc Rotation Speed	100-3000RPM
Drive	1.1KW DC motor, Constant Torque
Motor Controller	Thyrister converter, with full motor protection
Frictional Force	0-250 N, Digital readout with recorder output
Normal Load	0 to250N
Disc Material	EN-31 with hardness 60 HRC and Ra 0.3.
Wear Measurement Range	±2 mm, Digital readout with recorder
Power	230V, 15A, 1phase, 50Hz AC

As mentioned earlier materials were procured from the market and sample of 100 mm. dia. And 25 mm. long pins were prepared for each type of materials. Three different materials (Brass, Bronze and Cast Nylon) are selected. The material properties are shown in Table(2).Readings were recorded on every 10 seconds and time span for each set up was 90 minutes. In this study, friction coefficient, temperature values and wear losses of bearing samples are determined by wearing on radial journal bearing wear test rig.(Figure 3A and 3B). All three materials were tested with the identical lubricating condition i.e. during the test SAE40 oils were utilized.

Table: 2 Mechanical and Physical properties of Bearing Materials

Materials	Density Kg/m^3	Poisson Ratio	Young's Modulus MPa	Co-efficient of Thermal expansion	Thermal Conductivity	Remarks
Cast Nylon	1150	0.39	32800	9.555-05 /C or /K	24.8 W/m-K	Cast Nylon6 Commercial Name
Gunmetal	8719	0.33	95100	1.883e-05 /C or /K	74.8 W/m-K	CuPb5Sn5Zn5 C83600
Brass	8490	0.31	112000	1.900e-05 /C or /K	115 W/m-K	CuZn33Pb2Si C36000

III. RESULT AND DISCUSSION

The tests on the adhesion wear has been done on three different material specimens and its average values are given in Table(3).With the help of software and arrangement made in the wear equipment made by Ducom,It was possible to record reading on every 10 seconds and for the 60 Minutes testduration 360 readings were recorded for the Wear, Temperature and Coefficient of friction.

Table(3).A

Material : Gun Metal Duration 60 Minutes Oil : SAE40

Sr.	Load N	Speeds rpm	Coeff. Of friction	Temperature Centigrade	Wear (Micron)	Remarks
1	30	650	0.175503054	34.65091159	0.17550305	Average
2	50	850	0.017179584	40.25482415	0.03805515	Average
3	70	1000	0.081318852	41.13854613	0.08131885	Average

Table(3).B

Material : Nylon Duration 60 Minutes Oil : SAE40

Sr.	Load N	Speeds rpm	Coeff. Of friction	Temperature Centigrade	Wear (Micron)	Remarks
1	30	650	0.048303300	33.05381529	0.04830330	Average
2	50	850	0.064944286	39.53770003	0.02886508	Average
3	70	1000	0.028865088	40.16087564	0.02886508	Average

Table(3).C
Material : Brass Duration 60 Minutes Oil : SAE40

Sr.	Load N	Speeds rpm	Coeff. Of friction	Temperature Centigrade	Wear (Micron)	Remarks
1	30	650	0.259627300	37.56219655	0.259701089	Average
2	50	850	0.034753453	41.44805233	0.067622157	Average
3	70	1000	0.126244546	42.47527455	0.126244546	Average

The entire testing was divided in three phases. The details of all three phases are mentioned below:
First Phase : 650 rpm , load 30 N and duration 60 minutes
Second Phase : 850 rpm , load 50 N and duration 60 minutes
Third phase :1000 rpm , load 70 N and duration 60 minutes
The graphical representation of the test results are displayed on figure 4 & 5 below.

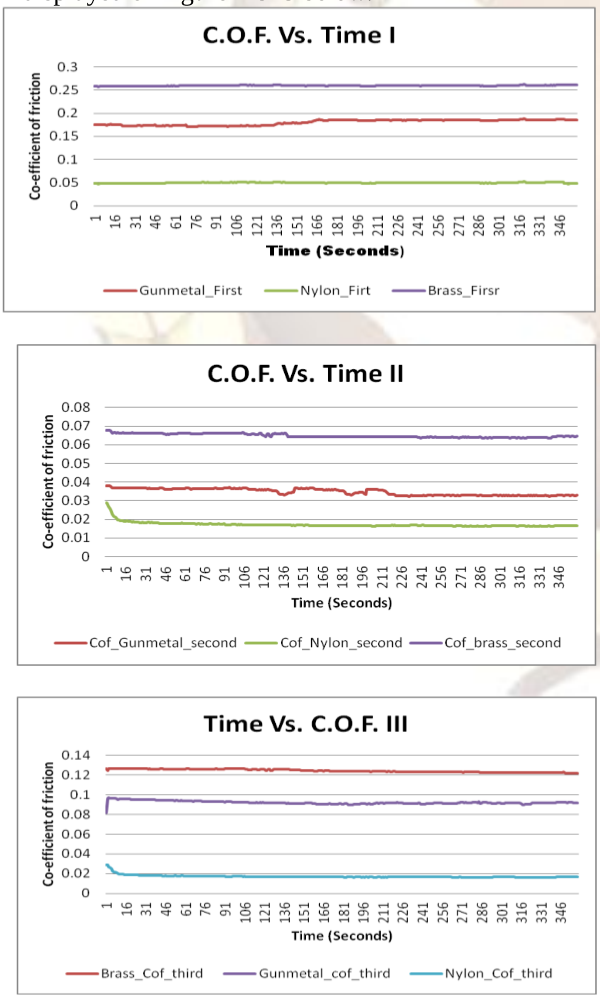

Figure : 4 (I, II and III phase graphs COF Vs. Time)

