iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: VIII Month of publication: August 2017

DOI: http://doi.org/10.22214/ijraset.2017.8212

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

A Study on Tribological & Statistical Investigation of PTFE, Tin Bronze and White Metal

Mr. Chavan A. M. [1], Mr. Gajare C. M.[2], Mr. Korade E. S.[3]
[1, 2, 3] *Department of Mechanical Engineering, SVCET, Pune*

Abstract: PTFE, Tin bronze and white metal widely used as journal bearing materials in tribological applications. Thus, the purposes of this study were to investigate the tribological properties of bearing alloys with different compositions used especially in heavy industrial service conditions. The specimens were fabricated using the powder metallurgy (sintering) techniques. The wear and coefficient of friction of all these materials are evaluated using pin-on-disc tribometer with respect to sliding speed and bearing load. Tests were carried out in dry sliding conditions, since despite the presence of lubricant film, under heavy service conditions dry sliding may occur from time to time, causing local wear. In this study, tribological and mechanical properties of these journal bearings manufactured by metals were investigated.

Keywords: Coefficient Of Friction, Journal Bearing Material, Pin-On-Disc Tribometer, PTFE, Tin Bronze, Wear, White Metal.

I. INTRODUCTION

Bearing is one of the most important parts in rotating equipment's, which permits constrained relative motion between two rotating parts. It provides much easier movement between two rotating parts, which increases efficiency and reduces energy consumption. Bearings are used in any rotating parts such as fans, jet engines, automobile parts, industrial equipment's, and application. For efficient operation and long service life journal bearings have to meet several requirements. Three critical parameters in journal bearings can be expressed as the Friction coefficient, Wear rate, which reflects material loss during the sliding, local bearing temperature, which is an important parameter in seizure. Main causes for journal bearing failure can be Excessive loads, Overheating, Lubricant failure, Corrosion, Misalignment.

In the past few years, wood, iron and skin have been used as journal bearing materials. Moreover, PTFE, Tin bronze, 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 are used where continuous lubrication is impossible and plastic materials are used in certain applications. Therefore, it is essential that the bearing material be chosen depending upon application area. Wear resistance is one of the most important properties that journal bearings should possess. There are several studies and investigations dealing with wear resistance improvements of these Materials.

PTFE is a high performance engineering plastics which is widely used in engineering field, medical field. It is used for manufacturing toys, small gears, wheels. Its use as sliding bearing material is now days increasing due to its properties such as low coefficient of friction, high resistivity against temperature, chemically neutral, self-lubricating, light weight etc. Its costs compared with metallic sliding bearing material are low. Again it provides clean operating environment which is the necessity of certain applications such as food industry. A liquid lubricants have many difficulties to use in sliding bearing, such as liquid lubrication sometimes requires complicated housing design with need for oil ways or nipples which increases overall cost, most of lubricants can be used in very limited operational temperature range. There are many certain applications where we cannot lubricate by liquid lubricants. Among the all polymeric materials PTFE which is high performance engineering Plastic widely used as a solid lubricant in engineering Industry. [3, 4]

Copper based materials are widely used as bearing material because they have high thermal and electrical conductivity, self-lubrication property, and good corrosion and wear resistance. The effect of tin on wear in copper based materials is important. Copper based tin bronzes that include tin are used as bearing material to have a high wear resistance. Friction and wear properties of these materials can be improved by adding tin. The tin bronze (90% Cu and 10% Sn) is the most suitable bearing material under corrosive conditions, at high temperatures and high loads. [6] The effect of tin on wear in copper-based materials is important. Copper-based tin bronzes that include tin are used as bearing materials to get high wear resistance. Friction and wear properties of these materials can be improved by adding tin. The tin bronze (90% Cu and 10% Sn) is the most suitable bearing material under corrosive conditions, at high temperatures, and under high loads. The effect of copper on the mechanical properties in tin-lead-based materials is important. Copper increases the mechanical properties of tin-lead-based materials. In addition, antimony increases the hardness and mechanical properties of tin-lead-based materials. It prevents shrinking in the course of solidification of tin-lead [8].

Tribo-materials used for crankshafts in automobiles have embedding ability and high wear resistance. These bearings contain lead, tin, aluminium and copper [7].

