STUDY OF TRIBOLOGICAL ANALYSIS OF PTFE & ITS FILLERS USING TAGUCHI APPROACH

[1]A. D. Diwate, [2]Dr. S. B. Thakre
Mechanical Department, TSSM'S Bhiwrabai Sawant College of Engineering and Research Narhe, Pune India[1], Professor, Mechanical Department, Prof. Ram Meghe Institute of Technology and Research, Badnera, Amravati. India[2]
addiwate@gmail.com[1], sbthakre2007@gmail.com2

ABSTRACT

Polytetrafluroethylene (PTFE), tough, waxy, non-flammable synthetic resin produced by the polymerization of tetrafluroethylene. Now a day's pure PTFE is widely used as bearing material and many such applications which is subjected to high wear rate, which can be reduced by adding suitable fillers. Also the effect of varying load, sliding distance, sliding velocity and filler content on wear in PTFE are studied. Experimentally, In this case there is an analysis of three composites (PTFE + 35% C, PTFE + 35% Glass, PTFE + 35% Bronze) is present showing how properties of PTFE can be improved by the addition of filler content. The results of experiment are presented in the table which proved that the wear is strongly influenced by the composition of filler content.

Keywords: PTFE composite, Pin-On-Disc Apparatus, Orthogonal Array, Minitab.

1. INTRODUCTION

Polytetrafluroethylene (PTFE) is a popular polymer solid lubricant because of its resistance to chemical attack in a wide variety of solvents and solutions, high melting point, low coefficient of friction, and biocompatibility. It is commonly used in bearing and seals applications. Also, it available in white or greycolour.Because of the relative softness of PTFE, it is logical to expect that its load-carrying ability and its wear resistance might be improved by the addition of suitable fillers [1]. Accordingly, several fillers were tried by researchers in combination with this plastic, including graphite, molybdenum disulfide, fiber glass, carbon ,bronze, dental silicate, silicon, titanium dioxide, silver, copper, tungsten and molybdenum [3].Polytetrafluroethylene (PTFE) is an important polymer based engineering material. It having low coefficient of friction but a high rate of wear when rubbed against a hard surface.

H.Unal et al.[3] study and analyze the influence of test speed and load values on the friction and wear behavior of purepolytetrafluoroethylene (PTFE), glass fibre reinforced (GFR), bronze and carbon (C) filled PTFE polymers. Adding glass fiber and bronze.Polytetrafluoroethylene (PTFE), tough,waxynonflammablesynthetic resin producedbythe polymerization of tetra fluoroethylene Known by such trademarks as Teflon, Fluon, Hostaflon, and Polyflon, PTFE is distinguished by its slippery surface, high melting point, and resistance to attack by almost all chemicals.

Deepak Bagale et al.[1] they study the the effects of load, velocity of sliding and sliding distance on sliding friction and sliding wear of polymer material made of polytetrafluoroethylene (PTFE) and PTFE composites with filler materials such as 40% bronze and 40% carbon are studied. The experimental work is performed on pin-on-disc apparatus and analyzed with the help of Design-Expert 7 software.Sandip B. Chaudhari et al.[5] The effect of load, Velocity of sliding and sliding distance on friction and wear of materials made of Polytetrafluoroethylele (PTFE) and PTFE composites under wet condition with filler materials such as 25% bronze, 25% glass fiber and 25 % carbon have studied. The experimental work has performed on pin-on-disc friction and wear test rig and analyzed with the help of Design Expert software.Through this study, He was developed the best bearing material for the various industrial applications which is available easily at the minimum cost.Some properties have made it familiar to consumers as the coating on nonstick cookware; it is also fabricated into industrial products, including bearings, pipe liners, and parts for valves and pumps.PTFE was discovered serendipitously in 1938 by Roy Plunkett, an American chemist for E.I. du Pont de Nemours & Company (now DuPont Company), who found that a tank of gaseous tetra fluoroethylenerefrigerant had polymerized to a white powder

2. OBJECTIVE OF THE PRESENT WORK

1. To find the effect of 35%Carbon filler in PTFE on wear rate.
2. To find the effect of 35%Bronze filler in PTFE on wear rate.
3. To find the effect of 35%Glass filler in PTFE on wear rate.
3. To Study the wear behaviour of the selected materials and the effect of various parameters like load, sliding velocity and sliding distance on wear rate.

