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A Review on Tribological Wear behaviour of Reinforced Glass Fiber, Carbon Fiber and MoS2 on PTFE

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Abstract: In this work, the paper reviews on tribological behaviors of Polytetrafluroethylene (PTFE) composites with filler materials such as reinforced glass fiber, carbon fiber and mos2 under parameters like varying load, sliding distance and sliding speed on pin on disc apparatus. Now a day's pure PTFE (polytetrafluoroethylene) is widely used as bearing material which is self lubricating and subjects to lower coefficient of friction, but problem with PTFE is that, it subjects to high wear rate, which can be reduced by adding suitable fillers.

Keywords: PTFE, filler materials, pin on disc, PTFE composites.

I. INTRODUCTION

Today thermoplastic polymer composites are widely used as structural materials in automotive, manufacturing, aerospace and chemical industries to provide lower weight alternatives and self lubrication to traditional metallic materials. These applications in the many industry sectors are concentrated on tribological machine parts, such as gears, cams, bearings and seals, due to their many advantages of polymer composites as self lubrication The main advantages of these polymers are high wear resistance, cost, weight, silent operation and manufacturability at non-lubricated dry conditions in journal bearing materials. Glass fibers (GF) and carbon fibers (CF) which are short fiber reinforcements have been successfully used to improve the strength to high pressure, high load carrying capacities and stiffness. In addition, to effectively reduce the coefficient of friction of journal bearings, PTFE additives more commonly known as Teflon. PTFE (Polytetrafluoroethylene) 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 mating counter faces during sliding. In addition, PTFE enhances to easily form the film layer on contact surfaces of steel and improve tribological behavior. However, PTFE exhibits poor wear behavior and abrasion resistance, especially over against to increasing the loads. The wear rate of ptfe can be significantly decreased by addition of suiatble filler materials

II. LITERATURE REVIEW

Jaydeep Khedkar et. al.,[1] have explained in the paper entitled „Sliding wear behavior of PTFE composites‟,[2002]that the tribological behavior of polytetrafluoroethylene (PTFE) and PTFE composites with filler materials such as carbon, graphite, E glass fibers, MoS2 and poly-p- phenyleneterephthalamide (PPDT) fibers, was studied. The present filler additions found to increase hardness and wear resistance in all composites studied. The highest wear resistance was found for composites containing (i) 18% carbon + 7%graphite, (ii) 20% glass fibers + 5% MoS2 and (iii) 10% PPDT fibers. Scanning electron microscopy (SEM) was utilized to exam in ecomposite microstructures and study modes of failure. Wear testing and SEM analysis showed that three-body abrasion was probably the dominant mode of failure for PTFE + 18% carbon + 7% graphite composite, while fiber pull out and fragmentation caused failure of PTFE + 20% glass fiber + 5% MoS2 composite. The composite with 10% PPDT fibers caused wear reduction due to the ability of the fibers to remain embedded in the matrix and preferentially support the load. Differential scanning calorimetry (DSC) analysis was also performed to study the relative heat absorbing capacity and thermal stability of the various composites in an effort to correlate these properties to the tribological performance. The results indicated that composites with higher heat absorption capacity exhibited improved wear resistance. The dominant interactive wear mechanisms during sliding of PTFE and its composites are discussed in view of the present findings.

Fuzhi Song, Qihua Wang, Tingmei Wang et. al [2] has reported in Materials and Design (2016) In this work, tribological behaviors and PV limit of chopped carbon fiber, glass fibers and MoS2 reinforced PTFE composites were investigated. The experiment results revealed that single incorporation of MoS2 could improve anti-wear property significantly under low velocity but shown a failure at 3 m/s. However, glass fibers deteriorated the wear resistance of the PTFE composite drastically as single filler. A synergistic effect was found for the