II. EXPERIMENTAL INVESTIGATIONS

A. *Experimental Materials*

In this study, PTFE, Tin bronze and White metals specimens were used as journal bearing and EN31 hardened steel of hardness 60 HRC was used as shaft.

Table 2.1 Chemical composition in % of Weight of the journal materials

Material	C	Mg	Si	P	Mn	Cr
EN31	1.5	0.05	0.22	0.05	0.52	1.3

Table 2.2 Chemical composition of the journal bearing materials (Wt. %)

Sr. No	Material	Specification of pin	Sn	Pb	Cu	Sb
1	PTFE	P1	-	-	-	-
2	Tin Bronze	P2	90	-	10	-
3	White metal	P3	80	3	6	11

B. *Specimen Preparation*

The PTFE Tin bronze and White metals material for the pin was used to prepare pin sample of dimensions ϕ10 mm and 25mm in length. PTFE, Tin bronze and White metals powder was purchased from market. The pins were manufactured by Powder Metallurgy from raw materials as mentioned in table 2.2 According to the dimensions required for test. The counterpart (ϕ 165mm and 8mm thickness) of EN31 steel fabricated as per test requirement.

C. *Test Setup*

The TR-20LE-PHM-400, Wear and friction monitor testing machine represents a substantial advance in terms of simplicity and convenience of operation, ease of specimen clamping and accuracy of measurements, both of wear and frictional force. The equipment is designed to apply load up to 200N & speeds starting from 200 to 2000 rpm, provision is made only to conduct tests under dry and heated conditions. This apparatus facilitates study of friction and wear characteristics in sliding contacts under different test conditions, sliding occurs between the stationary pin and a rotating disc. The Pin on disc apparatus was used to study the tribological behaviour of prepared composite material pins. The prepared samples of pins were used for the tribological test at P. Dr. V. Vikhe Patil College of Engineering, Ahmednagar, Maharashtra. The Wear was performed on a pin-on disc apparatus according to ASTM D2538 and ASTM D2396. The test rig was supplied by DUCOM Instrument Bangalore, India

D. *Operating Parameters*

Following operating parameters were selected for the test at room temperature condition.

Table 2.4.1 Operating Parameter

Parameters	Dimensions
Pin Size	10 mm diameter, 25 mm long
Disc Size	165 mm × 8 mm
Loads	5 Kg
Speed	500 rpm
Sliding velocity	0.42m/s
Temperature	Atmospheric temperature
Duration	30 minutes

E. Wear Test

Bearings materials in journal bearings are generally selected from materials which have lower wear strength than the shaft material, thereby lowering the wearing of the shaft significantly. Therefore, journal bearing wear test apparatus are designed to examine the wearing of bearing materials. In this study, a special bearing wear test apparatus has been designed to examine the wearing behaviour of bearing material and the shaft together. Therefore, it is possible to investigate different bearing and shaft materials and the effects of heat treatments on these materials. Such a mechanism provides wear of bearings rather than using standard methods as this is more appropriate direct. The Specimen pin ϕ10mm and 25 mm in length were run against the polished EN31 disc. The sample of the pin was kept in pin holder or collect which was kept inside the collet holder. During the test, load values were selected as 5 Kg. The speed of the disc was selected as 500 rpm. The readings were recorded for 30 minutes duration. The readings were recorded for a sample of Pl, P2, and P3 pin. Speed and time were set for the readings.

F. Hardness Test by Brinell Hardness Tester

The basic principle, as with all common measures of hardness, is to observe the material's ability to resist plastic deformation from a standard source. The hardness number is determined by the load over the surface area of the indentation and not the area normal to the face, and is therefore not a pressure. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The hardness number can be converted into units of Pascal's, but should not be confused with a pressure, which also has units of Pascal's.

III. RESULTS AND DISCUSSION

A. Wear Test

For the comparative study between different materials, the test was carried out under different operating parameters. Results obtained from this study were correlated with each other. Wear behaviours of given materials was studied with respect to time.

