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Tribological Behavior of PTFE Composite For Journal Bearing

[#1]P. D. Pansare,[#2]D. S. Bajaj

[1]pavanpansare12@gmail.com
[2]dipakbajaj@yahoo.com

[#12]Department of Mechanical Engineering, Amrutvahini College of Engineering, SavitribaiPhule Pune University, Sangamner, [MS], India-422 608.

ABSTRACT

Polytetrafluroethylyne (PTFE) composites filled with different fillers and various filler proportions were made by compression molding. In sugar factory, the material for journal bearing (gun metal) could be replaced by the PTFE composite material. The tribological behavior of PTFE and PTFE composite with different fillers such as combination of i) 15% carbon and 10% graphite, ii) 40% bronze, iii)15% E glass fiber and 3% molybdenum disulphide was studied. The present filler additions found to increase hardness and wear resistance in all composites studied. Scanning electron microscopy (SEM) was utilized to examine composite microstructures and study modes of failure. 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.

Keywords— **Polytetrafluroethylyne, Scanning electron microscopy (SEM), Differential scanning calorimetry (DSC)**

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I. Introduction

Sliding bearings used in most large power generation machines are designed to operate in the fully hydrodynamic regime with a thick oil film separating the sliding and stationary surfaces. In the full film regime, these bearings provide low friction and extremely long service life. White metal (Babbitt) materials have traditionally provided acceptable performance. However, changes in electricity markets and the introduction of variable power sources have resulted in more frequent starts and stops of power generating machines. Because the Babbitt material currently in use is not optimum for these conditions due to its potential for being damaged by seizure at start-up, hydraulic jacking systems are often used to flood the bearing pads and lift the machine prior to start-up. Since its invention in the 1930s, countless studies have found PTFE to provide low friction in dry sliding . However, PTFE is also associated with some of the highest wear rates among crystalline polymers in dry contacts. A review of work related to polymers, including PTFE, with nano-particle fillers found that the choice of the counter-surface material's chemical properties had no effect on the wear rate of PTFE. Presumably, wear of the PTFE is primarily caused by the roughness of the counter-surface. Formation and property of transfer film are crucial wearreduction factors for many tribological engineering materials,especially those used under dry friction situation. Increasing tribologicaluse of polymer has made the study on transfer film ofpolymer very important and in urgent need.

To many polymers,it has been found introduction of filler could greatly change theirtribological behavior. Such change on tribological behavior ofthe bulk composite material is directly related to the change oftribological properties of the corresponding transfer film formedduring the friction process. Nowadays, reduction of lubricants is considered of great importance being their regeneration and disposal governed by harsh acts which entail high added costs. In fact, they are estimated to be used by 46% in the automotive and factory farm industry, by 47% in general production industry and by 7% in the marine and aeronautical industry. One of the most used material taken for the purpose of pollution free and non-lubricated in dry running reciprocating movement is Polytetrafluoroethylene (PTFE). It is well known for its relevant tribological characteristics, in particular low friction and quasi-absence of sticking effect, high resistance to temperature and good compatibility. Furthermore, PTFE fibrils broke along their length, leaving fragment running along the surface as well as transferred to the counterface, oriented along the sliding direction. Such fragments fractionally cover the counterface filling in the roughness valleys to form a transfer film. Because of its chemical inertness, PTFE cannot be cross-linked like an elastomer, therefore it has no memory and is subject to creep: compounding fillers are used to control unwanted creep, as well as to improve wear, friction and other properties. It is important to keep in mind that PTFE fillers do not act like elastomer fillers, which become chemically bonded to the elas- tomer: the high shear modulus fillers are encapsulated and bound by the low shear modulus PTFE .

The most commonly used fillers for tribological applications are carbon, bronze, glass fibers, graphite and molybdenum disulfide in different percentages and sometimes combined between them for improving the wear resistance and the coefficient of friction. Of course other impor- tant properties are affected like abrasiveness (glass fibers and carbon), thermal conductivity (glass fibers), electrical conductiv- ity (bronze), chemical inertness (bronze). Generally the fillers improve the wear resistance from 10 to 500 times and increase the thermal conductivity from 2 to 3 times. In a previous study the authors have found the increment in thermal conductivity and diffusivity of PTFE composites improve their wear resistance to adhesion. The low-friction characteristics of PTFE were largely responsible for the inception of this project. This resin is waxy in appearance, and white or gray in color, except that thin sheets are transparent. It is a crystalline solid with good stability from -320° to +500° F, and is chemically inert to known reagents and solvents except molten alkaline metals and gaseous fluorine under pressure. Its relative softness and poor heat conductivity limit its suitability as a bearing material to applications involving low speeds and low unit pressures.