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combination of MoS_2 and glass fibers, which lead to the best tribological properties with the highest PV limits of 9.5 MPa·m/s at 1 m/s and 15 MPa·m/s at 2 m/s. The synergistic effect of MoS_2 and glass fibers has great effect on improving tribological behaviors and PV limit of composite E. The anti-wear property and PV limit are improved significantly when combines MoS_2 particulates with glass fibers especially under higher velocities.Polytetrafluoroethylene (PTFE) is one of the most promising polymers for engineering applications as structural and lubricating materials, such as shaft seals,sliding bearings, piston rings, etc. It is a semi-crystalline polymer with the lowest friction coefficient, high melting point (~330 °C), excellent chemical resistance and outstanding anti-aging performance. However, the poor wear resistance is one of thelargest drawbacks limiting the application of PTFE MoS_2 reduces the wear rate significantly by reducing counterface scratch damage and stress concentration on fibers, which alleviates the fibers pulling out from the resin acting as hard abrasive particles. Meanwhile, the composite C presents the best anti-wear properties at 1 m/s (0.78×10^{-6} mm^3/Nm) and 2 m/s (1.50×10^{-6} mm^3/Nm) under 4 MPa·m/s, respectively, but the wear rate of C increases greatly at 3 m/s due to the failure of transfer film and material surface failure. Composite C is suitable to operate in low velocity conditions. The PV limit is 6 MPa·m/s under 1 m/s, and the highest possible PV values under 1 m/s is 5.5 MPa·m/s with low wear rate (1.58×10^{-6} mm^3/Nm) and friction coefficient (0.113).Glass fibers show poor reinforcement in improving anti-wear property of PTFE composite D due to severe abrasive wear. Composite D shows the worst anti-wear property range from 1 m/s to 3 m/s, while it performs the lowest friction coefficient (0.083 at 1 m/s under 6 MPa·m/s). However, the glass fibers provide a tough and homogeneous transfer film with good interfacial compatibility above 2 m/s, which provides counterface with an effective support and protection from scratching and reduces the wear rate of transfer film dramatically.The synergistic effect of MoS_2 and glass fibers has great effect on improving tribological behaviors and PV limit of composite E. The anti-wear property and PV mlimit are improved significantly when combines MoS_2 particulates with glass fibers especially under higher velocities. The PV limit of composite E is reached to 9.5 MPa·m/s (1 m/s) and 15 MPa·m/s (2 m/s), respectively. It is suitable to operate in high velocity conditions and 2 m/s is the best.

Marcelo Kawakame, Jos´e Divo Bressan [3] has reported in his literature has invistegated Normal load, velocity and air relative humidity were considered variable in the wear tests. The friction and the wear mechanisms are briefly reviewed. Various polymeric materials containing solid lubricants inside its microstructure were investigated. The selflubricating characteristics of the added charge as well as the polymeric matrix were considered in the composite selection. Discs of pure PTFE (Teflon), composites PTFE + graphite, PTFE + MoS_2 + glass fibres, PTFE + bronze were tested against pins of quenched and tempered SAE 1045steel. Pins of PTFE + MoS_2 + glass fibres were also tested against 1045 steel disks. In all tests, debris and flakes of worn materials were deposited on the pin counter face and these particles defined the wear mechanism. Through the analyses of micrograph taken by scanning electron microscopy,the following conclusion can be drawn: friction and wear in polymers are fundamentally different from the mechanisms which occurs in metals and ceramics, although they are due to the same wear micro-mechanisms: micro-plowing, micro-cutting and flake delamination. A very important conclusion on wear resistance of polymers and composites is its strong dependence on the environmental relative humidity and normal load. Variations observed in the relative air humidity from 50 to 70% can duplicate the lost volume by wear and, consequently, to double the wear rate.Among the tested materials, the composites PTFE with additive graphite or MoS_2 and glass fibres have shown the greatest sliding wear resistance. Finally, analyzing the results from the pin-on-disc tests, it can be concluded that the reinforced PTFE with 15% glass fibers type E and additived with 5% of solid lubricant molybdenum disulphide (MoS_2) and the PTFE additived with 15% graphite presented the better characteristics for polymer wear resistance,
in such case they are more indicated to be utilized in lip seals in electrical motors
P.D. Pansare et al [4] "Tribological behaviour of PTFE composie material for Journal bearing"in IJIERT[2015]In this study, the effect of load and sliding velocity on friction and wear of materials made of PTFE and PTFE composites with filler materials such as 25% carbon, 35% carbon, 40% bronze, 15% glass fiber, 15% glass fiber + 5% MoS_2 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. The results of experiments are presented in tables and graphs which shows that the addition of carbon, bronze, glass filler to the pure PTFE decreases wear rate significantly and there is slight increase in coefficient of friction. The highest wear resistance was found for 15% glass fiber + 5% MoS_2 filled PTFE followed by 35% carbon, 25% carbon, 15% glass fiber, 40% bronze and pure PTFE. Through this study, we can suggests the best suitable self lubricating material for sugarcane milling roller journal bearings to enhance the wear life.

S.M. Yadav et al [5] "Studies on wear resistance of PTFE filled with glass & bronze particle based on Taguchi techniques" in [2013]An attempt has been made to study the influence of wear parameters like applied load, sliding speed, sliding distance on the dry sliding wear of PTFE, PTFE+25% Glass and PTFE+40% Bronze composites. A plan of experiments, based on techniques of Taguchi, was performed to acquire data in controlled way. An orthogonal array and the analysis of variance were employed to investigate the influence of process parameters on the wear of composites. The experimental results shows that sliding distance and applied load were found to be the more significant factors among the other control factors on wear. The objective is to establish a correlation between dry sliding wear of composites and wear parameters. These correlations were obtained by multiple regressions. A good agreement between the predicted and actual wear resistance was seen.