A. Wear (Microns) of pin P1, P2, P3 at 5 Kg, 500rpm B. Coefficient of friction of pin P1, P2, P3 at 5 Kg, 500rpm

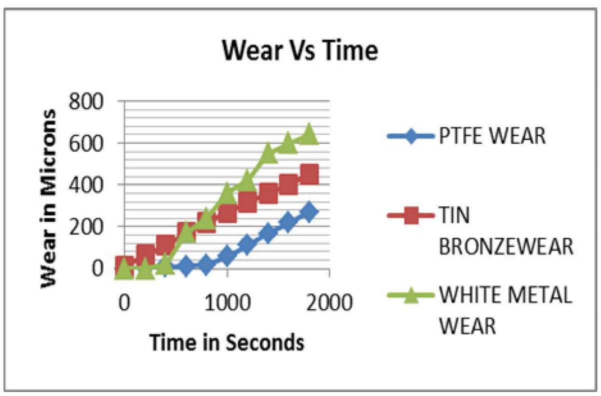


Fig. 3.1.4 Wear (Microns) vs. Time (sec)

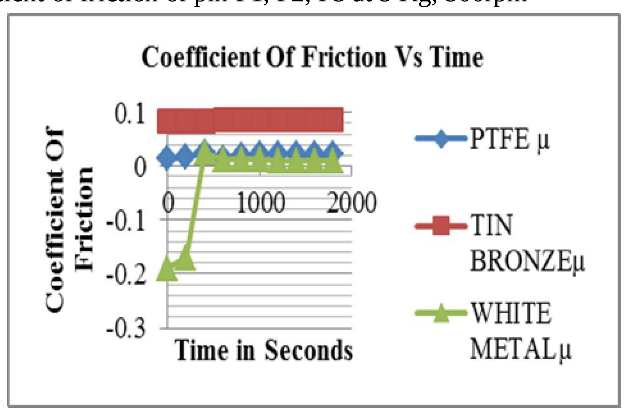


Fig. 3.1.8 Coefficient of friction Vs. Time (sec)

From the comparative study between the different material samples at different loading and speed conditions, it was observed that PTFE has the lowest wear among all the three materials and White metal having the lowest Coefficient of friction among all the three materials. PTFE having the moderate Coefficient of friction among all the three materials.

B. Hardness Test by Brinell Hardness Tester

Table 3.2.1 Hardness (HB) of the materials

Materials	PTFE	Tin bronze	White metal
Hardness (HB)	58	100	30

From the comparative study for hardness test between the different material samples, it was observed that among all the three materials. Tin bronze shows the highest hardness, PTFE shows the moderate hardness and White metal shows the lowest hardness Properties.

IV. STATISTICAL INVESTIGATIONS

A. Taguchi Technique

Taguchi technique is a powerful tool for the design of high quality systems. It provides a simple efficient and systematic approach to optimize designs for performance, quality and cost. The methodology is valuable when design parameters are qualitative and discrete. Taguchi parameter design can optimize the performance characteristics through the setting of design parameters and reduce the sensitivity of the system performance to source of variation. This technique is multi-step process, which follow a certain sequence for the experiments to yield an improved understanding of product or process performance. This design of experiments process made up of three main phases: the planning phase, the conducting phase and analysis interpretation phase. The planning phase is the most important phase one must give a maximum importance to this phase. The data collected from all the experiments in the set are analyzed to determine the effect of various design parameters. An outline Procedure for Taguchi Approach This approach is to use a fractional factorial approach and this may be accomplished with the aid of orthogonal arrays. Analysis of variance is a mathematical technique, which is based on a least square approach. The treatment of the experimental results is based on the analysis of average and analysis of variance.

B. Plan of Experiment

The experiments were conducted as per the standard orthogonal array. In the present investigation, an L9 orthogonal array was chosen, which has 9 rows and 2 columns as shown in Table 1, where 1, 2 and 3 are levels. In L9 array one can study 2 factors at a time with 3 levels also one can edit these level and factor values with experimentally decided values. The wear parameters chosen for the experiment are (1) Time (2) load (3) and response factor are wear and coefficient of friction. The experiment consists of 9 tests (each row in the L9 orthogonal array) and the columns were assigned with parameters. The first column was assigned to Time (s), second column was assigned to Load and the remaining columns were assigned to their interactions. The response to be studied was the wear and coefficient of friction with the objective of smaller is the better. The experiments were conducted as per the orthogonal array with level of parameters given in each array row. The wear test results were subject to the analysis of variance.