From the above figure 4 it is quite evident that the co-efficient of friction is very low of Cast Nylon compared to Brass and Gunmetal. In first phase keeping rpm 650 and load 30 N, the C.O.F.(Co-efficient of friction) of Brass is approximately Five times more compared to Cast Nylon. Also the COF of Gun metal is nearly three times more than Cast Nylon. Remaining two images of figure 4 revealed the same facts i.e. the COF of Cast Nylon is quite low with respect to Brass and Gunmetal.

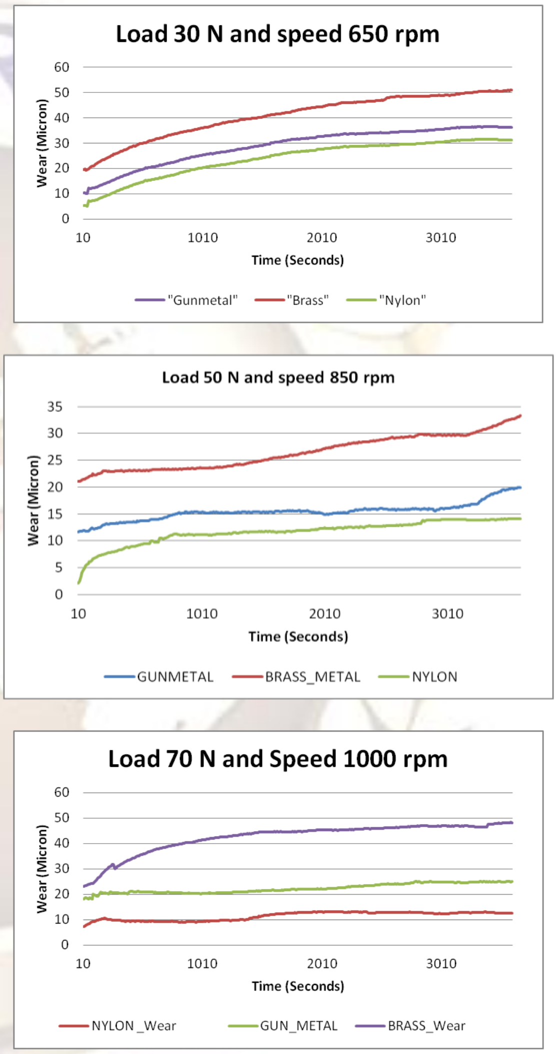

Figure : 5 (I, II and III phase graphs Wear Vs. Time)

From the above figure 5 it is quite clear that the Wear rate of material keeping same Lubricating condition i.e. SAE30 oil ,it is observed in first phase lowest wear rate for the Cast Nylon (31.55364886 Micron) and highest wear rate for same speed and load is for the Brass (50.92923749 Micron).This fact is applied in other two case of phase II and III of figure 5. Compared to other non ferrous material in general Brass is little bit hard material and therefore its wear rate is higher compared to other.

IV. CONCLUSION

The basic intention of the test carried out on the Wear Test Rig for the Brass, Gun metal and New material named Cast Nylon was to check existing materials and new material tribological behavior. While analyzing the available data it is found that the Cast Nylon is lighter in weight and heaving low co-efficient of friction and good wear and chemical resistance. At present Brass and Gun Metal both are utilized for the manufacturing of Bush Bearing of small end connecting rod. Both metals are quite heavy compared to Cast Nylon(Table 2).If we can replace existing material by lighter weight material like Cast Nylon, the overall engine performance can be improved. We know that the power lost due to friction can be find out by using equation (P=μVW).

(1) At highest speeds i.e. 1000 rpm,,referring Table 3 the coefficient of friction of Gun Metal is Four Times higher and Coefficient of friction of Brass is Six times more compared to Cast Nylon coefficient of friction at 1000 rpm.Here we have taken same lubricating oil SAE 30 for all three materials. Hence if we replace conventional Bushing of small end connecting rod by new material Cast Nylon and we can reduce power lost due to friction and increased over all efficiency of the engine.

(2) There are two different load sources in an engine; inertia and combustion. These two load source cause both bending and torsional load on the crankshaft and connecting rod. Because of its low density , nearly 1/7 th times compare to Brass and Gun Metal, Cast Nylon required to handle less inertia force.

(3) At 1000 rpm and 70 Newton load, the temperature induced is 42.47 ^{0}C in Brass, Gunmetal 41.12 ^{0}CC and Cast Nylon 40.16 ^{0}C. Because of less temperature for Cast Nylon, the requirement of artificial cooling would be reduced and it would increase bearing life.

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