Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

TRIBOLOGICAL PERFORMANCE ANALYSIS OF COMPOSITE MATERIALS FOR JOURNAL BEARING

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Abstract—The tribological behavior of composites having base material as polyether-ether-ketone (PEEK) and filler materials like Polytetrafluroethylene (PTFE), MoS2, bronze and the conventionally used brass is studied. The wear rate analysis is carried out using the pin on disk apparatus. The journal bearing in connecting rod of an internal combustion engine was taken as an application for the study. The main objective behind this is to find the wear rate of different materials and to suggest the best material which will give minimum wear also to give the best values of parameters at which minimum wear occurs. PEEK having mechanical properties like high wear resistance, strength, low thermal conductivity also it is an injection moldable polymer with a high operating temperature and chemical resistance. PTFE having excellent tribological properties. By the addition of PEEK and PTFE with fillers modifies the tribological properties. During the experiment variable load and speed was selected according to the application.

Keywords—Composite, PEEK, PTFE, Bronze, MoS2, Journal Bearing

I. INTRODUCTION

A bearing is a system of machine element whose function is to support an applied load between the relative moving surfaces. The applied load may be radial, axial or a combination of all these loads. Bearings are classified according to the direction of applied load. If the bearing supports a radial load, it is called as a radial or journal bearing. On the other hand, a thrust bearing supports a thrust or an axial load. Some bearings can support both radial and axial loads and these types of bearings are known as conical bearings. The journal bearing used in the connecting rod of an IC engine is selected here as application [4]. Bearing materials are a special type of materials, which carry a moving or rotating component with least friction or wear between them. The high wear rate is a serious problem in a large number of industrial applications such as compressor piston rings and bearings. Meanwhile, to meet the combination of light weight and high strength demands of polymer-based materials are increasingly applied in many industries.

To cater for the problems of wear arising from the conventional materials it is needed to develop novel composites [2] by using polymeric materials like poly-ether-ether-ketone (PEEK) and polytetrafluoroethylene (PTFE) by the addition of one or more non-conventional filler materials which are having required properties to improve wear resistance. PEEK is a polymeric matrix material with excellent mechanical properties like high wear resistance, strength, low thermal conductivity. Also, it is an injection moldable polymer with a high operating temperature and chemical resistance [1]. Because of its robustness, PEEK is used to fabricate items used in applications like bearings, piston parts, pumps, compressor plate valves. On the other hand, PTFE is finding increasing utility due to its advantageous tribological properties such as high-temperature stability, high chemical inertness, lower friction coefficient. Because of these properties PTFE is widely used as filler material in various applications [1]. However PTFE has poor abrasion and wear resistance, but it can be significantly improved by the addition of suitable filler materials [2].

In present investigation, we have tested various types of composite polymer materials such as PEEK (poly-ether-ether-ketone) as a base material and PTFE (polytetrafluoroethylene), MoS2 and Bronze as filler materials with different amount of weight percentages. These composites are tested and the analysis is done against the conventionally used Brass material

II. EXPERIMENTAL WORK

A. Preparation of Specimen:

The investigation was done to find the best suitable composite material than the material which is conventionally used an i.e. brass material for journal bearing in connecting rod of an IC engine which will give minimum wear. The brass material for the pin was purchased from the market to prepare pin sample of dimensions ϕ4 mm and 20 mm in length. PEEK with 450G powder with an average diameter 100µm is a commercially available material which was supplied by Victrex, PTFE powder with diameter 60µm was supplied by PCEE textile Kanpur, bronze powder with 10% tin was supplied by Pometon India ltd., molybdenum disulfide powder of diameter 100µm supplied by Vishal Pharmachem, Navi Mumbai. The pins of composites were prepared by compression molding. All the materials were mixed with different proportions. Digital weighing machine was used to take a proper proportion of different materials. Uniform mixing was done by compounding of raw materials. Twin screw extruder was used during the compounding of material. This compounding was done by compression molding. The product of this process was a long thread like pallets and then it would be again cut into small granules. Then the pins were manufactured according to the dimensions selected. Following proportions were used to prepare specimens.

Table 1. Composition of Materials

Sr. No.	Notations for specimens	Proportions of Raw Materials (% by weight)
1	P1	Brass 100 %
2	P2	PEEK(65)+PTFE(20)+BRONZE(15)
3	P3	PEEK (65) + PTFE (20) + MoS2(15)

The image of prepared pin specimens is as shown below.