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 were tried in combination with this plastic, including graphite, molybdenum disulfide, bronze, carbon, fiber glass, dental silicate, silicon, titanium dioxide, silver, copper, tungsten, and molybdenum.

II. Review of papers

HuLin Li, ZhongWei Yin (2014), have explained in the paper entitled “Tribological behavior of hybrid PTFE/Kevlar fabric composites with nano-Si3N4 and submicronsizeWS2 fillers” that the Hybrid PTFE/Kevlar fabric composite specimens were prepared with nano-Si3N4 and/or submicron size WS2 as fillers. Thetribological behaviors of these composites were studied. The morphologies of the worn surface, transfer film and debris were analyzed by means of scanning electron microscopy. In addition, an energy-dispersive X-ray spectrometer was used for analysis of the elemental distribution and content in the transfer film. The results indicate that single nano-Si3N4 fillers can effectively reduce the wear rate of composites, but they do not reduce the friction coefficient. Hybrid Si3N4 and WS2 fillers can significantly reduce the wear rate and friction coefficient of composites.[1]

M. Conte (2012), A.Igartua., have explained in the paper entitled “Study of PTFE composites tribological behavior” that the a comparative analysis of seven PTFE composites is presented showing how properties of PTFE can be improved even if the most attractive characteristic of low friction is lost due to the presence of hard particles in the polymer matrix. How the use of both soft and hard phases in a polymer matrix enhances the self-lubricating and the load-carrying properties of the matrix improving the tribological properties of the PTFE is presented. [2]

ArashGolchin A.(2012), GregoryF.Simmons have explained in the paper entitled “Break-away friction of PTFE materials in lubricated conditions” that this study investigates the tribological characteristics at initiation of sliding (break-away friction) of several polytetrafluoroethylene based materials. Four PTFE composites, pure PTFE, and white metal were tested in a reciprocating tribo-meter with the block on plate configuration against a steel counter-surface. Apparent contact pressure and oil temperature were varied from 1 to 8 MPa and 25 to 85 ^{o}C respectively. SEM investigations revealed wear patterns of the PTFE materials and the abrasive nature of hard fillers. Bronze filled, carbon filled, and pure PTFE were found to provide lower break-away friction and less variation over the course of testing and generally superior properties. [3]

David L. Burris et. al.(2012), have explained in the paper entitled “A Low Friction and Ultra Low Wear Rate PEEK/PTFE Composite” that a PEEK filled PTFE composite exhibits low friction and ultra-low wear. In its neat form, PEEK has high wear resistance, strength, operational temperature, friction coefficient ($\mu \geq 0.4$ in dry sliding), and low thermal conductivity. PTFE is a widely used and well-known solid lubricant that suffers from a high wear rate. Fillers are added to PEEK to reduce the friction coefficient and they are added to PTFE to increase the wear resistance. Samples having a PEEK content greater than 32 wt.% had no wear transients. The wear rates were observed to increase with increasing PEEK content approaching that of unfilled PEEK. This composite material has a friction coefficient lower than unfilled PTFE and PEEK and a wear rate lower than unfilled PTFE and PEEK for every sample tested.[4]G.Y. Xieet. al.(2010), have explained in the paper entitled “Tribological behavior of PEEK/PTFE composites reinforced with potassium titanate whiskers” that the tribologicalbehavior of PEEK/polytetrafluoroethylene (PTFE) composites reinforced with potassium titanate whiskers (PTW) has been investigated using the pin-on-disk configuration under dry sliding conditions at different applied loads. It was found that the PTW reinforced PEEK/PTFE composites exhibited much better tribological properties than those without PTW. Both the friction coefficient and the wear rate decreased with the increase of the PTW content. Moreover, the friction coefficient and the wear rate of the composites showed a decreasing tendency with the applied loads increasing from 1.0MPa to 2.0 MPa. The crystallinity of the composite measured from differential scanning calorimeter (DSC) slightly decreased with the addition of PTW, which might imply that the crystallinity of PEEK was not the dominant factor that influenced the tribological properties of the composites. It was believed that the abrasive effect on the counterface by the whiskers at the initial stage, the formation of a thin, uniform and tenacious transfer film on the counterface.[5]

