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Wear Behavior Investigations of Journal Bearing of an I.C. Engine Small End Connecting Rod for Brass, Gunmetal & Cast Nylon

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Abstract

In this study the wear behavior of brass, gun metal and Cast Nylon based Bushing bearing in wet conditions at a speed of 900 rpm . The wear test of these bearing was performed in new wear testing machine. The wear test were carried out under different loads like 10N, 20N, 30N and fixed speed of the motor at 900 rpm. The Lubricant used for the test is SAE#) and it is used for all test. The wear characteristics were determined with respect to load, shaft speed and time. The main objective of the study is to evaluate the wear rate of different journal bearings at different loading conditions. The main objective of this experimental study was to checked and compares conventional bearing materials with respect to new bearing material name Cast Nylon. It was found that because of co-efficient of friction, the power loss due to friction was five times in Brass and 2.5 Times in Gun Metal compare to Cast Nylon, comparing at the same speed, load and lubricant. Even density of the Brass and Gun Metal is approximately seven times heavier than the Cast Nylon. Therefore, we can replace conventional bearing made either from the Brass or Gunmetal by the new material name Cast Nylon and improve the performance of the engine bearing by way of reducing power loss and less induced temperature due to lower value of co-efficient of friction.

Keywords: Wear rate, Journal bearings, co-efficient of friction, power loss, engine performance, Weight loss.

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

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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 mechanism is shown in the FIGURE 1 and 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] .

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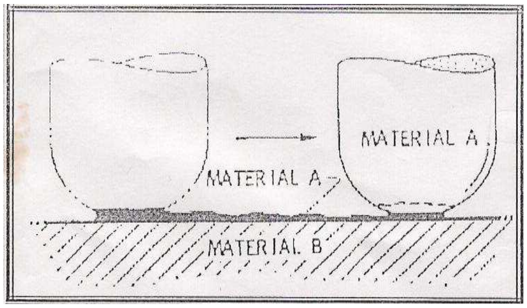

FIGURE-1 The mechanism illustration of adhesion wear

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].Bearings materials are generally selected from the materials which has lower wear strength compare to the shaft material, thereby lowering the wearing of the shaft significantly. Now a days to meet the industry requirement and taking the advantage of technology, if we replaced Brass and Gun Metal sliding component by the Cast Nylon, we find that the Co-efficient of friction at 1000 rpm of Gun Metal is Four times and the co-efficient of friction of Brass is Six times higher compared to Cast Nylon [21].

Experiment Setup And Procedure

In this study, the connecting rod's small end Bush bearing made from the materials like BRONZE, BRASS, and CAST NYLON 6 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 dimension of the Bushing were 32 mm. inside diameter and 38 mm outside diameter , length were 48 mm..In the middle of the length there was a 8 mm diameter hole for the lubrication purpose. Before the experiments, the inside surface of each bushings were finished with CC-1500 abrasive paper so that they had the same surface conditions . The all three Bushings are shown in the FIGURE–2.In the FIGURE first Bushing is made from Gun metal. Second is made from Cast Nylon and last is made from the Brass.


FIGURE – 2 Three different investigated Bushings

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 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.