Figure 1. Image of Pins

The counterpart was prepared as per the considerations of application. Normally the journal bearing material for connecting rod made up of stainless steel or gray cast iron, so that the counterparts also selected as made up of same material. So the disc material was selected steel with grade EN 8 and grey cast iron.

Figure 2. EN 8 Disc With Size Ø 165×8 mm

B. Test Setup:

The Pin on disc apparatus was used to study the tribological behavior 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, which is shown in fig below:

Figure 3. Wear and friction measuring test rig TR-20

C. Operating Parameters:

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

Pin Size	4 mm diameter, 15 mm long
Disc Size	160 mm × 8 mm
Loads	10, 20, 30 N
Speed	100, 150, 200 rpm
Sliding velocity	0.5m/s to 3.4m/s
Temperature	Atmospheric temperature (23ºC)
Duration	30 minutes

D. Wear Test:

Initially, the calculations were done before the test. The Specimen pin ϕ4mm and 15 mm in length were run against the polished steel disc of grade EN-8. The value of sliding velocity was selected in the range from 0.5 m/s to 3.4 m/s. 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 10N, 20N, 30N. The operating speeds for very large engines with bore sizes on the order of 0.5 m (1.6 ft.) typically operate in the 200- to a 400-RPM range [1]. Therefore the speed of the disc was selected as 100, 150, 200 rpm. The readings were recorded at every interval of 5 minutes. Firstly the readings were recorded for a sample of Pl pin. For this, the brass material pin was kept in the pin holder. The pin holder was kept in the collet. At the other end of collet, weight was added with the help of a pulley. For the first reading weight of 1 kg was added to the weight pan. Speed and time were set for the readings. Readings were recorded in the table. Again weight of 1kg was replaced by the 2kg and same procedure was done for carrying out experimental work for P2 and P3 composite pins.

III. COMPARATIVE STUDY OF RESULTS

A. Comparative Study for Wear:

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 behavior of given materials was studied with respect to time.

- Comparative study of wear for P1, P2, P3 samples at 10 N, 100 rpm:

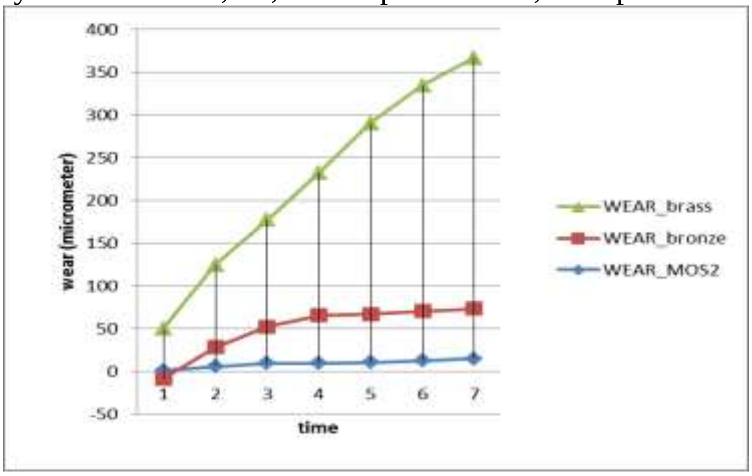

Figure 4 . Comparative Study of Wear for 10 N, 100 Rpm

- Comparative study of wear for P1, P2, P3 samples at 20 N, 150 rpm:

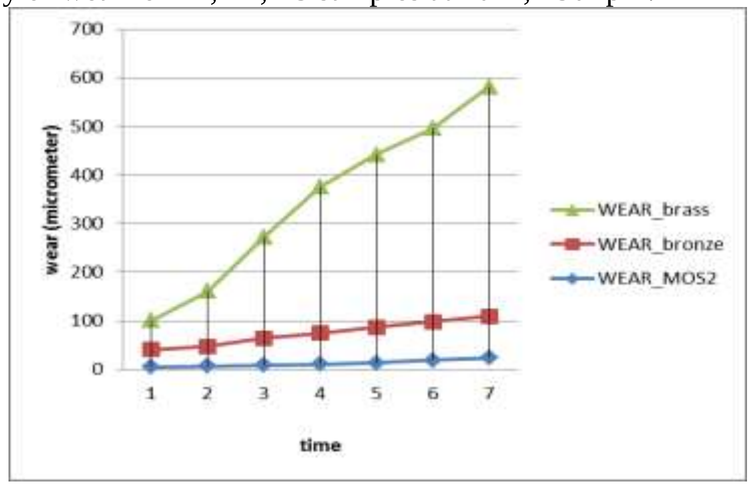

Figure 5. Comparative Study of Wear for 20 N, 150 Rpm

- Comparative study of wear for P1, P2, P3 samples at 30 N, 200 rpm:

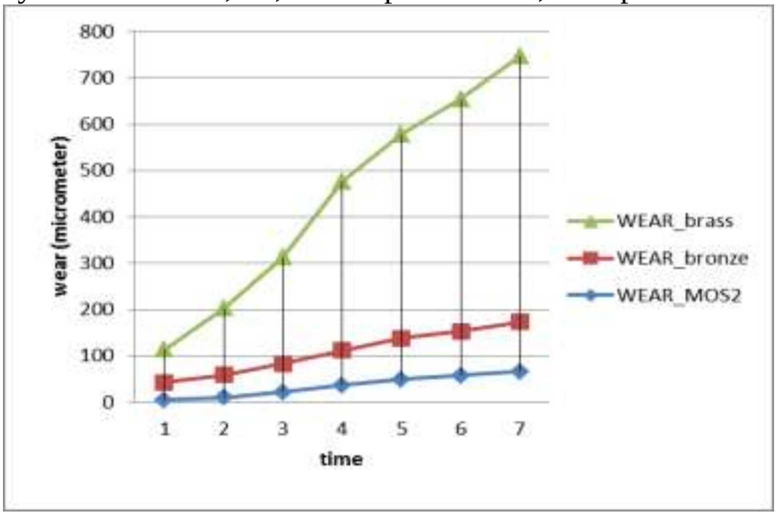

Figure 6. Comparative Study of Wear for 30 N, 200 Rpm

From the comparative study between the different material samples at different loading and speed conditions, it was observed that MoS2 was having the lowest wear among all the three materials.

B. Coefficient of Friction Calculations:

Also, the coefficient of friction was calculated from the frictional force obtained during the experiment and normal load applied.

$$F = \mu \times F_N$$
$$\mu = F/F_N$$

where, F_N = Normal load on pin (N)
F = Frictional Force (N)
μ = Coefficient of friction

IV. TAGUCHI ANALYSIS

Taguchi analysis was done for the pin with PEEK, PTFE and MoS2 material because wear for this material found to be less than other pin sample materials. The objective of Taguchi analysis was to obtain the best value from the parameters which will give the best optimum value at which minimum wear of pin samples occurs to validate the results obtained from experimental work. Main effects plot were plotted from the readings recorded during the experiment which is as shown below.

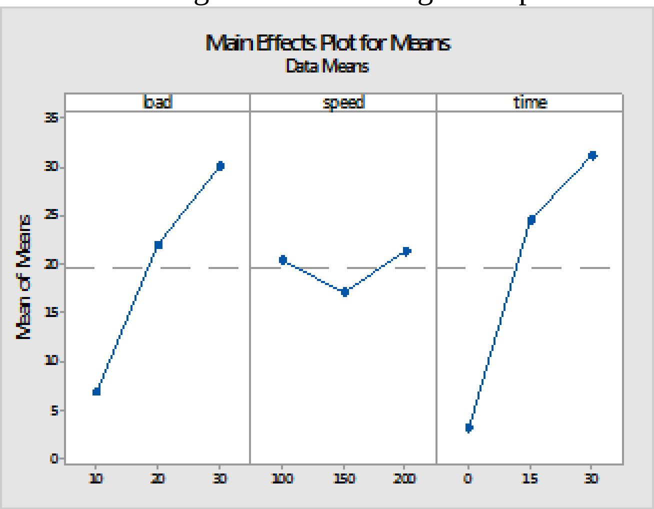

Figure 7. Main Effects Plot for Wear

Taguchi analysis was implemented successfully to obtain the set of values for the parameters and by using these values we can obtain the minimum amount of wear. The confirmation test can be carried out to validate the results.

Table 2. Response Table for Means of Wear

Level	Load (Factor A)	Speed (Factor B)	Time (Factor C)
1	6.950	20.467	3.267
2	22.033	17.150	24.533
30	30.017	21.383	31.200
Delta	23.067	4.233	27.933
Rank	2	3	1

From the above response table for means for wear, it was observed that time is the dominant factor than load and speed. The estimated value for wear of sample of pins can be calculated using the standard prediction equation.