Yunxia Wang et. al.(2007),have explained in the paper entitled "A study on tribologicalbehaviour of transferfilms of PTFE/bronze composites" that the transfer films of PTFE/bronze composites with 5–30% volume content of bronze were prepared using a RFT friction and wear tester on surface of AISI-1045 steel bar by different sliding time (5–60 min). Tribological properties of these transfer films were studied using a DFPM reciprocating tribometer in a point contacting configuration under normal loads of 0.5, 1.0, 2.0 and 3.0 N. Thickness and surface morphology of the transfer films were investigated. It was found thickness of the transfer films slightly increased along with the increase of bronze content of corresponding composites. Increased sliding time of transfer film preparation is helpful to form transfer film with better ductibility and continuity, but sliding time almost has no effect on tribological properties of the transfer film. Higher bronze content in the composite improved tribological properties of the corresponding transfer film, i.e. reduced friction coefficient and prolonged wear life. These transfer films are sensitive to load change. [6]

Yunxia Wang (2006), have explained in the paper entitled "Tribological properties of transfer films of PTFE-based composites" that PTFE-based composites containing 15 vol.% MoS2, graphite, aluminum and bronze powder, were respectively prepared by compression molding at room temperature and subsequent heat treatment in atmosphere. Transfer films of pure PTFE and these composites were prepared on the surface of AISI-1045 steel bar using a friction and wear tester in a pin on disk contacting configuration. Tribological properties of these transfer films were investigated using another tribometer by sliding against GCr15 steel ball in a point-contacting configuration. Morphology of the transfer films and worn surface of the steel ball were observed and analyzed using SEM and optical microscopy. It was found all these fillers improved wear resistant capability of the composites. Compared with pure PTFE, introduction of the fillers made the corresponding transfer films have longer wear life. Introduce of fillers is helpful to improve load bearing capability of the transfer films when sliding against steel ball which are also favorable to prolong the wear life of the transfer films. Tribological properties of these transfer films are sensitive to load change. Generally, increased load shortened wear life of transfer film. [7]

JaydeepKhedkar (2002), have explained in the paper entitled "Sliding wear behavior of PTFE composites " that the tribological behavior of polytetrafluroethylene (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 examine composite 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. [8]

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III. EXPERIMENTAL PROCEDURE

A. Working Steps

- Carry out the literature survey carefully.
- Find out the problem statement regarding the research work.
- Find out the research gap and the objectives of the research work.
- Selection of proper fillers for selected application.
- Testing is carried out on Pin on disk trobotester under prescribed condition.
- Compare the anti-wear properties of various filler materials with reference to materials of journal bearing.
- Make a conclusion regarding hardness, wear, coefficient of friction from the results.

B. Wear Testing Machine

Experimental set up which is available in Amrutvahini College of Engineering, Sangamner is as shown in following photograph. Using a pin-on-disc Tribometer (TR-20LE) readings will taken

.

Fig 5.1 – Pin on disk tribometer(TR - 20LE)

C)Sample Preparation:-

For the testing PTFE composite,materials are purchased from Perfect packaging, MIDC, Bhosari, Pune. This material is in the form of cylindrical rod with dimentions 12.5 mm diameter and 105 mm length. The test specimens (pins) of 10mm diameter and 30mm length are cut from , Workshop of Amrutvahini college of engineering, sangamner, Dist – Ahmednagar. The disc of materal AISI SS 304 stainless steel plate is finished by prathmesh Industries, MIDC, Moshi, Pune. The surface roughness Ra for counter surface i.e. for disc is measured on the SURFTEST 221 series 178, MITUTOYA (Japan made) instrument, in metrology & quality control laboratory of Amrutvahini college of engineering, Sangamner.