Table 4.2.2 Response table for S/N ratio-COF

Materials	Level	Time	Load
PTFE	1	-12.04	-27.22
	2	-18.06	-33.29
	3	-21.58	-37.01
	Delta	36.59	9.80
	Rank	1	2
Tin Bronze	1	-35.85	-44.61
	2	-40.98	-47.22
	3	-44.61	-49.21
	Delta	17.22	4.61

	Rank	1	2
White Metal	1	*	-51.21
	2	-26.02	-44.24
	3	-44.61	-51.07
	Delta	30.10	6.97
	Rank	1	2

Table 4.2.1 Response table for S/N ratio-Wear

Material	Level	Time	Load
PTFE	1	34.89	34.17
	2	32.04	32.78
	3	36.48	34.13
	Delta	4.44	1.39
	Rank	1	2
Tin bronze	1	21.51	21.38
	2	21.51	21.38
	3	21.31	21.31
	Delta	0.20	0.07
	Rank	1	2
White Metal	1	*	39.21
	2	32.04	36.82
	3	38.42	39.47
	Delta	7.96	2.65
	Rank	1	2

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

C. Analysis Using S/N Ratio

Experiments were conducted accordance to the orthogonal array and the corresponding values of wear and c.o.f. The influence of input process parameters on wear and c.o.f. were determined using S/N ratio. The parameter with the highest S/N ratio gives minimum wear and maximum c.o.f. The response table for S/N ratio was shown in Table 4.2.1 and 4.2.2 for both wear and c.o.f. The difference between the maximum and minimum values of S/N ratio gives delta. Ranking of parameter were done according to the delta value. The parameter with the highest value of delta has the greatest influence on wear.