2.1 MATERIALS

Pure PTFE and two PTFE based composite materials were studied in present work.The Composite material classified into following two groups.

Group I
PTFE+ 15%Glass fiber+5%MoS_2
PTFE+ 20%Glass fiber+5%MoS_2
PTFE+ 25%Glass fiber+5%MoS_2
Group II
PTFE+ 15%Carbon fiber+5%MoS_2
PTFE+ 20%Carbon fiber+5%MoS_2
PTFE+ 25%Carbon fiber+5%MoS_2

III. EXPERIMENTAL TOOLS, TECHNIQUES AND METHODOLOGY

3.1 Design of Experiment It is methodology based on statistics and other discipline for arriving at an efficient and effective planning of experiments with a view to obtain valid conclusion from the analysis of experimental data. 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.

3.2 Introduction to Design Expert 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

3.3 Taguchi Method:

Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal array. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment. The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Englishman, Sir R. A. Fisher. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments which produces the most information is known as a partial fraction experiment. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments.

IV. EXPERIMENTAL DETAILS

4.1 Disc

The disc of diameter160mm and thickness 8 mm is selected as the rotating counter surface. Disc made by spheroid graphite. The disc having four equidistance holes at 145 mm pitch circle diameter.

4.2 Pin Size

The specimens for wear test were prepared of diameter 6mm and length 30mm. For hardness test specimens were prepared of diameter 10mm and height 10mm.

4.3 EXPERIMENTAL SET UP

Experimental set up which is available in Dr. VitthalraoVikhe Patil College of Engineering, Viladghat, Dist-Ahmednagar, is as shown in following fig.1. Using pin-on-disc Tribometer (TR-20LE) readings of wear and frictional force are taken.

Fig.1 .photograph of experimental set up (Tribometer Tr-20 LE)

Table 1. Specification of Pin-on Disc Friction and Wear Monitor Tr-20

Pin size	**3 to 12 mm diagonal**
Disc size	**160 mm dia. X 8 mm thick**
Wear track diameter (mean)	**10 mm to 140 mm**
Sliding speed range	**0.26 m/sec. To 10 m/sec.**
Disc rotation speed	**100-2000 rpm**
Normal load	**350 N maximum**
Friction force	**0-200N,digital readout, recorder output**
Wear measurement range	**4mm,digital readout, and recorder output**
Power	**230 v, 15a, 1 phase, 50 hz**
Temperature Range	**0^o c to 300^o c**

V. VARIABLES IN WEAR TESTING

- Load
- Velocity
- Temperature
- Contact Area
- SURFACE FINISH
- Sliding Distance
- Environment
- Material
- Counterface-1
- Counterface-2
- Hardness of counter face

The TR-20LE Pin on disc wear 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 & Frictional force. The machine is designed to apply loads up to 200N and is intended both for dry and lubricated test conditions

Load:-
It is a common knowledge that the friction force is proportional to the normal applied load (the first law of friction).Load is applied through the lever and the pulley arrangement. Considering the pressure of 11.38 N/mm² in the application between sugar mill journal & bearing in this particular experimental set up is applied by the weight of 17.63 kg.

Velocity:
It is agreed that the friction force is independent of the sliding velocity. This proposal is valid with a good approximation only in the case where the contact temperature varies insignificantly and, as a result, the interface does not change its behavior.
The unit is equipped with a 1.5 HP, variable speed motor with a ± 0.5% accuracy (full scale) configured for 220 V, single phase, 50 Hz

Temperature:
Polymers as viscoelastic materials are very sensitive to frictional heating. It is well known that friction is a typical dissipative process in which mechanical energy is converted into heat. The thermal state of friction contact is frequently a decisive factor when evaluating the performance of a friction unit. In this particular experimental work no such facilities were available for the test rig. The room temperature during the test condition was kept about 27°C.During the test the environmental temperature can be recorded.

Contact Area:
Contact area between the pin and disc Contact area between the pin and disc is 50.265 mm². (Diameter of pin is 8 mm.)

Surface Finish:
The surface finish was 1.31 micron & 0.56 micron, which gives the different wear between the disc & bearing materials.

Sliding Distance:
Sliding distance was constant throughout the experiment for different mating surfaces for all condition Experiments on Group I and II are under process

VI. CONCLUSIONS

From the analysis on the results of dry sliding wear of the PTFE Filled with Bronze, Mos2 composites, the following conclusions can be drawn from the study
1. Pure PTFE gives very high wear rate as compared to composite PTFE.
2. Composite PTFE has much good mechanical and tribological properties as compared to Plain PTFE.
3. Wear rate is directly proportional to load applied.
4. Coefficient of friction is inversely proportional to the Load applied the study
Composite PTFE has much good mechanical and tribological properties as compared to Plain PTFE.
5. Wear increases as roughness of counter surface increases.

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