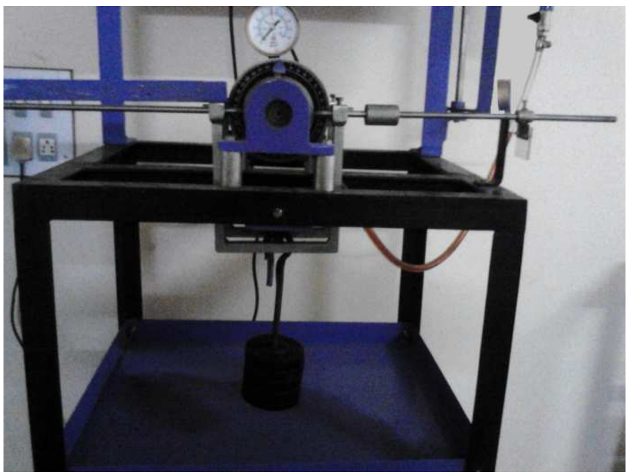

FIGURE 3A Experimental complete setup

FIGURE 3B Side view of the Wear Testing Machine

The system is formed by a weight applied by a rigid bracket made from the M.S. angle, a steel bar connected to the bearing from a distance and a comparator. Friction coefficient is determined from the friction force formed along the rotating direction of the bearing and from the movement of the steel bar connected to the bearing. Bearing Radial wear test rig is illustrated in Fig. 3A and 3B. In the experiments performed under lubricated conditions using SAE30 oil, very little movement had taken place for high comparator's spring coefficient and low friction. Therefore, a tensile spring of k = 0.004 N/mm has been connected on the opposite side of the comparator. The movements formed by the effect of the friction force have been measured by this method. Bearing Radial wear test rig is illustrated in Fig.3A and 3B. Samples of Bushings made from namely Gun Metal, Cast Nylon and Brass are shown in the FIGURE2.

In the experiments under lubricated conditions, very little movement was taken place for high comparator's spring coefficient and low friction. Therefore, a tensile spring of k = 0.004 N/mm has been connected on the opposite side of to the comparator. The movements formed by the effect of the friction force have been measured by this method. The bearing specimens were worn by radial journal bearing wear test rig under lubricated condition. Friction coefficient was determined as a function of normal and friction force. The wear losses were measured under lubricated conditions of 20 N loads,900 rpm and every 10 minutes reading were taken for 60 minutes. Lubricating system was accomplished by using SAE 30 gear oil.

As mentioned earlier Bushings were procured from the market having dimension 32 mm. inside diameter and 38 mm outside diameter , length were 48 mm..In the middle of the length there was a 8 mm diameter hole for the lubrication purpose. Three different materials (Brass, Bronze and Cast Nylon) are selected. The material properties are shown in Table(1).Readings were recorded on every 10 Minutes and time span for each set up was 60 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.

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Table 1

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

Mechanical and Physical Properties of Bearing Materials

The tests on the adhesion wear has been done on three different Bushing material specimens and its values are given in Table(2).With the help of arrangement made in the wear testing machine it was possible to record reading on every 10 Minutes for the 60 Minutes. During the Test duration readings were recorded for the Wear and Coefficient of friction.

TABLE(2).A

First Test Set : Load Applied : 20 N Lubricant : SAE30 OIL Speed: 900 rpm.

Sr. No.	Time Duration (Minutes)	C.O.F. Brass	Power Loss Brass (Watt)	C.O.F. Gunmetal	Power Loss Gun Metal (Watt)	C.O.F. Cast Nylon	Power Loss Cast Nylon (Watt)	Remarks
1	10	0.4719	14.22592	0.2557	7.708333	0.083	2.501952	
2	20	0.3920	11.81759	0.2421	7.300485	0.079	2.381376	
3	30	0.3790	11.42554	0.2327	7.014991	0.076	2.290944	
4	40	0.3567	10.75345	0.2205	6.647928	0.072	2.170368	
5	50	0.3548	10.69744	0.2178	6.566358	0.071	2.140244	
6	60	0.353	10.64143	0.2178	6.566358	0.071	2.140244	
	Average	0.3846	11.59356	0.2311	6.967394	0.075	2.270837	

TABLE (2) B

Second Test Set : Load Applied :30 N Lubricant : SAE30 OIL Speed: 900 rpm

Sr. No.	Time Duration (Minutes)	C.O.F. Brass	Power Loss Brass (Watt)	C.O.F. Gun Metal	Power Loss Gun Metal (Watt)	C.O.F. Cast Nylon	Power Loss Cast Nylon (Watt)	Remarks
1	10	0.4263	19.27851	0.2949	13.33664	0.112	5.064192	
2	20	0.3724	16.84183	0.2692	12.17427	0.095	4.29552	
3	30	0.3502	15.83849	0.2543	11.50132	0.087	3.933792	
4	40	0.3391	15.33049	0.2381	10.7672	0.079	3.572064	
5	50	0.3249	14.69181	0.2300	10.40013	0.075	3.3912	
6	60	0.3106	14.0468	0.2273	10.27778	0.073	3.300768	
	Average	0.35398	16.0046	0.2523	11.4095	0.08683	3.926256	