D. The Main Effects Plot for Mean and S/N Ratio (Wear and COF)

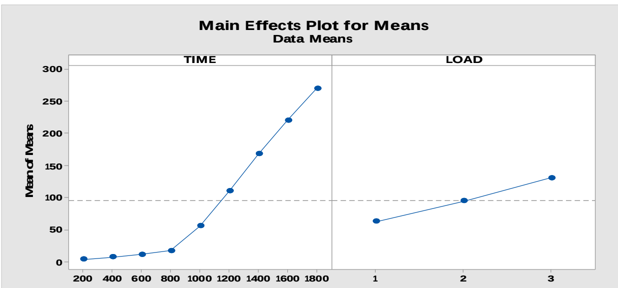


Figure 4.4.1 Main effects plot for Means-Wear PTFE

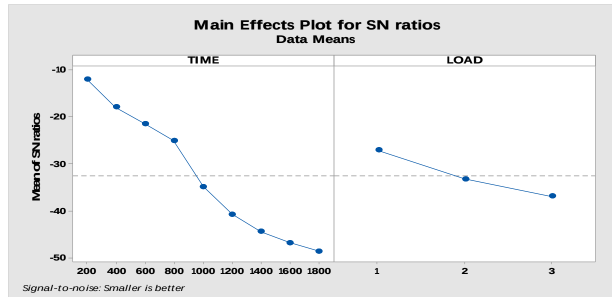


Figure 4.4.2 Main effects plot for SN ratios -Wear PTFE

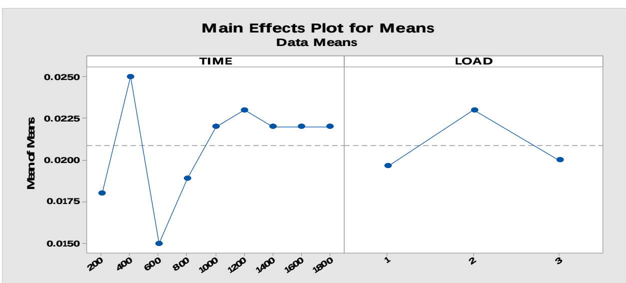


Figure 4.4.3 Main effects plot for Means- COF PTFE

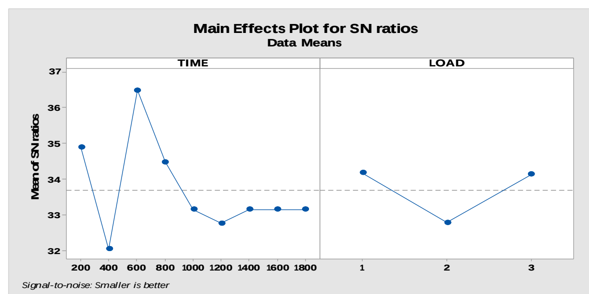


Figure 4.4.4 Main effects plot for SN ratios - COF PTFE

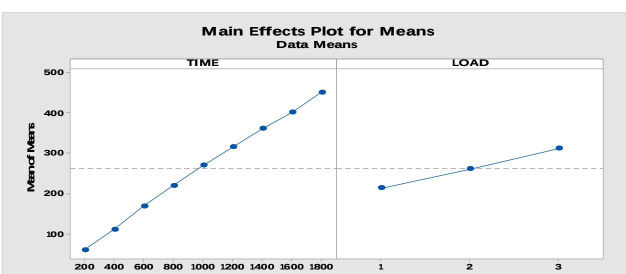


Figure 4.4.5 Main effects plot for Means-Wear Tin bronze

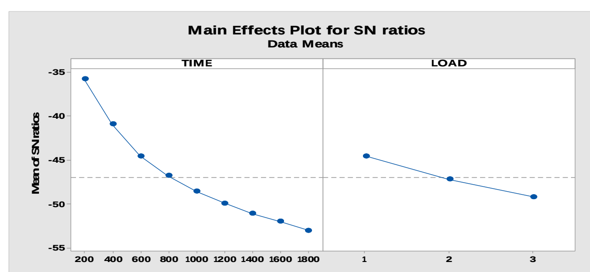
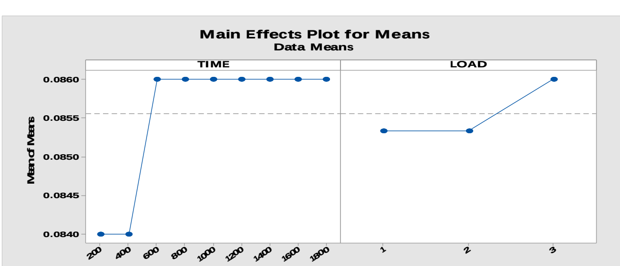


Figure 4.4.6 Main effects plot for SN ratios -Wear Tin bronze



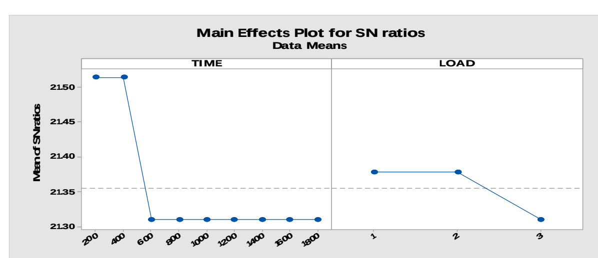
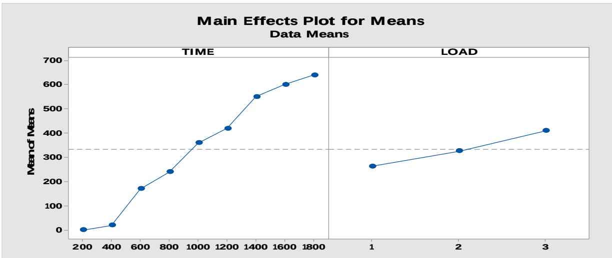