Ƞopt = Ƞm + (optimum level for factor A - Ƞm) + (optimum level for factor B - Ƞm) + (optimum level for factor C - Ƞm),

Where, Ƞopt = predicted optimum average,

Ƞm = overall average of all the experimental data for response.

By putting the values from table number in the formula for optimum predicted average formula, the predicted value was found to be 1.544.

Confirmation test was carried out to validate results obtained from Taguchi analysis. The optimum parameters were selected for the confirmation from the main effects plot. These are as follows.

Table 3. Optimum Parameters for Confirmation Test

Factors	Optimum Values
Load	10 N
Speed	100 rpm
Time	0 minutes

Confirmation Results were obtained by using the optimum parameters for the confirmation test obtained from the main effects plot which is as shown in the table below.

Table 4. Confirmation Test Results

Experiment No.	Wear (micrometer)
1	1.73
2	1.54

From the confirmation test, it was observed that the percentage deviation from predicted and confirmation result was found to be 0.93. This indicated that the optimum values from main effects plot give best parameters.

V. RESULTS AND DISCUSSION

A. Results for Wear:

The results obtained are recorded in a tubular form for the wear for all the samples of pins as shown in table below:

Table 5. Wear Rate (micrometer) of Pins

Sample of Pins	Wear (micrometer)		
	10 N, 100 rpm	20 N 150 rpm	30 N, 200 rpm
P1	363.43	588.29	736.23
P2	70.47	101.24	171.26
P3	24.50	26.36	80.38

From the above results it is observed that pin sample P1 of brass has given the highest wear rate and pin sample P3 with PEEK, PTFE and MoS2 has given the least wear. P2 sample of the pin with PEEK, PTFE and bronze shows the moderate wear.

B. Results for Coefficient of Friction:

Results for the coefficient of friction are calculated by dividing frictional force obtained during the experimental work to the normal load applied on the pin. Calculated results are tabulated as shown below:

Table 6. Coefficient of Friction

Samples	Coefficient of Friction		
	10 N, 100 rpm	20 N 150 rpm	30 N, 200 rpm
P1	0.41	0.285	0.233
P2	0.25	0.165	0.14
P3	0.07	0.095	0.096

C. Taguchi Analysis Results:

Taguchi analysis was done for the pin with PEEK, PTFE and MoS2 material because wear for this composite material found to be less than other pin sample materials. The objective of Taguchi analysis was to obtain the best value from the parameters which will give the best optimum value at which minimum wear of pin samples occurs to validate the results obtained from experimental work.

Main effects plot was obtained by using the readings obtained from experimental run conducted. From the main effects plot, it was observed that the minimum wear occurs at parameters i.e. 0 minutes, 10 N and 100 rpm. This shows that the results obtained from experimental work are validated.

By using the values from response table for means, the optimum predicted value was calculated at which minimum wear occurs by using the formula for optimum predicted average. From this formula, optimum predicted average value was found to be 1.544. To validate this value again the confirmation test was conducted. From the confirmation test, it was observed that the percentage deviation from predicted and confirmation result was found to be 0.93 which is tolerable. This indicated that the optimum values from main effects plot gives best parameters.

VI. CONCLUSION

- From the comparative study at different speed and loading conditions between the conventionally used brass and composite materials, it was found that as the load and speed increases wear rate also increases. Composite material with PEEK, PTFE and MoS2 gives very less wear rate compared to other materials.

- The coefficient of friction value was obtained from the frictional force from the experimental result and normal load applied on the pin. Brass was having highest coefficient of friction value i.e. 0.233 while for material with PEEK, PTFE and MoS2 found to be 0.096.
- Composite with PEEK, PTFE and MoS2 shows best results. Composite with PEEK, PTFE and Bronze shows moderate results. While Brass material pin sample has shown poor results.
- Taguchi analysis was carried out for the MoS2 composite because it gave least wear rate than other materials. The objective was to find best values of parameters at which minimum wear occurs. From main effects plot the best values of parameters was 10 N, 100 rpm, 0 min. This validated the experimental results. Optimum predicted value obtained found to be 1.544.
- Confirmation test was carried out to validate the results from optimum prediction value. From the confirmation test, it was observed that the percentage deviation from predicted and confirmation result is tolerable.

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