3. EXPERIMENTAL TOOLS, TECHNIQUES AND METHODOLOGY

A. METHODOLOGY

In this study the wear rate of each material i.e. PTFE + 35% carbon filled, PTFE+35% bronze filled PTFE and 35% glass filled PTFE have been calculated under the wet conditions (Lubricated condition). So, we need the Pin-on-Disc apparatus for the experimental work which must provide the lubrication facility. For the present work following methodology has been followed.

1. It starts with the specimen preparation according to the "Pin-on-Disc Friction and Wear Testing Machine" specifications. The sample specimens has been prepared by performing necessary turning and facing operations on the respective rods.

2. After specimen preparation perform the wear test on each of the specimen for varying conditions of load, sliding distance and sliding velocity.

3. Then calculating the wear rate of each material. For the present work we are using "Pin-on-Disc Friction and Wear Testing Machine" manufactured by Magnum Engineers which gives the direct values of wear, coefficient of friction and frictional force so, there is no need to calculate the wear and coefficient of friction manually.

4. Then experimental results are analyzed with the "Design Expert 8 Software". Analysis involves the regression analysis of all four materials which can be done in "Design Expert 8 Software". Analysis of experimental data using the design expert software generates the equation of wear for each material. This equation contains the variables as load, velocity of sliding and sliding distance. By putting the values of all variables in the given equation we can calculate the wear of all materials. Then we will compare the values of experimental wear with the values of wear which are obtained by solving the equation of wear.

Then perform the confirmation test. Confirmation tests are done to check the accuracy of the model by selecting the random values of all involved variables.

A. DESIGN OF EXPERIMENT

Design of experiments determines the pattern of observations to be made with a minimum of experimental efforts. To be specific Design of experiments (DOE) offers a systematic approach to study the effects of multiple variables / factors on products / process performance by providing a structural set of analysis in a design matrix. More specifically, the use of orthogonal Arrays (OA) for DOE provides an efficient and effective method for determining the most significant factors and interactions in a given design problem.Design-Expert, version 8 software (DX8) is a powerful and easy-to-use program for design of experiments (DOE). With it you can quickly set-up an experiment, analyze your data, and graphically display the results. This intuitive software is a must for anyone wanting to improve a process or a product. Design-Expert software offers an impressive array of design options and provides the flexibility to handle categorical factors and combine them with mixture and/or process variables. After building your design, generate a run sheet with your experiments laid out for you in randomized run order. DX8 offers features for ease of use, functionality and power that you won't find in general statistical packages. Add, delete or duplicate runs in any design with the handy design editor. Rotatable 3-D colour plots make response visualization easy [3].

INTRODUCTION TO TAGUCHI METHOD

A full factorial design will identify all possible combinations for a given set of factors. If an experiment consist of m number of factors & each factor at X levels, then Number of trails possible (Treatment Combination) = X^m

TYPICAL ORTHOGONAL ARRAY (OA):

Each of the arrays is meant for a specific number of independent design variables and levels.Standard notation for orthogonal Arrays is,$L_n(X^m)$

Where,

n=Number of experiments to be conducted

X=Number of levels,

m= Number of factors.

Common Orthogonal Arrays are listed below for quick reference,

(2- Level arrays) - L_4 (2^3), L_8 (2^7), L_{12} (2^{11}), L_{16} (2^{15}), L_{32} (2^{31}), L_{64} (2^{63}) etc.

(3- Level arrays) - L_9 (3^4), L_{18} (2^1*3^7), L_{27} (3^{13}), L_{54} (2^1*3^{25}), L_{81} (3^{40}) etc.

(4- Level arrays) - L_{16} (4^5), L_{32} (2^1*4^9) etc.

Note: Arrays L_{18} (2^1*3^7), L_{54} (2^1*3^{25}), L_{32} (2^1*4^9) etc. are for mixed level factors.

Also, one wants to conduct an experiment to understand the influence of 4 different independent variables with each variable having 3 set values (levels), then an L_{27} orthogonal array might be the right choice. The L_{27} OA is meant for understanding the effect of 4 independent factors each having 3 factor level values.

This array assumes that there is interaction between any two factors, while in many cases, no interaction model assumption is valid, and there are some cases where there is a clear evidence of interaction. In this investigation work, which is carried out for 4 factors (Material, load, sliding velocity, and sliding distance), each factor at 3 levels, an L_{27} (3^{13}) orthogonal array is chosen for conducting the experiments. Table 5.1 shows an L_{27} (3^{13}). There are totally 27trials (experiments) to be conducted and each trial is based on the combination of level values as shown in the table.