Figure 4.4.7 Main effects plot for Means- COF Tin bronze

Figure 4.4.8 Main effects plot for Means- COF Tin bronze



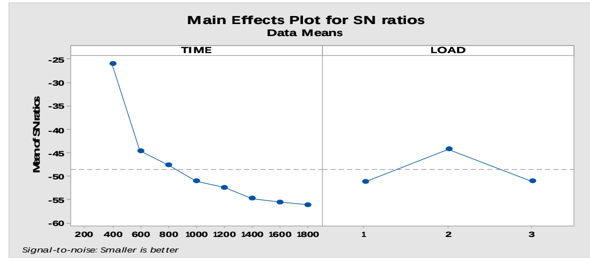
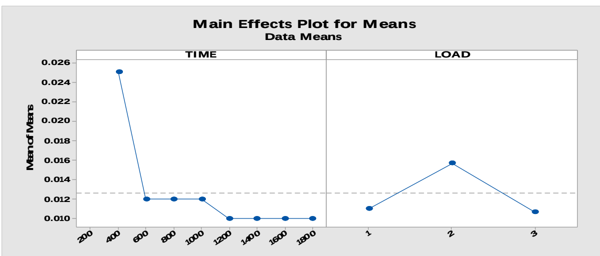


Figure 4.4.9 Main effects plot for Means-Wear White Metal

Figure 4.4.10 Main effects plot for SN ratios - Wear White Metal



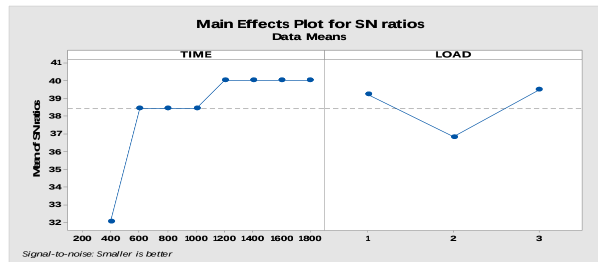


Figure 4.4.11 Main effects plot for Means- COF White Metal

Figure 4.4.12 Main effects plot for SN ratios- COF White Metal

The main effects plot for mean was shown in Figure 6.4.2, 6.4.4 and 6.4.6 it was inferred that wear rate increases with increase time. As the temperature increases, the material becomes softer and hence more material has been removed from the wear surface. The main effects plot for S/N ratio was shown in Figure 6.4.2, 6.4.4 and 6.4.6 the input process parameter value which has the highest S/N ratio gives the optimum wear rate. From the Figure, it was found that at 200 s it gives the optimum condition for wear. From the Figure, it was found that at 1800 s it gives the optimum condition for COF. The given optimal condition is nearly same seen from graphs of mean effect plot and S/N graphs.

E. Analysis of Variance (ANOVA)

ANOVA was used to analyse the effect of control parameters like applied load, sliding velocity and Time on wear and coefficient of friction of all materials. The analysis was performed for a level of significance, α=0.05.

Table 4.5.1 Analysis of Variance for Wear

	Source	DF	Adj SS	Adj MS	F-Value	P-Value
PTFE	Regression	1	73780	73780	62.99	0.000
	TIME	1	73780	73780	62.99	0.000
	Error	7	8199	1171		
	Total	8	81980			
Tin Bronze	Regression	1	139298	139298	3306.81	0.000
	TIME	1	139298	139298	3306.81	0.000
	Error	7	295	42		
	Total	8	139593			

White Metal	Regression	1	457627	457627	434.46	0.000
	TIME	1	457627	457627	434.46	0.000
	Error	7	7373	1053		
	Total	8	465000			

Table 4.5.2 Analysis of Variance for Coefficient of Friction (COF)

	Source	DF	Adj SS	Adj MS	F-Value	P-Value
PTFE	Regression	1	73780	73780	62.99	0.000
	TIME	1	73780	73780	62.99	0.000
	Error	7	8199	1171		
	Total	8	81980			
Tin Bronze	Regression	1	139298	139298	3306.81	0.000
	TIME	1	139298	139298	3306.81	0.000
	Error	7	295	42		
	Total	8	139593			
White Metal	Regression	1	0.000090	0.000090	5.88	0.051
	TIME	1	0.000090	0.000090	5.88	0.051
	Error	6	0.000092	0.000015		
	Total	7	0.000182			

The ANOVA was shown in Table 4.5.1 and 4.5.2 for wear and Coefficient of friction (COF) respectively. Last column in the table shows the percentage contribution of each input process parameter on the wear and COF. It shows that for case of wear time 0.028 has the greatest contribution on wear rate. Further, it shows that for case of coefficient of friction 0.083 has the greatest contribution on coefficient of friction. It was found that interaction of factors also have significant effect on the wear coefficient of friction.