D. Tribological Testing

1. Connect the power input cable to 230 V, 50 Hz, and 15 Amps supply. Switch ON controller. Allow 5 minutes for normalizing all electrical items. Thoroughly clean specimen pin, remove burs from the circumference using emery paper. Clean the wear disc thoroughly with solvent and clamp it on holder using four screws. With the help of dial indicator, clamp disc within 10 µm run out.
2. Insert specimen pin inside the hardened jaws and clamp to specimen holder. Set the height of specimen pin above the wear disc using height adjustment block, ensuring the loading arm always horizontal. Tighten clamping screws on jaws to clamp specimen pin firmly.
3. Swivel off the height adjustment block away from loading arm.
4. Set the required wear track radius by moving the sliding plate over graduated scale on base plate. Tighten all 6 clamping screws to ensure assembly is clamped firmly.
5. Wear display: Loosen LVDT lock screw, rotate thumbscrew to bring LVDT plunger visually to mid position, the wear reading display on controller should be as near to zero. Initialize wear display to ‘0’ by pressing ‘ZERO’ push button on controller.
6. Frictional force display: Move loading arm away from frictional force load cell button and set frictional force display ‘0’ by pressing corresponding ‘ZERO’ button on controller.
7. Place required weights on loading pan to apply normal load.
8. Setting disc speed: Set 10 minute time on controller, press test start push button and rotate. Set rpm knob on controller in clockwise direction till required test speed is displayed. Continue to run for the remaining time to observe for any fluctuation. Press STOP button on controller.
9. Setting test duration on controller: Test duration is set either in time mode (set in hr, min, sec) or counter mode (set in no. of cycles, max. is 100000 cycles). Mode selection is by the toggle switch below timer display, the switch position indicates selection as either time or counter.
10. Setting of computer for data acquisition:
    - Connect the data acquisition cable from controller to PC.
    - Open the software Winducom 2008 on PC.
    - Click on mode run continuously icon on software screen to activate screen.

E) DSC Experiments:-

DSC studies on the PTFE and PTFE composites were carried out using a SEIKO 6200 system coupled with a computer station (HP 712/60). The objective here was to study possible reactions taking place between the fillers and the matrix at high temperatures and investigate the thermal stability of the present composites. All experiments were carried out in an oxygen atmosphere and at a heating rate of 5 $^{\circ}$C/min up to 400 $^{\circ}$C. The amount of heat absorbed by the materials during melting (i.e. heat of fusion in mJ/mg) was also estimated for each case by calculating the area of the melting peak. The results were obtained as input energy versus temperature.

IV. EXPECTED OUTCOME

Examinethe tribological properties of the filler materials is main basic task of research work. I am going to make a conclusion about hardness, wear, coefficient properties of filler materials from the materials of journal bearing. So from the result it is expected that the filler materials have better propertiesthan the material of selected journal bearing application.

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REFRENCES

1. HuLin Li, ZhongWei Yin “Tribological behavior of hybrid PTFE/Kevlar fabric composites with nano-Si3N4 and submicronsizeWS2 fillers” , Tribology International 80(2014)172–178

2. M. Conte ,A.Igartua., "Study of PTFE composites tribological behavior", Wear 296 (2012) 568–574.
3. ArashGolchin a, Gregory F. Simmons "Break-away friction of PTFE materials in lubricated conditions" , Tribology International 48 (2012) 54–62
4. David L. Burris et. al., "A Low Friction and Ultra Low Wear Rate PEEK/PTFE Composite" Three-dimensional and dynamic modeling, Wear 270 (2012) 431–438.
5. G.Y. Xieet. Al., "Tribological behavior of PEEK/PTFE composites reinforced with potassium titanate whiskers", Wear 268 (2010) 424–430.
6. Yunxia Wang et. al., "A study on tribologicalbehaviour of transferfilms of PTFE/bronze composites", wear 262 (2007) 876–882.
7. Yunxia Wang, "Tribological properties of transfer films of PTFE-based composites", Wear 261 (2006) 1359–1366.
8. JaydeepKhedkar have explained in the paper entitled "Sliding wear behavior of PTFE composites " , Wear 252 (2002) 361–369.
9. Fei Li,et. al., "The tribological behaviors of copper-coated graphite filled PTFE composites", Wear 237 _2000. 33–38.
10. M. Khonsari, et. al,"Applied Tribology 2e; Bearing Design and Lubrication", John Wiley & Sons,Ltd,2008,(3-4).