TABLE (2) C
Third Test Set : Load Applied : 40 N Lubricant : SAE30 OIL Speed: 900 rpm

Sr. No.	Time Duration (Minutes)	C.O.F. Brass	Power Loss Brass (Watt)	C.O.F. Gun Metal	Power Loss Gun Metal (Watt)	C.O.F. Cast Nylon	Power Loss Cast Nylon (Watt)	Remarks
1	10	0.5351	32.26034	0.3990	19.16887	0.131	7.897728	
2	20	0.4682	28.22781	0.3642	16.96648	0.102	6.149376	
3	30	0.4626	27.89176	0.3441	15.90608	0.092	5.546496	
4	40	0.4366	26.32355	0.3221	14.84568	0.084	5.064192	
5	50	0.4180	25.2034	0.3112	14.35626	0.079	4.762752	
6	60	0.3938	23.74721	0.3075	14.11155	0.079	4.762752	
	Average	0.452423	27.27568	0.341402	15.89249	0.0945	5.697216	

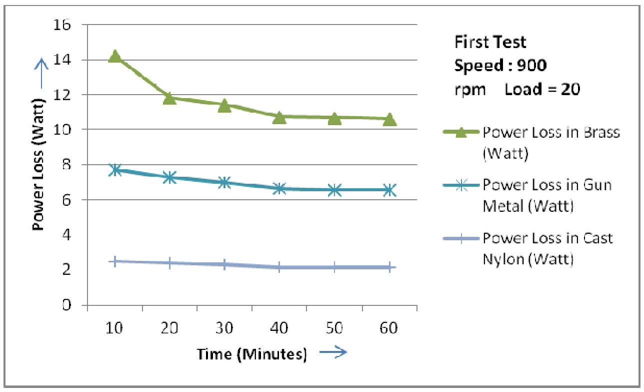

FIGURE 4 (A) Relationship b/w Power Loss and Time at 900 rpm with Load 20 N.

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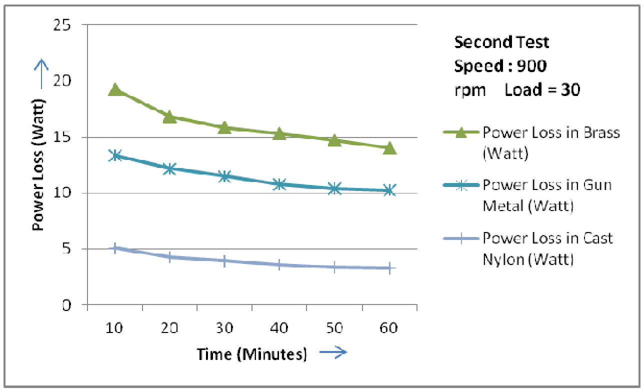

FIGURE 4 (B) Relationship b/w Power Loss and Time at 900 rpm with Load 30 N

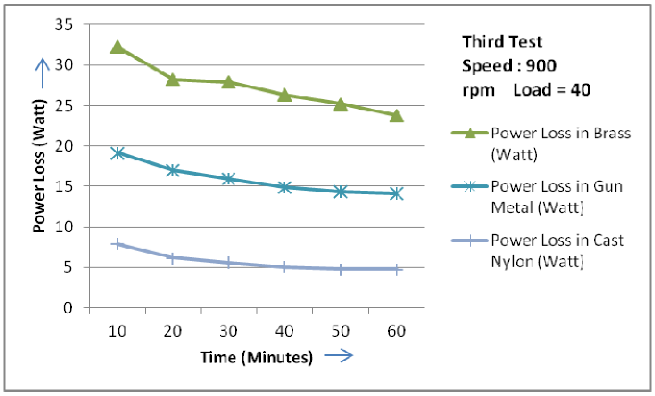

FIGURE 4 (C) Relationship b/w Power Loss and Time at 900 rpm with Load 40 N

Result and Discussion

The tests on the Co-efficient of friction wear done on three different material specimens and its average values are given in Table(2).With the help of arrangement made in the wear equipment it was possible to record reading on every 10 Minutes for the 60 Minutes. Readings were recorded for the Wear and Coefficient of friction.