F. Regression Analysis and Confirmation Test

A regression model was developed based on the experimental results and this establishes a correlation between the significant parameters. The regression equations developed for wear and coefficient of friction for all three materials are given as,

1) *PTFE:*

$$\text{Wear} = -79.1 + 0.1753 \times \text{Time} \quad \text{......} \quad 4.6.1$$

$$\mu = 0.01879 + 0.000002 \times \text{Time} \quad \text{......} \quad 4.6.2$$

2) *Tin Bronze:*

$$\text{Wear} = 21.19 + 0.24092 \times \text{Time} \quad \text{......} \quad 4.6.3$$

$$\mu = 0.084389 + 0.000001 \times Time \quad \text{......} \quad 4.6.4$$

3) *White Metal:*

$$\text{Wear} = -103.3 + 0.4367 \times \text{Time} \quad \text{......} \quad 4.6.5$$

$$\mu = 0.02068 - 0.000007 \times \text{Time} \quad \text{......} \quad 4.6.6$$

Where,

μ = Coefficient of friction

To validate the conclusions obtained from the analysis, confirmation experiment was conducted and comparison was made between the experimental values and computed values developed from regression model. Table 4.6.1 show the confirmation experiment and its results.

Table 4.6.1 Result of Confirmation Experiment for Wear

Exp. No.	Material	Exp. Wear (micron)	Reg. Model Wear (micron)	Error %	Exp. COF	Reg. Model COF	Error %
1	PTFE	220	201.38	8.46	0.022	0.0219	0.045
2	Tin Bronze	400	406.63	-1.65	0.086	0.0859	0.012
3	White Metal	600	595.42	0.76	0.01	0.0094	5.2

Based on the confirmation experiment, it was observed that the error associated with experimental values and computed values was minimal and hence this regression model obtained from L9 array can be used effectively to predict the wear and coefficient of friction of the Material with good accuracy. From above table it is also seen that the PTFE gives less wear so out of all materials it is recommended as good material for future use.