III.LABORATORY WORK

EXPERIMENTAL SET UP

The Pin on Disc Friction & Wear Testing Machine designed and developed by MAGNUM ENGINEERS is primarily intended for determining the tribological characteristics of wide range of materials under conditions of various normal loads, sliding speeds & temperatures (optional). A stationary pin mounted on a pin holder is brought into contact against a rotating disc at a specified speed as the pin is sliding, resulting frictional force acting between the pin and disc are measured by arresting the deflecting pin holder against a load cell. Both normal load and speed can be set as desired. Results such as wear rate, frictional force and coefficient of friction etc. are displayed digitally on the computer screen.

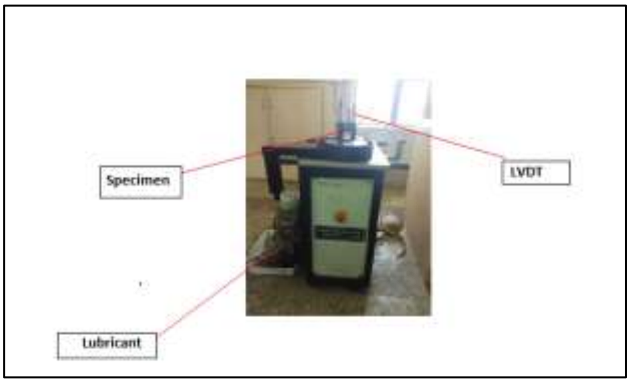


Fig1:- Experimental set up of friction and wear test rig

Specifications of Friction & Wear Test Rig

1. Normal Load Range : 0 – 200 N

2.Specimen Size :3mm-12mm

3.Specimen Length: 30mm -60 mm

4. Wear Measurement range : +/-2mm,least count 1 Micron

5. Rotating Disc Speed : 100 to 3000 rpm

6. Wear Disc Track Diameter :10 mm- 140 mm

A. SPECIMEN PREPARATION

The Standard rod of virgin PTFE and its composite with fillers such as 35% bronze, 35% glass fiber and 35% carbon are available in the market. Each specimen has the following dimension:

1. Diameter of Specimen: 8 mm-12mm

2. Length of Specimen:30 mm – 60mm

Fig 2: Test specimen

Procedure:

1. Insert the test specimen into the pin holder.

2. Put the desired load on load span.

3. Switch on the control panel and set the desired speed and time.

4. Switch on the computer which is connected to the control panel and open the program Wear & Friction monitor by double clicking the icon.

5. Then enter the desired parameters such as specimen diameter, speed, time, load etc. in the program.

6. Now click on "START TEST" icon of program and press the button "CYCLE START" simultaneously. So the test will start after pressing the button.

7. Test will automatically stopped once preset time is over and the results are directly saved in computer. There is no need to take the readings manually.

Above procedure can be used for various conditions of load, speed and time and for all test specimens.

Table 1: Assigning Codes for Four PTFE Materials

MATERIAL	CHEMICAL COMPOSITION IN WT.%
I	35% Carbon filled PTFE
II	35% Bronze filled PTFE
III	35% Glass filled PTFE

Table 2: There are some Levels to the variable as Applicable to Pin-on-Disc machine

LEVELS	LOW	MEDIUM	HIGH
Load(kg)	2	3	4
Speed rpm	300	600	900
Sliding Distance (km)	1.5	3	4.5
Materials	PTFE+ 30% Carbon	PTFE+ 30% Bronze	PTFE+ 30% Glass

4. SAMPLE OBSERVATIONS ON PIN ON DISC MACHINE FOR DIFFERENT MATERIALS:

I. Wear v/s Time plot for PTFE with 35% Carbon Material for following operating Conditions.

Load: 2kgSliding Velocity: 1.57m/s, Sliding Distance: 1.5km .

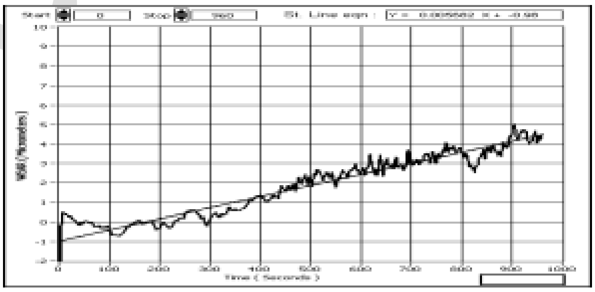
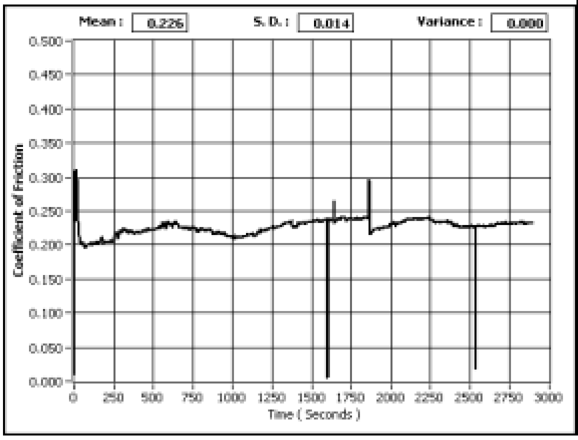