From the above FIGURE 4(A), 4(B), and 4(C) it is quite evident that the co-efficient of friction is very low of Cast Nylon compared to Brass and Gunmetal and therefore we have less power loss due to friction for the Cast Nylon. In first phase keeping 700 rpm and load 20 N, the C.O.F.(Co-efficient of friction) of Brass is approximately Ten times more compared to Cast Nylon. Also the COF of Gun metal is nearly Eight times more than Cast Nylon. Remaining two images of FIGURE 4(B) and 4(C) revealed the same facts i.e. the COF of Cast Nylon is quite low with respect to Brass and Gunmetal.

The basic intention of the test carried out on the Wear Test Rig for the Brass, Gun metal and Cast Nylon was to check existing materials and new material tribological behavior. While analyzing the available test data it is found that the Cast Nylon is lighter in weight and heaving low co-efficient of friction compared to Gunmetal and Brass. Also having good wear and chemical resistance

Wear Model

With the knowledge of constant pressures and the surface velocities, the wear rate on the wristpin and connecting rod small end bearing surfaces can be calculated using Archard law [22,23] mentioned below

$$W_r = k\frac{W x V}{H}$$

Where W_r is the wear rate, W is the applied load, H is the Hardness of the sliding material, V is the sliding speed, and k is a constant, referred to as the wear coefficient. In the current problem the applied load on the journal, as well as the sliding velocity is time dependant, therefore using the Archard law instantaneously, and averaging over the cycle gives the cycle average wear rate. The constant k for wear coefficient, which is an input to the problem, is not easily obtainable and it is the function of several variables including lubrication conditions, lubricity and sliding velocity. In the current study, a single value for the wear coefficient is used all three materials to make it more identical and realistic.

Before the test and after the test the weight of the specimen is measured by a precise electronic weighing machine A&D Japan makes shown in the figure 5 with an accuracy of 0.0001g (Model MC-1000). Using the mass loss technique wear rate can be calculated. The lubricant used in wet condition is SAE30.The results are mentioned in the TABLE 4.Generally wear rate is calculated per Kilometer distance travelled by the bearing. Here we have taken in all cases speed as the 900 rpm, therefore we have not opted for such calculation

Wear rate (W) = weight loss /Sliding distance (mg/km) sliding distance S in km,

FIGURE 5 A&D JAPAN MODEL MC-1000(1100 grams x 0.0001 g.)

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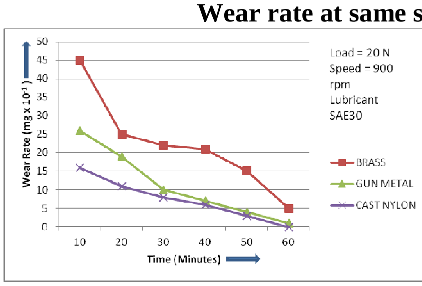
Wear results are recorded after every 10 minutes for 60 minutes cycle mentioned in TABLE 3 below:

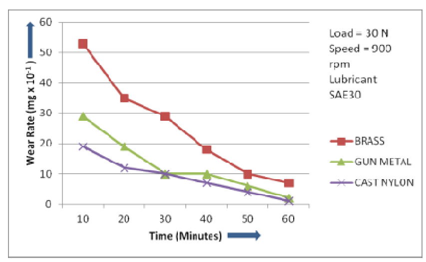
TABLE 3

Load Applied : 20 N Lubricant : SAE30 OIL Speed: 900 rpm. TOTAL DISTANCE: 1.5072 m/second					
Sr.No	Time Duration (Minutes)	Reduction in weight after test (mg)x10^{-1}	Reduction in weight after test (mg)x10^{-1}	Reduction in weight after test (mg)x10^{-1}	Remarks
		BRASS	GUN METAL	CAST NYLON	
1	10	45	26	16	
2	20	25	17	11	
3	30	22	9	8	
4	40	21	7	6	
5	50	15	4	4	
6	60	5	1	0	
Load Applied :30 N Lubricant : SAE30 OIL Speed: 900 rpm. TOTAL DISTANCE: 1.5072 m/second					
		BRASS	GUN METAL	CAST NYLON	
1	10	45	26	16	
2	20	25	17	11	
3	30	22	9	8	
4	40	21	7	6	
5	50	15	4	4	
6	60	5	1	0	
Load Applied :40 N Lubricant : SAE30 OIL Speed: 900 rpm. TOTAL DISTANCE: 1.5072 m/second					
		BRASS	GUN METAL	CAST NYLON	
1	10	45	26	16	
2	20	25	17	11	
3	30	22	9	8	
4	40	21	7	6	
5	50	15	4	4	
6	60	5	1	0	

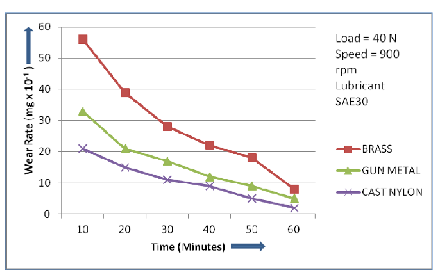
Wear rate at same speeds and different loads



6 (a)



6 (b)



6 (c)

Figure 6 Relationship between wear Rate and Time for Same speed and different loads

Conclusion

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 Bearing performance can be optimized and hence engine's overall performance can be improved. We know that the power lost due to friction can be find out by using equation

(P=μVW).

1. At 900 rpm and 20 N load, referring Table 3(A) the coefficient of friction of Gun Metal is Three Times higher and Coefficient of friction of Brass is Five times more compared to Cast Nylon coefficient of friction at 900 rpm.Here we have taken same lubricating oil i.e. SAE 30 for all three materials. Hence if we replace conventional Bushing of small end connecting rod by new material Cast Nylon, we can reduce power lost due to friction and increased over all efficiency of the engine.
2. At 900 rpm and 20 N load, referring Table 3(A) the Power loss due to friction of Gun Metal (6.967394 Watt) is Three Times higher and power loss due to friction of Brass (11.59356 watt) is Five times more compared to Cast Nylon (2.270837 Watt)power loss due to friction at 900 rpm.Here we have taken same lubricating oil i.e. SAE 30 for all three materials. Hence if we replace conventional Bushing of small end connecting rod by new material Cast Nylon we can reduce power lost due to friction and increased over all efficiency of the engine.
3. At 900 rpm and load 30 N and 40 N, if we refer available test data recorded in Table 3(B) and Table 3(C), we find that power loss is nearly Three times in the case of Gunmetal and nearly Five times power loss in the case of Brass compared to power loss due to friction in the case of Cast Nylon. Hence it is the general characteristics of C
4. If we replaced conventional Bearing material i.e. BRASS by new non-metallic material i.e. Cast Nylon, we can improve small end connecting rod Bearing performance nearly FIVE times.
5. If we replaced conventional Bearing material i.e. GUNMETAL by new non-metallic material i.e. Cast Nylon, we can improve small end connecting rod Bearing performance nearly THREE times.
6. The Weigh loss due to the friction is observed and recorded in the Table 3. We can see that due to the more hardness the weight loss in the Brass in the beginning is higher and heading towards ^0 Minutes test durations it is stabilized. Same is the case for the Gunmetal. In the case of Cast Nylon, we can see in all the three cases that because of the Low co-efficient of friction characteristics, right from the beginning of the test to the end the weight loss is quite low.
7. At highest loads i.e. 40 Newton and speed at 900 rpm, the weight loss is 2.75 times in the Brass and 1.5 Times in the Gunmetal compared to weight loss have in the Cast Nylon. Hence we can conclude that the bearing life of the Cast Nylon would be longer that Brass and Gunmetal.

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