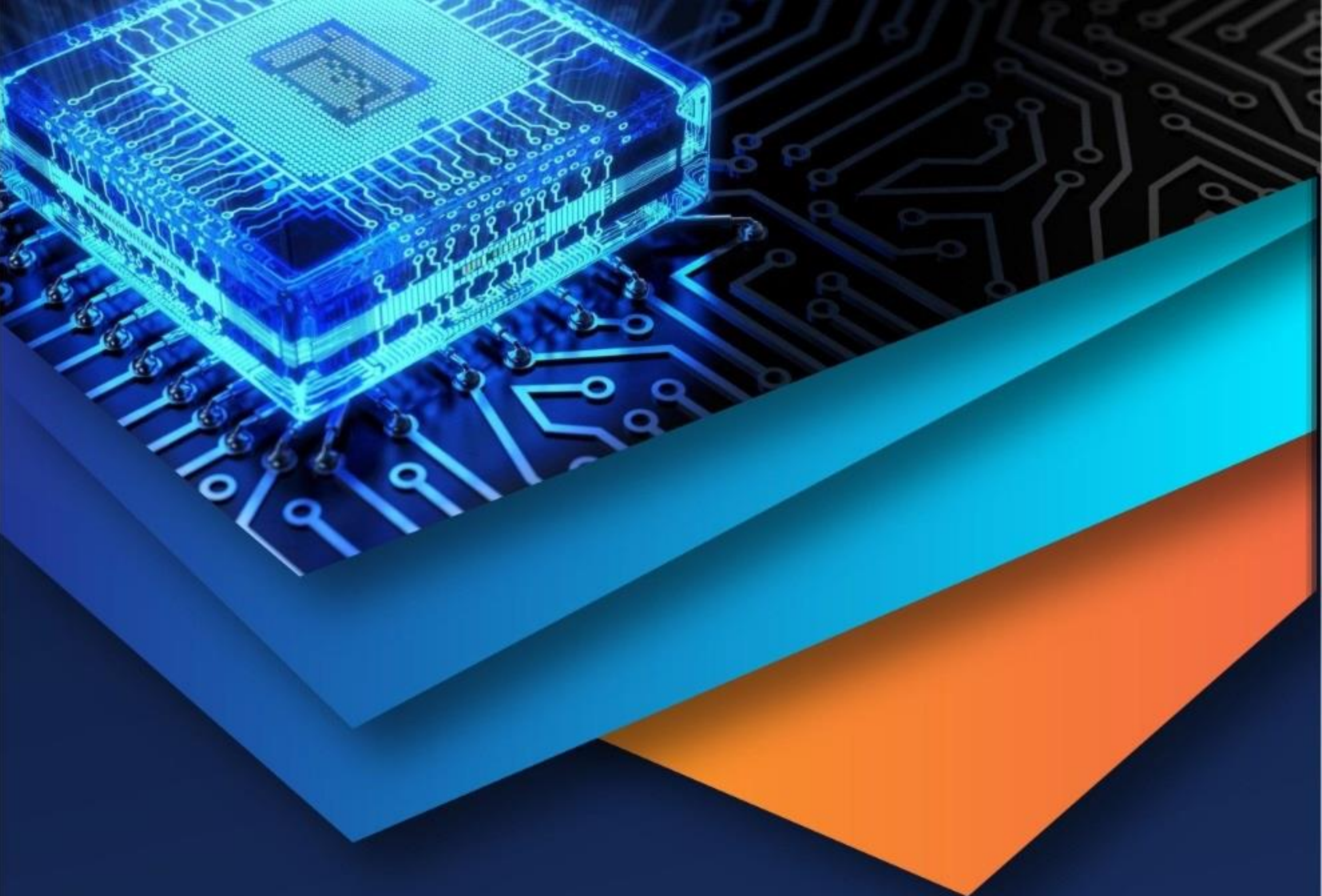
V. CONCLUSIONS

In this study, tribological properties of journal bearings manufactured by PTFE, Tin bronze and White metal were investigated by Pin on disc tribometer at various operating parameter. The following conclusions can be drawn:

A. The lowest wear occurred in PTFE, moderate Wear occurred in tin bronze and the highest wear occurred in White metal.
B. The lowest coefficient of friction occurred in White metal, PTFE shows the moderate coefficient of friction and tin bronze shows highest coefficient of friction among all the three materials.
C. PTFE is seemed to be a very good polymer material which can be effectively used for many applications and hence PTFE acts as good solid lubricants for journal bearing application.

REFERENCES

[1] B. S. Unlu, *Determination of the Usability of Boronized Ferrous-Based Materials as Bearings and Their Tribological Properties in Journal Bearings* [In Turkish], PhD Thesis, Celal Bayar University, Manisa (2004).
[2] Atik E, Ünlü B S and Meriç C 2001 *Design of radial journal bearing wear test rig*, Conference of Mach. Mater. and Technol. (in Turkish) (Turkey), 2 pp. 98–103
[3] Jaydeep Khedkar, Ioan Negulescu, Efstathios I.Meletis, *"Sliding wear behavior of PTFE composites*", Wear 252 (2002) 361-369.
[4] Unal, E.Kurtulus, A.Mimaroglu, M.Aydin, *"Tribological performance of PTFE Bronze filled composites under wide range of application conditions"*, Journal of Reinforced plastics and composites 29, pp.2184-2191, 2010.
[5] I.E. Kalashnikov, L.K. Bolotova, P.A. Bykov, L.I. Kobeleva, I.V. Katin, R.S. Mikheev, and N.V. Kobernik, *"Tribological Properties of the Babbitt B83–Based Composite Materials fabricated by Powder Metallurgy"*. Russian Metallurgy (Metally), Vol. 2016, No. 7, pp. 669–674.
[6] L.I. Kobeleva, L.K. Bolotova, I.E. Kalashnikov, I.V. Katin, P.A. Bykov *"Composite Granules of Tin Based Alloy"*, Inorganic Materials: Applied Research, 2016, Vol. 7, No. 3, pp. 395–401.
[7] A. Zeren, E. Feyzullahoglu, M. Zerenet, *"A study on tribological behaviour of tin based bearing material in dry sliding"*, Materials and Design 28 (2007) 318–323.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY