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Friction & Wear Analysis of PTFE material & its composites

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Abstract— PTFE (Polytetrafluroethylene) has low coefficient of friction and high thermal stability. Low coefficient of friction concludes from the ability of PTFE's extended chain, linear to form film layer upon its surfaces and counter faces during sliding and increasing the pressure to PTFE enhances to easily form the film layer and improve tribological behaviour. However, PTFE exhibits poor wear behavior and abrasion resistance. To overcome inferior low mechanical properties, the addition of filler materials (glass, carbon, graphite fiber) to PTFE can advance its wear resistance. All of above findings suggest PTFE fillers provide the wear resistance, lower coefficient of friction. The aspect ratio of PTFE seems to be very critical parameter to determine the best working conditions for providing wear resistance and low coefficient of friction of polymer journal bearings. The tribological behavior of PTFE bearings which were run in the experiments under the sliding distance, load and velocities will be investigated. The experimental work is performed on Pin-on-disc Test Rig apparatus and analyzed with the help of minitab software. The results of experiment will be presented in terms of graphs, tables and will be analyzed.

Index Terms—. PTFE (Polytetrafluroethylene), Friction & wear, load, sliding velocity, sliding distance, bearing materials.

1 Introduction

Polytetrafluoroethylene (PTFE) is a useful bearing material since it registers a low coefficient of friction when rubbed against metallic engineering surfaces. This coefficient of friction is an order lower than that recorded for other engineering polymers such as high density polyethylene (HDPE), low density polyethylene (LDPE), nylon and polyetheretherketone (PEEK). The wear resistance of PTFE is, however, rather low, which somewhat impairs its usefulness as an engineering material. Early attention to the complex tribology of PTFE was drawn by Professor David Tabor and his coworkers at the Cavendish Laboratory in the early 1960s. They rubbed PTFE against glass plates and observed that in the steady state the rubbing interaction is confined to the transfer film and a very thin slice of the pin surface. They also noted that this interaction is highly sensitive to sliding speed and inferred that the participation of the amorphous phase in the shear process activates a viscoelastic response which dominates the speed effect. It is interesting to note that this model remained substantially valid even 20 years after it was proposed and after scores of subsequent research investigations. The latter tended to tackle a number of important questions which arose from the early observations. Some of these questions have been answered and recent work tends to use this model to design new PIT%-based composites for essentially enhancing wear resistance without sacrificing the low friction performance.

Polytetrafluoroethylene (PTFE) is an important polymer based engineering material. When rubbed against a hard surface, PTFE exhibits a low coefficient of friction but a high rate of wear. It is white or gray in color. It is an ideal bearing material for heavy and light load pressures with medium and low surface speeds. PTFE has all qualities of bearing alloy like compatibility, conformability; embed ability, load capacity, fatigue strength, corrosion resistance and hardness. The low-friction characteristics of PTFE are largely responsible for the inception. 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. Unfortunately, PTFE suffers from poor wear resistance. 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. Accordingly, several fillers are 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.

There are different opinions in literature about the reducing wear of polymer by incorporating the different types of filler. Study and analyze the influence of test pressure, sliding velocity and time values on the friction and wear behavior of pure-polytetrafluoroethylene (PTFE), glass fiber reinforced (GFR) and Molybdenum disulfide (MoS_2) filled PTFE polymers. Adding glass fiber and Molybdenum disulfide fillers to PTFE were found effective in reducing the wear rate of the PTFE composite. The present filler additions found to increase hardness and wear resistance in all composites studied. The influence of wear parameters like applied load, sliding speed, sliding distance and percentage of reinforcement on the dry sliding wear of the metal matrix composites.

3. Objective

Following are the main objectives of the study.

1. To find the effect of carbon filler, graphite filler, and glass filler in PTFE on wear and coefficient of friction.
2. To study the friction and wear behavior of the selected materials and the effect of various parameters like load, sliding velocity and sliding distance on

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wear and coefficient of friction.
3. To find the optimization of process parameters.
4. To study the mathematical model of bearing materials.
5. To study the brief comparison of bearing materials.

