International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Tribological Behaviour for Friction of Composite Dry Journal Bearing

Tanay D. Shinde
Sinhgad College of Engineering, Pune
Dr. (Mrs.) P.S.Gajjal
AISSMS College of Engineering, Pune

ABSTRACT

In the new world of composite materials, the tribological applications relying on composites has been put into focus, for applications such as bearing materials where the extreme tribological applications have not yet been fulfilled by ceramics and many other materials. In order to evaluate composite materials for journal bearing applications that have to serve without lubrication for a long operational life time, an experiment with bearings made from composite materials such as ABS has been carried out on a dry journal bearing test rig. Parameters such as load, sliding velocity and time are taken into consideration in the experiment conducted. As operational conditions strongly determine the choice of composite materials for successful unlubricated bearing applications.

Keywords

Bearings, Tribology, Composite Materials, Taguchi Method, ANNOVA, ABS (Acrylonitrile butadiene styrene).

1. INTRODUCTION

These days, polymers and polymer based composites are utilized usually in circumstances where a decent tribologicalproperty is required. The tribological properties of polymers is a great method to improve the friction coefficient and wear rate. The main objective of this project was to use different composite materials for the dry journal bearing as composite materials have better properties than the conventional bearing materials. The current composite material with several mechanical advantages like higher strength and higher temperature resistance is ABS (Acrylonitrile butadiene styrene) which is a well-known engineering thermoplastic terpolymer which is used for the specimen. Acrylonitrile gives chemical resistance and heat stability, butadiene gives toughness and impact strength and the styrene gives rigidity and easiness of process ability. By doing a survey on literature reviews it was observed that only a limited research was done on ABS as a bearing material and ABS having the desired properties could be an efficient material for a dry journal bearing having less friction and wear properties.

Various kinds of literature shows us a thorough study of Design of Experiments, Taguchi Method etc. BekirSadikUnlu, EnverAtik, depicted the effect of tribologicalparameters on different bearing materials. The writers have discussed the effect of friction on bronze radial bearings which is a journal bearing. A new test rig and method were developed for measuring the coefficient of friction of journal bearing. The results indicated that the friction force increased with the increase in load and velocity. Also coefficient of friction increased in the beginning due to dry friction and then later it decreased. [1] BekirSadikUnlu, EnverAtik, CevdetMeric studied friction and wear properties of journal bearings manufactured by CuSn10 bronze and the effect of p-v (pressure–velocity) parameter on the bearing. Bearing material are made of copper based materials because of high thermal and electrical conductivity, self-lubrication, and good corrosion and wear resistance of the copper based material. By adding tin the properties of the material can be increased. Hence the tin bronze is the most suitable bearing material under high temperatures and loads [2].Stefan GheorgheCristina Teisanu, Andrei Tudorhave studied the effect of applied load on the friction coefficient of the sintered iron-based bearings. The mechanical properties of a part, highly depends on the

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
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composition of the material. The friction nature of such sintered bush bearings is a function of pore size, applied load, velocity, temperature, the quality and quantity of stored oil can appear as hydrodynamic, mixed and limit friction. The author has deeply studied the tribological parameters of iron-sintered bearings using a dry journal bearing test rig setup[6]. S Basavarajappa G Chandramohan J Paulo Davim, have explained the effects on dry sliding wear behavior of the composite aluminum metal matrix using graphite and reinforced SiC and compared it with Al/SiCp composite. Taguchi technique was used to acquire the data in a controlled way. An orthogonal array and analysis of variance was used to investigate the influence of wear parameters as normal load, sliding speed and sliding distance on dry sliding wear of the composites. The main aim was to find out which design parameter significantly affects the dry sliding wear. Taguchi technique is used for the design of high quality systems as it provides a simple efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi parameter design can optimize the performance characteristics. This technique is multi-step process, made up of three main phases: the planning phase, the conducting phase and analysis interpretation phase. The results are obtained by analysis of average and analysis of variance [5].

2. EXPERIMENTAL DETAILS

There are various devices used for measurement of friction and wear. Devices like pinon-disc, ball-on-disc etc are used. So to find actual values of friction and wear, a dry bearing test rig has been specially designed. The test bearing is mounted in the step provided on the shaft and covered with support bush and rotates around this shaft and bush. The test rig consists of frame on which motor is mounted. The motor is supported at its shaft ends by means of a pedestal block. The loading is done through a loading arm which is connected from supported bush and load is applied by pulling the bush downward. A load cell, which is connected to loading arm, measures the load applied on the bearing.

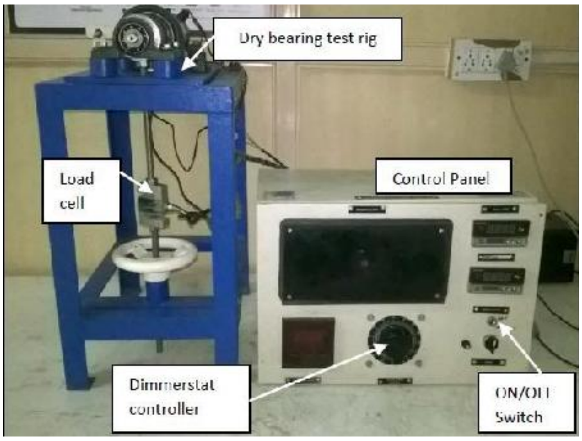

Fig 1. Dry Journal Bearing Test Setup Full View

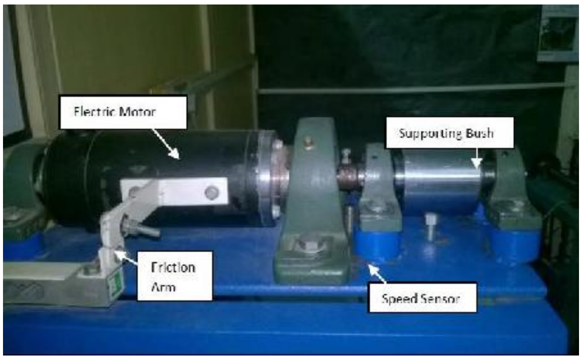

Fig 2. Components of Dry Journal Bearing Setup Close up

2.1 MATERIALS UNDER CONSIDERATION

ABS is made by a combination of styrene-acrylonitrile copolymer, which is brittle in nature with polybutadiene; it makes ABS tougher. ABS is an amorphous material. It is tough, stiff and abrasion resistant; it is widely used in boat shells and food containers. Some plastic materials absorb certain quantities of moisture and change their mechanical properties with the quantity of absorbed moisture. Also the dimensions of such materials change with the quantity of absorbed moisture. However in case of ABS the absorbed moisture does not affect the properties of the finished item as well as the dimensional stability. Size of the test bearing used is given in the below section.

2.2 TEST CONDITIONS

Post literature survey and expectation of parameters was determined to be applied for testing, out of the number of parameters available some of them have a stronger influence on friction and wear, and these parameters are load, sliding velocity and time, giving the results of friction and wear.

Table 1. Process Parameters

Iterations / Parameters	1	2	3
Load (Kg)	5	7	9
SlidingVelocity(m/s)	0.8	1	1.5
Time(Seconds)	10	20	30

3. FRICTION ANALYSIS

3.1 EFFECTS OF PROCESS PARAMETERS ON THE COEFFIENT OF FRICTION

The constructional and experimental details with test material are explained briefly in the previous section. For the first time pure ABS was loaded and taken under consideration for experimentation. Due to friction, dissipation of energy takes place which reduces operating efficiency by increasing power loss and rate of component replacement. To reduce friction solid and liquid lubricants can be used. A solid lubricant is basically any solid material which can be placed between two bearing surfaces and which will shear more easily under a given load than the bearing material themselves.

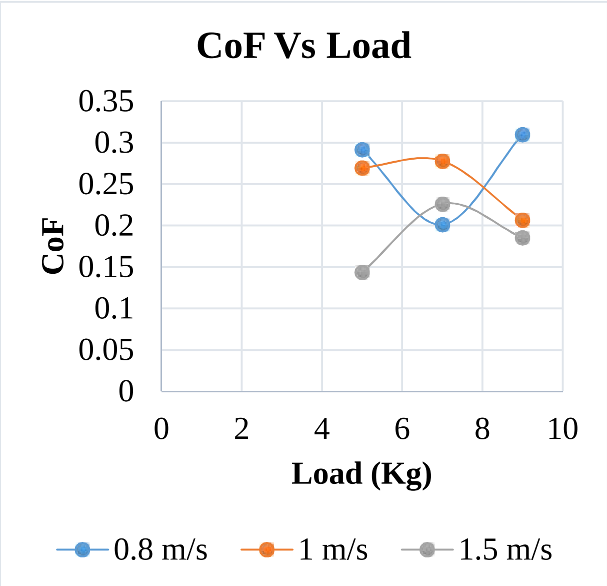

Fig 3.Coefficient of friction Vs Load

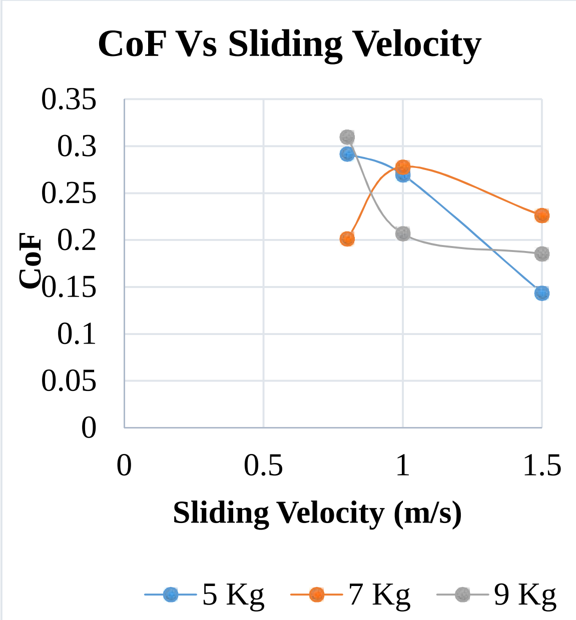

Fig 4. Coefficient of friction Vs Sliding Velocity

3.2 DESIGN OF EXPERIMENTS (DOE): Taguchi Method

The method of processing and analysing all possible parameters involving multiple factors is known of design of experiment. In the experiment, we have three process parameters and three different variations. Each variation has different values of parameters. So, to find out the effect of all parameters and variations DOE was used.DOE has three phases namely planning, processing and optimization. The verification was done on Minitab® 17. It is a statistical tool used for analysis and optimization of experiments and also gives contour plots for response variables and predictor variables. Taguchi method helps in the approach to plan trails and experiments in simple ways with restricted parameters. Taguchi strategy can bifurcate data more decisively and effectively. Additionally, number of tests that are required are minimal considering the quantity of factors that can be tested. Taguchi's experimental design and analysis are conducted by experimental design (Taguchi Orthogonal Arrays) to determine the influence of the factors and their levels and identify the best combination of parameters, it has been shown that this method yields the same or even better results (in terms of precision) compared to another DOE. Consider a system which has 3 parameters and each of them has 2 values. To test all the possible

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www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
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combinations of these parameters we will need a set of 3^2 = 09 test cases.Using orthogonal array testing, we can maximize the test coverage while minimizing the number of test cases to consider. Here our three parameters chosen are Load, Sliding Velocity and Time and are arranged in the columns (refer Table. 1) given by the L_9orthogonal array, tests are then carried out according to the orthogonal array.

$L_9(3^2)$	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 2. L_9 Orthogonal Array

Experimental observations are transformed into signal to noise ratio with the objective as smaller the best, which was calculated as shown below,

$$\frac{S}{N} = -10 \times lc \;\; \frac{1}{n}\left(\sum y^2\right)$$

Where 'n' is the number of observations, "y'' is the measured value of coefficient of friction.

Load	Sliding Vel.	Time	CoF	S/N Ratios
5	0.8	10	0.2919	10.6953181
5	1	20	0.2697	11.38238107
5	1.5	30	0.1436	16.8569112
7	0.8	20	0.2013	13.9231245
7	1	30	0.278	11.11910408
7	1.5	10	0.2262	12.91014799
9	0.8	30	0.31	10.17276612
9	1	10	0.2068	13.68898931
9	1.5	20	0.1854	14.6378054

Table 3. Shows the L_9 orthogonal array which contains estimated values of coefficient of friction and S/N ratios

The effect of process parameters on coefficient of friction is seen through the signal to noise ratio response table as shown in table 3.

Table 4. Response Table for S/N Ratio

Level	Load	Sliding Velocity	Time
1	12.98	11.6	12.43
2	12.65	12.06	13.31
3	12.83	14.8	12.72
Delta	0.33	3.2	0.88
Rank	3	1	2

Table 4. Shows us the ranking of the parameters which tells us which parameter has the most effect on coefficient of friction.

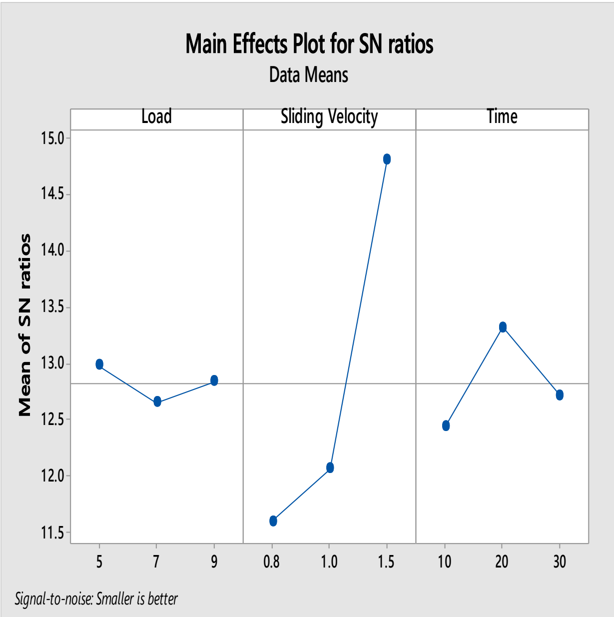

Fig. 5 Main effects plots for signal to noise ratio for the coefficient of friction

3.3 ANALYSIS OF VARIANCE (ANOVA)

ANOVA provides a statistical test of whether or not the means of several groups are equal. ANOVAs are useful for comparing (testing) three or more means (groups or variables) for statistical significance.The analysis is made with 95% confidence level. The percentage contribution shows how much the process parameter affects the coefficient of friction. This is seen in table 5.

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Table 5. Analysis of Variance for Coefficient of Friction

Term	DOF	S	V	P	%
Kg	2	0.161	0.080	0.044	20.84
m/s	2	17.98	8.992	0.023	47.16
S	2	1.218	0.609	0.049	24.01
Error	2	18.69	9.349		
Total	8	38.06			

3.5 REGRESSION ANALYSIS

A regression analysis provides an equation which describes the statistical relationship between one or more predictors and the response variable and provides new results. Here, it gives a linear relationship which shows the relationship between the coefficient of friction and process parameters.

Table 6. Regression Summary

Term	Coefficients	Standard Error	T	P
Constant	0.367	0.108	3.4	0.019
Load	-0.0002	0.0105	-0.02	0.982
Sliding Velocity	-0.1209	0.0584	-2.07	0.093
Time	0.00011	0.00211	0.05	0.96

The regression equation obtained for the coefficient of friction is given below;

μ=0.367- 0.0002 Load- 0.1209 Sliding Velocity + 0.00011 Time

With this equation we can calculate coefficient of friction for any values of parameters for this experiment.

4. RESULTS

4.1 CONFIRMATORY TEST

A confirmation experiment is the final step in the design process. The test was conducted using a specific combination of the parameters and levels to validate the statistical analysis. The key task is the determination of the preferred combination of the levels of the factors indicated to be significant by the analytical methods and also to validate the conclusions drawn during the analysis phase. Table 7 shows the results of confirmation test and comparison was made between the experimental values and the computed values developed from the regression model.The experimental value of coefficient of friction is found to be varying fromcoefficient of friction calculated in regression equation by error percentage between 5% to 9%. Thus, the calculated coefficient of friction from the regression equation and experimental values agree fairly within experimental values.

Kg	m/s	sec	CoF_{exp}	CoF_{reg}	Error
4	1	10	0.2322	0.2464	5.74%
9	1.2	10	0.20465	0.22122	7.49%
6	0.8	20	0.24892	0.27128	8.24%

Table 7. Confirmatory Table for Coefficient of Friction

4.2 COUNTOUR PLOTS

A contour plot is a graph that is used to explore the potential relationship between three parameters. Contour plots display the 3-dimensional relationship in two dimensions, with x- and y-factors plotted on the x- and y-scales and response values represented by contours. These plots have a limitation that a specific plot can be used only for the specific experiment for which it has been plotted.

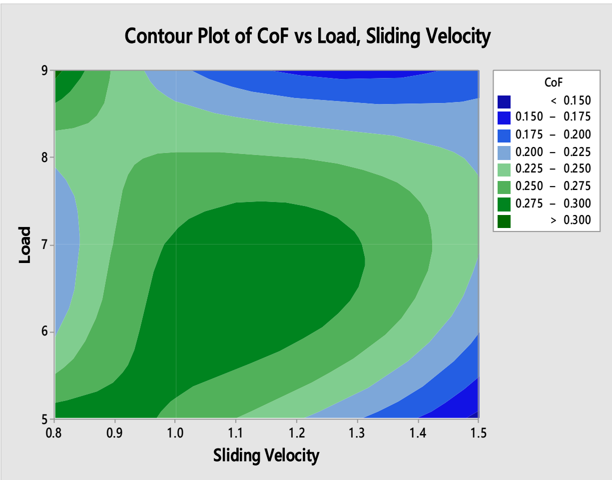

Fig 6. Contour plots for CoF Vs load sliding velocity

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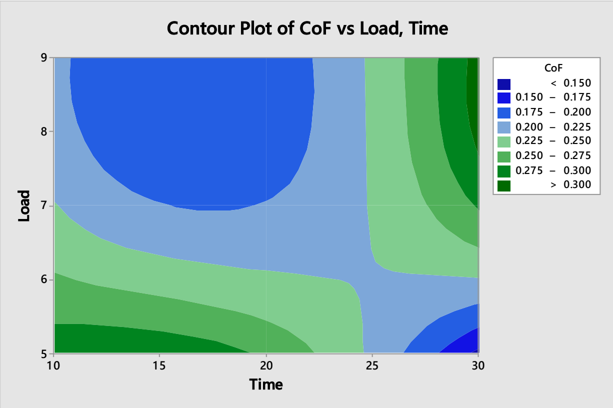

Fig 7. Contour plots for CoF Vs load, time

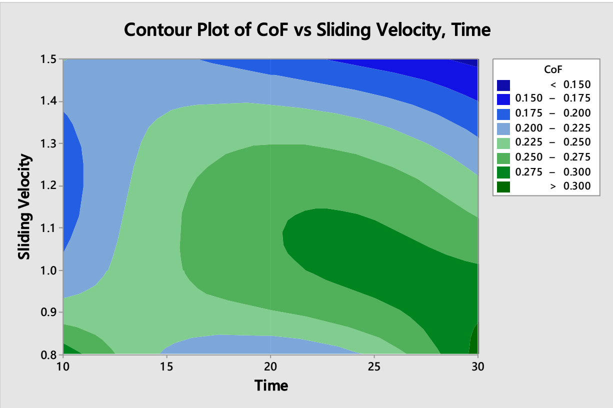

Fig 8.CoF Vs Sliding Velocity, Time

4.3 CONCLUSIONS

Experimental as well as theoretical analyses are the important phases in this project, with given test conditions the experiment was performed and the results were obtained. The results of friction and wear analysis were observed and the following conclusions were made:

1) It has been observed that as the applied load increases, the coefficient of friction decreases.
2) The coefficient of friction increases at the beginning and a sudden drop is observed with further increase in sliding velocity.
3) Using S/N ratio from Taguchi Method the ranking of parameters was devised. These rankings define the percentage contribution and were obtained from ANOVA. Sliding velocity was ranked 1st, time 2nd, and load was ranked 3rd. percentage contributions from ANOVA.
4) Using 95% confidence level percentage contributions were obtained as follows 47.16% for sliding velocity, 24.01% for time and 20.84% for load which shows the correlation between ranking and percentage contribution.
5) Regression equation was obtained using regression analysis in Minitab® 17. This equation is a liner equation which gives the relation between the predictors and response, this equation can be used to calculate coefficient of friction for any values of parameters for this experiment as shown in the confirmatory test.

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