Fig No.3a: Wear v/s Time



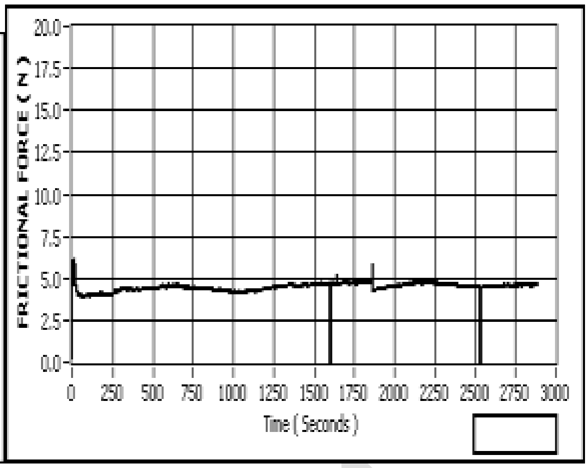


Fig No.3b: Coefficient of Friction v/s Time

Fig No.3c: Frictional Force v/s Time

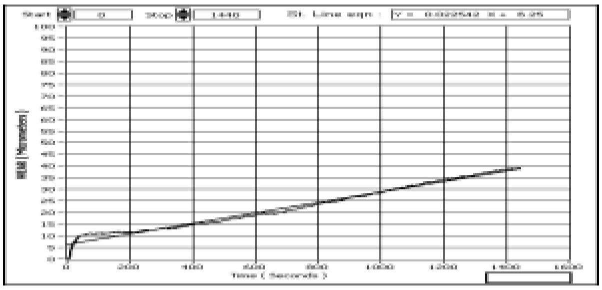


Fig No.4a: Wear v/s Time

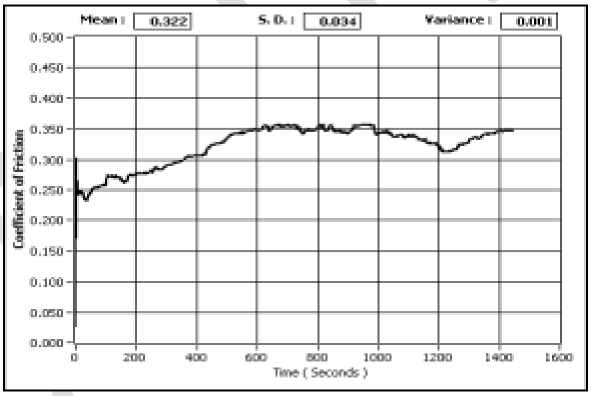


Fig No.4b: Coefficient of Friction v/s Time

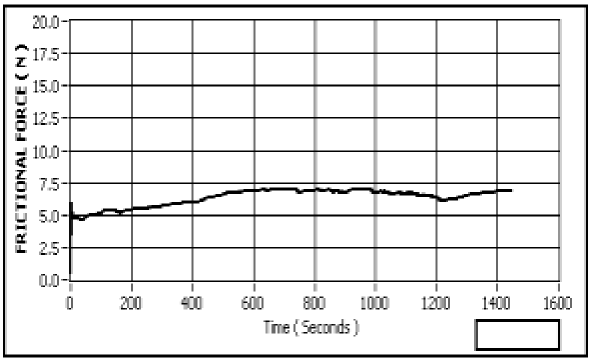
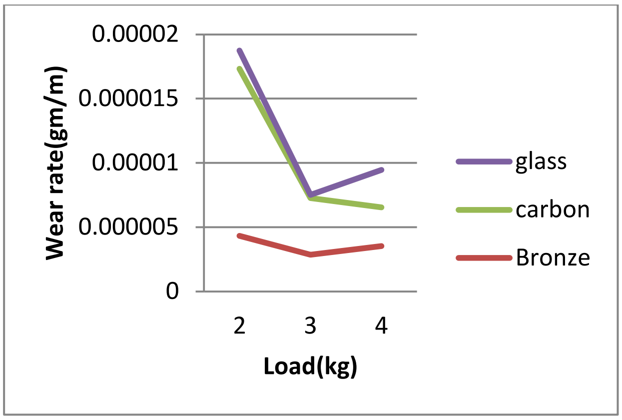
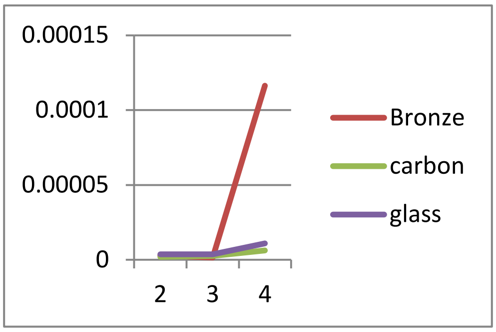
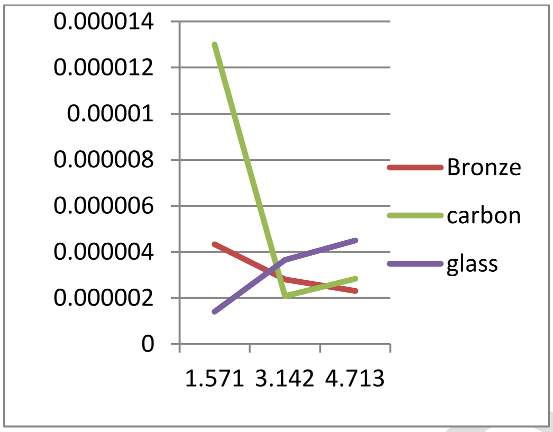
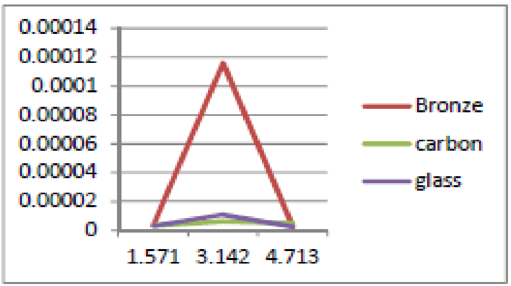


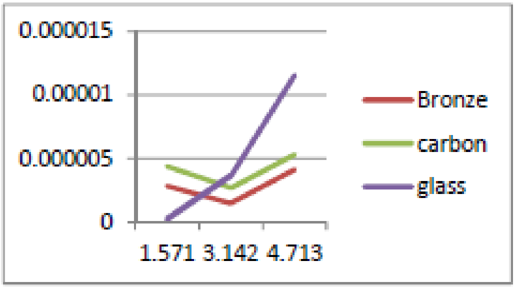
Fig No.4c: Frictional Force v/s Time











. RESULT AND CONCLUSION

1. As load increases wear rate is observed to be decreased for all materials at low sliding speed i.e. 1.57 m/s and at high sliding speed at 4.713 m/s
2. As sliding velocity increases, wear rate decreases at 2kg and 4 kg loadings while found increases for 3 kg loading.
3. PTFE with bronze is found lowest war rate while PTFE with glass is found higher wear rate for almost most of the operating conditions.
4. More detail analysis is required to carry out using Taguchi method design of experiment for accurate conclusion.

REFERENCES

1. Deepak Bagale “Wear Analysis of Polytetrafluroethylene and its composite under dry condition using Design Expert” Volume 3, Issue 1, January 2013,Pp 1-5.
2. M. Xanthos, Functional Fillers for Plastics, in: Polymers and Polymer Composite, 2005 WILEY-VCH, Pp.1-16.

3. H. Unal, A. Mimaroglu, U. Kadıoglu, H. Ekiz, -Sliding friction and wear behaviour Of Polytetrafluroethylene and its composites under dry conditions, Materials and Design 25 (2004) Pp.239-245.
4. S.Basavarajappay and G.Chandramohan,-Wear Studies on Metal Matrix Composites: A Taguchi Approach, J. Mater. Sci. Technol. 21 (2005) Pp.845-850.
5. Sandip B. Chaudhari, {Wear Analysis of Polytetrafluoroethylene (PTFE) and it’s Composites under Wet Conditions” Volume 8, Issue 2 (Jul. - Aug. 2013), Pp. 07-18
6. Shubhangi G Varpe, “Comparative Analysis of PTFE Composite With Different Filler Material Using Taguchi Approach Method” volume 1 Issue 8 –AUGUST 2015 Pp.194-198