4. Scope

The present study will be aimed at developing a new bearing material, which is cost effective. Bearing materials are special type of materials, which carry a rotating or moving part with least friction and wear. One of the principal difficulties in developing a good bearing material is that the two practically conflicting requirements are to be satisfied by a good bearing material. . The work is done by evaluation of tribological properties by changing the process parameters, such as load, sliding velocity, sliding distance etc.

5 Methodolgy

1. Problem Definition
2. Taguchi Method
3. Experimentation
4. ANOVA
5. Regression Analysis
6. Analysis and Interpretation of Result Citations

6 Friction of material

Friction is the resistance to relative motion, which is experienced whenever one solid body slides over another. The resistive force, which is parallel to the direction of motion, is called the friction force. If the solid bodies are loaded together and a tangential force is applied, then the value of the tangential force, which is required to initiate sliding, is the static friction force. The tangential force required to maintain sliding is the kinetic friction force. Kinetic friction is generally lower than static friction.

6.1 Laws of Frictions

1. First law states that the friction is independent of the apparent area of contact between the contacting bodies.
2. Second law states that the friction force is proportional to the normal load between the contacting bodies.
3. Third law states that the kinetic friction is nearly independent of the speed of sliding.

First two laws are often referred to as Amontons laws and Coulomb introduced third law.

6.2 Coefficient of Friction

The second law states that the friction force F is proportional to the normal load L.
i.e., F α L
Therefore, F = μ L
Where, μ is a constant known as the coefficient of friction and is a constant only for a given pair of sliding materials under a given set of ambient conditions and varies for different materials and conditions. We know that nearly all surfaces are rough on a microscopic scale and real contact is obtained over a small fraction of the apparent contact area. Thus the real area of contact is independent of the apparent area of contact so thefirst law of friction is explained that friction is related to the real area of contact and independent of the apparent area of contact.

6.3 Friction Measuring Devices

Any apparatus for measuring friction must be capable of supplying relative motion between two specimens, of applying a measurable normal load and of measuring the tangential resistance to motion. Commonly used devices are pin on cylinder or disk and disc on disc. In these cases, one specimen, usually a disc or a cylinder is driven continuously while a second specimen nominally stationary is loaded against it.

6.4.Materials

From literature survey, it was noted that friction gets affected by the material properties and PTFE is mostly used for tribology applications. Due to poor wear rate and coefficient of friction this material is weak in performance. From the addition of fillers wear rate and coefficient of friction can be reduced, therefore author decided to do experimental study of friction with some composites materials of PTFE.
Pure PTFE and three PTFE based composite materials were studied in the present work. The compositional details of each material are:

Table 3.1.Composition (vol. %) of PTFE composites

Materials
Pure PTFE
75.0% PTFE + 25% E glass fibers
75.0% PTFE + 25% carbon
75.0% PTFE + 25% graphite

legible. We suggest at least 1 point.

7. Experimatal details

From literature survey it was noted friction gets affected by material properties, process parameters, constructional parameters and geometrical parameters. Therefore, experimental study of friction with process parameters is carried out. Friction and wear test rig is used to carry out the experimental analysis because the test rig gives a detailed idea about all the process parameters and the corresponding output results to study the effect of friction on the materials. The experimental test rig is as shown

Figure 3.1 Experimental Setup of Friction and Wear test rig

7.1 Specifications of friction & wear test rig

1. Pin Diameter: 10 mm
2. Disc Size: 140*30*8mm (OD, ID, H)
3. Disc Rotation Seed: 60 to 100 rpm, continuously variable with tachometer
4. Sliding Speed: 0 to 15 m/s

Normal load: 20 kgf maximum

7.2 Observations

Distance of loading point from pivot (L_1) = 830mm
Distance of pin center from lever pivot (L_2) = 445mm
Distance of load cell link connected on lever from pivot (L_3) = 250mm

7.3 Calculations

Coefficient of friction (μ):

μ =

Where, F_t = frictional force = load indicator reading * L_3/L_2
W = load on pin = dead weight * L_1/L_2
L_1 = 830mm, L_2 = variable, L_3 = 250mm
Here, L_2 will vary as per the pin travel radius,
Assuming, track radius 45mm
L_2 = 500-45= 455mm
L_1/L_2 = 1.824 and L_3/L_2 = 0.5494

Sliding distance (D):

Sliding distance (D) = V * t
Where, V = sliding velocity,
t = time of test in sec.
And
Sliding velocity (V) = π * r * N…. (m/s)
Where, r = track radius of pin in m
N = speed of disc in rps.

Sample Calculations

For Wear,
For material no. 1 & reading no. (1),
We have, N=138 rpm, L=1 Kg, d=45 mm, T=30min
Sliding velocity (V) = π * r * N…. (m/s)
V =
V = 0.325 m/s
V = 0.3 m/s
Sliding distance (D) = V * t
D = 0.3*1800
D = 540 m
For Friction,
For material no. 1 and reading no. 1
We have, N=150rpm, L=2kg, T=10min.
F_t = frictional force = load indicator reading * L_3/L_2
F_t = 1.1*0.5494
F_t =0.60434
W = load on pin = dead weight * L_1/L_2
W= 2*1.824
W= 3.648
μ =
μ =
μ = 0.1656

7.4 Effect of process parameters on friction

There are several parameters which change the properties of material during experimentation i.e. sliding velocity, sliding distance and applied load. All these parameters affect the tribological properties of materials. Table depicts the process parameters.

Table Process parameters and levels for friction

Level	Sliding Velocity (m/s) (V)	Load (kg) (L)	Sliding Distance (m) (D)
1	0.3	2	210
2	0.7	3	426
3	0.9	4	528

7.5 Effect of process parameters on friction

By considering the various combinations of process parameters experimentation was carried out which gave the output values of coefficient friction. From this various relations between the output and the input parameters were obtained and were eventually compared with each other.

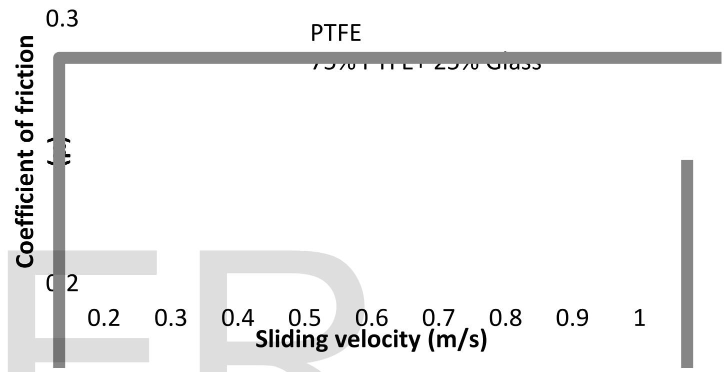

Figure - Coefficient of friction v/s Sliding velocity

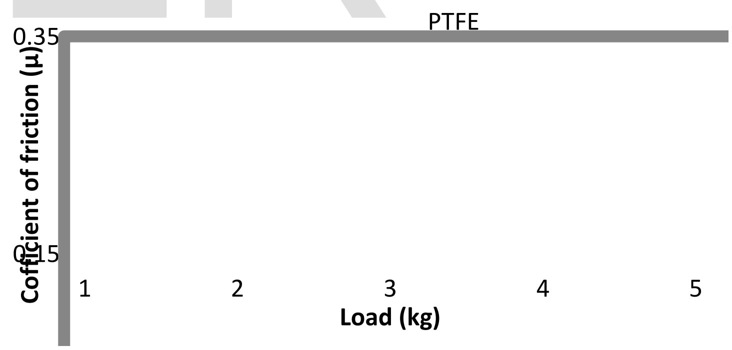

Figure -Coefficient of friction v/s Load

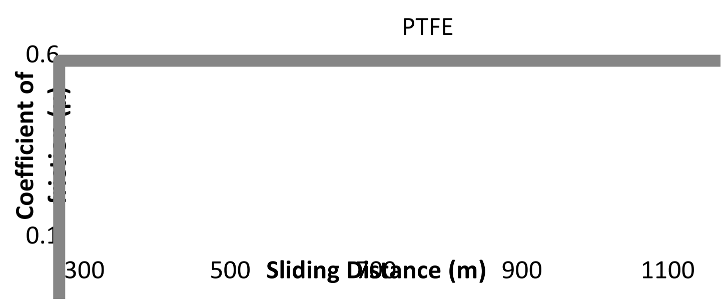

Figure- Coefficient of friction v/s Sliding distance

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7.6. Effect of process parameters on wear

There are several parameters which change the properties of material during experimentation i.e. sliding velocity, sliding distance and applied load. All these parameters affect the tribological properties of materials. Table 4.1 depicts the process parameters.

Level	Speed (m/s) (V)	Load (kg) (L)	Sliding Distance (m) (D)
1	0.3	1	540
2	0.6	2	1080
3	0.8	3	1440

Table - Process parameters and levels for wear

By considering the various combinations of process parameters experimentation was carried out which gave the output values of wear. From this various relations between the output and the input parameters were obtained and were eventually compared with each other.

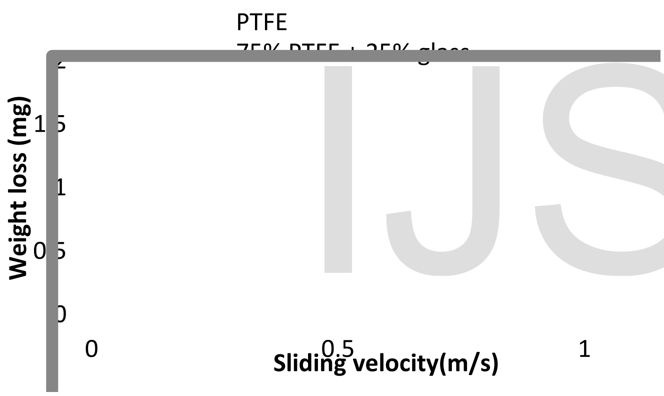

Figure - Weight loss v/s Sliding velocity

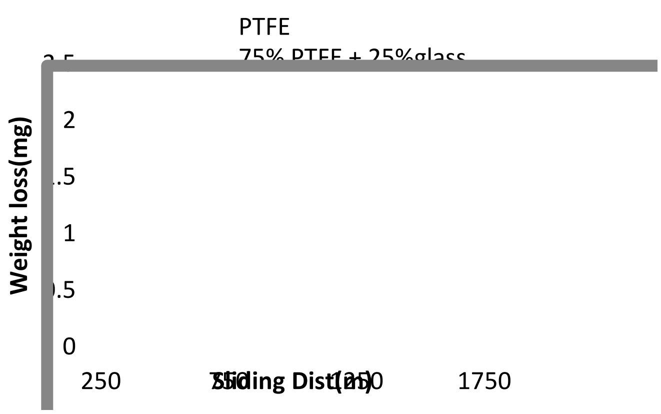

Figure - Weight loss v/s Sliding distance

8. CONCLUSION

- Sliding distance (64.09%) has the highest influence on weight loss followed by sliding velocity (20%) and applied load (7.71%) also Applied load (88.65%) has highest influence on coefficient of friction followed by sliding velocity (9.08%) and sliding distance(0.57%) for pure PTFE.
- Sliding distance (61.75%) has the highest influence on weight loss followed by sliding velocity (16.46%) and applied load (20.92%) also Applied load (81.51%) has highest influence on coefficient of friction followed by sliding velocity (14.97%) and sliding distance(2.50%) for 25% glass.
- Sliding distance (70.20%) has the highest influence on weight loss followed by sliding velocity (16.64%) and applied load (12.21%) also Applied load (83.56%) has highest influence on coefficient of friction followed by sliding velocity (13.31%) and sliding distance(2.22%) for 25% carbon.
- Sliding distance (69.01%) has the highest influence on weight loss followed by sliding velocity (19.08%) and applied load (10.90%) also Applied load (85.24%) has highest influence on coefficient of friction followed by sliding velocity (11.94%) and sliding distance(1.99%) for 25% graphite.
- Coefficient of friction of Pure PTFE is less than 25% glass, 25% graphite and 40% carbon.
- Coefficient of friction slightly increases or remains same by adding fillers.
- From confirmation test it is observed that coefficient of friction is in the range of 0.2 to 0.3 which interprets that all the three materials are significant.
- Depending upon load, sliding velocity and sliding distance, material used in this study can be ranked as 75% PTFE + 25% Graphite> 75% PTFE + 25% carbon> 75% PTFE + 25% Glass> Pure PTFE for their wear performance.
- Depending upon load, sliding velocity and

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