

# A Comparative Study of Different PTFE Composite Materials by Scanning Electron Microscopy Analysis

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**Abstract** - Polytetrafluoroethylene (PTFE) is an important engineering material. When rubbed or slide against a hard surface, PTFE exhibits a low coefficient of friction but a high rate of wear. So to enhance the wear rate of PTFE, different fillers are added. 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, 40% bronze, 15% glass fiber, 15% glass fiber + 5% MoS<sub>2</sub> at wet condition are 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<sub>2</sub> 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. Scanning Electron Microscopy (SEM) was utilized to examine composite microstructures and study modes of failure.

**Keyword:** Design of Experiment, Scanning Electron Microscopy (SEM), Polytetrafluoroethylene (PTFE),

## I. INTRODUCTION

Tribology is the science of rubbing surfaces in relative motion. It is the study of the friction, wear and lubrication of engineering surfaces with a view of understanding surface interactions in detail and then prescribing improvements in given applications. One of the important objectives in tribology is the regulation of the magnitude of frictional force according to whether we require a minimum or a maximum. This objective can be realized only after a fundamental understanding of the frictional process for all conditions like load, sliding velocity, lubrication, surface finish, temperature and material properties [1].

In recent times, there has been a remarkable growth in the large-scale production of polymers and polymer matrix composites. Polymer composites are being more and more used as structural components that are very often subjected to friction and wear loadings under use. In certain situations, the coefficient of friction is of the highest importance, but largely it is the mechanical load-carrying capacity and the wear life of components that determine their acceptability in industrial applications under different operating conditions.

Variables in friction and wear testing are load, velocity, contact area, surface finish, sliding distance, environment,

material of counter face, type of lubricant used, hardness of counter face and temperature. Usually wear is undesirable, because it makes necessary frequent inspection and replacements of parts and also it will lead to deterioration of accuracy of machine parts. It can induce vibrations, fatigue and consequently failure of the parts. For the particular practical application the kind of wear loading can be different, and therefore the structure of the composite material used for these applications can also be different in order to fulfill the particular requirements.

For over sixty years, our world and the quality of its inhabitant's lives have been improved by a resin known as polytetrafluoroethylene or PTFE. It is discovered in 1938 by a DuPont chemist, Mr. Roy J. Plunkett. Upon examination, DuPont learned that PTFE provided a combination of friction, temperature, chemical, mechanical and electrical resisting properties. PTFE ( $(C_2F_4)_n$ ) is recorded in The Guinness Book of World Records for the lowest coefficient of static and dynamic friction as 0.02 - equivalent to wet ice on wet ice [4]. PTFE is a kind of self lubricating material having super low coefficient of friction, outstanding corrosion resistance, chemical inertness and wide service temperature range [5]. PTFE is a frequently used as a solid lubricant both as a filler and matrix. PTFE is currently finding increasing utility in high performance

mechanical seals due to its unique properties like high chemical resistivity, low coefficient of friction and high temperature stability [20]. However, its application has been greatly limited due to its poor mechanical properties, high linear expansion coefficient, bad thermal conductivity and poor wear and abrasion resistance [5, 6].

The wear resistance of PTFE can be significantly improved by addition of suitable filler materials. Besides the type, the shape and size of the materials added also influence the tribological properties. In the past, research in this area has been confined to the PTFE filled with conventional filler materials like glass fibers, graphite, carbon fibers, etc. However, with the growing demand for utilizing PTFE in a variety of applications, significant effort is needed towards developing the novel composite materials by adding one or more non-conventional filler materials possessing the potential of increasing the wear resistance. It is established that PTFE exhibits significantly low coefficient of friction when sliding against steels. The low coefficient of friction results from the ability of its extended chain linear molecules,  $-(CF_2-CF_2)_n-$ , to form low shear strength films upon its surface and mating counter-faces during sliding [10].

In this work it is tried to suggest the replacement of the existing hydrostatically lubricated gun metal or brass bearing used for sugar mills by a self lubricating PTFE composite bearings. For this, the investigation of friction and wear behavior of PTFE composites filled with bronze particles is carried out considering the parameters like loads and sliding velocities of existing bearing of sugar mills. Wear tests are carried out by rubbing the test pin of PTFE composites against AISI SS 304 stainless steel disc surface ( $R_a = 0.07-0.21 \mu m$ ) in dry condition using a pin-on-disc Tribometer (TR-20LE) at room temperature.

## II. PROPERTIES OF OF PTFE COMPOSITE MATERIAL

Table 1 Material composition of experimental samples of PTFE composites.

Sample	Matrix	Filler Particles	% Weight	Condition	Colour	Density g/cm <sup>3</sup>
A	PTFE	Bronze	40	Filled	Brown	3.20 - 3.30
B	PTFE	Glass fiber	15	Filled	White	2.16 - 2.24
C	PTFE	Glass fiber + MoS2	15 + 5	Filled	Gray	2.21 - 2.25

## III. EXPERIMENTATION

### 1.1 Preparation of specimen

For the testing of PTFE composite, materials are purchased from Dhawane Polymer industries, Ahmadabad. This material is in the form of cylindrical rod with dimentions 16.5 mm diameter and 105 mm length. The tests pecimens

(pins) of 10mm diameter and 30mm length are cut. The disc of material AISI SS 304 stainless steel plate.

### 3.2 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-20LE).

### 3.3 Material and test conditions

#### 3.3.1 Variables in Wear Testing

The variables in Wear Testing are as follows.

#### a) Normal Load

In sugar cane mill bearing hydrostatic lubrication is used. Hydrostatic oil pressure varies from 775 psi to 900 psi depending on the load on mills.

Therefore, considering the masses available with the testing unit TR-20LE, loads to be applied on the test pins through the lever and the pulley arrangement are selected as 16.23 kg, 17.50 kg and 18.76 kg. i.e. the normal loads of 159.16 N, 171.60 N and 184.02 N. are to be taken for the experimentation.

#### b) Sliding Velocity

Sugar cane milling roller rotates slowly from 4.5 rpm to 6 rpm depending load on it. Therefore sliding velocity of journal of  $\varnothing 380$  mm in hydrostatic bearing is:

$$V_{\min} = \pi dN/60 = 0.09 \text{ m/s.}$$

$$V_{\max} = \pi dN/60 = 0.12 \text{ m/s.}$$

$$V_{\text{avg}} = \pi dN/60 = 0.105 \text{ m/s}$$

So sliding velocities 0.09 m/s, 0.105 m/s, and 0.12 m/s can be taken for the experimentation. The track diameter of 40 mm and 110 mm on disc surface has taken for the selected sliding velocities.

#### IV. SCANNING ELECTRON MICROSCOPY ANALYSIS

##### 4.1 SEM of 40 % Bronze Particles Filled PTFE Composite Sample for dry and wet condition

Fig. 4.1 illustrates the SEM photograph of 40% bronze filled PTFE sample before wear test at 159.16 N load and at 0.09 m/s sliding. Fig. 4.2 shows the SEM photograph of 40 % bronze particles filled PTFE composite sample after wear test. Transfer film is not uniform and broken at some points showing the further wear of composite with the formation of new plowing tracks. An incidence of few cracking on the surface perpendicular to the sliding direction proves that the cracks developed are because of tensile stress in that direction. Fig. 4.3 shows the SEM photograph of worn surface of 40 % bronze particles filled PTFE composite sample after wear test. Very small amount of Transfer film is developed showing the further wear of composite with the formation of new plowing tracks because of oil which continuously removing transfer film.

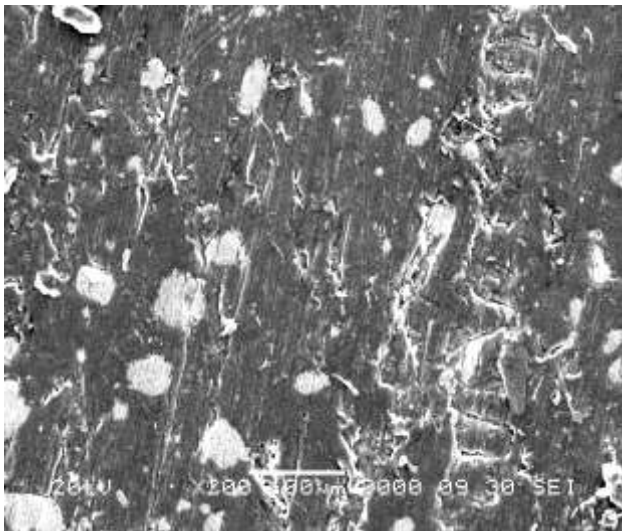


Fig 4.1. SEM of 40 % Bronze filled PTFE sample before wear test

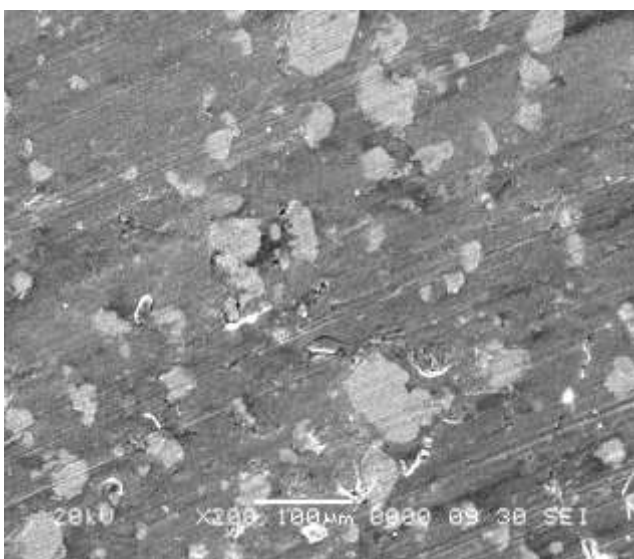


Fig 4.2 SEM of 40 % Bronze filled PTFE sample after wear test at dry condition

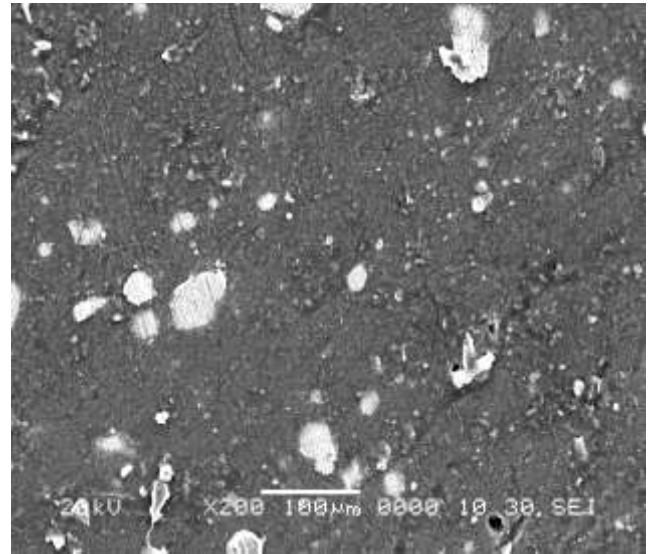


Fig 4.3 SEM of 40 % Bronze filled PTFE sample after wear test at wet condition

##### 4.2 SEM of 15 % Glass fiber Particles Filled PTFE Composite Sample for dry and wet condition

Fig. 4.4 illustrates the SEM photograph of 15% glass fiber filled PTFE sample before wear test at 184.02 N load and 0.12 m/s sliding velocity. Fig. 4.5 shows the SEM photograph of 15 % glass fiber particles filled PTFE composite sample after wear test for dry condition. One of the disadvantage of glass fiber is that, it is abrasive to mating surface especially in rotary applications so the flakes are observed in the structure at such high load and sliding velocity. Fig. 4.6 shows the SEM photograph of worn surface of 15 % glass fiber particles filled PTFE composite sample after wear test for wet condition. The oil continuously removing the transfer film so plowing tracks is observed which results in a further wear.

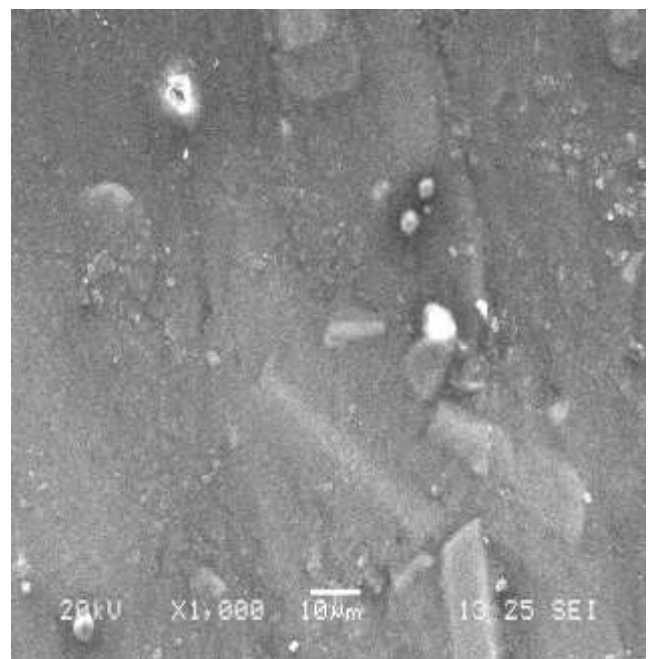


Fig 4.4. SEM of 15% Glass fiber filled PTFE sample before wear test

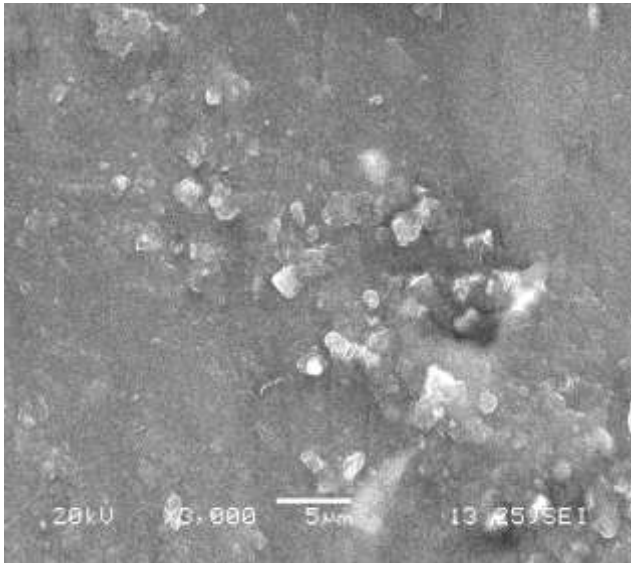


Fig 4.5. SEM of 15% Glass fiber filled PTFE sample after wear test at dry condition

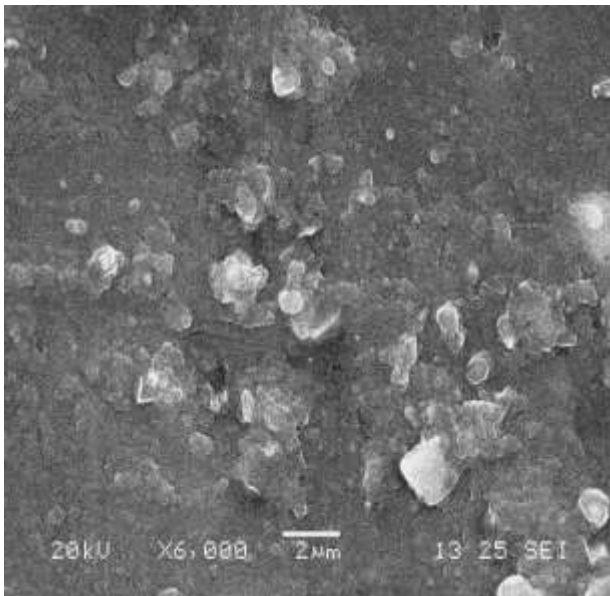


Fig 4.6. SEM of 15% Glass fiber filled PTFE sample after wear test at wet condition

#### 4.3 SEM of 15 % Glass fiber + 5% MoS<sub>2</sub> Particles Filled PTFE Composite Sample for dry and wet condition

Fig. 4.7 illustrates the SEM photograph of 40% bronze filled PTFE sample before wear test at 159.16 N load and at 0.09 m/s sliding. Fig. 4.8 shows the SEM photograph of 15 % Glass fiber + 5 % MoS<sub>2</sub> particles filled PTFE composite sample after wear test for dry condition. Glass fiber smoothen the surface, the transfer film is uniform and stable and it doesn't showing any plowing tracks. So wear as well as friction reduces and gives the better result. Fig. 4.9 shows the SEM photograph of worn surface of 15 % Glass fiber + 5% MoS<sub>2</sub> particles filled PTFE composite sample after wear test for wet condition. Rod like shape is the glass fiber and small white spot is MoS<sub>2</sub>. MoS<sub>2</sub> reduces

the abrasiveness of the PTFE material, therefore it lowers the wear and friction.

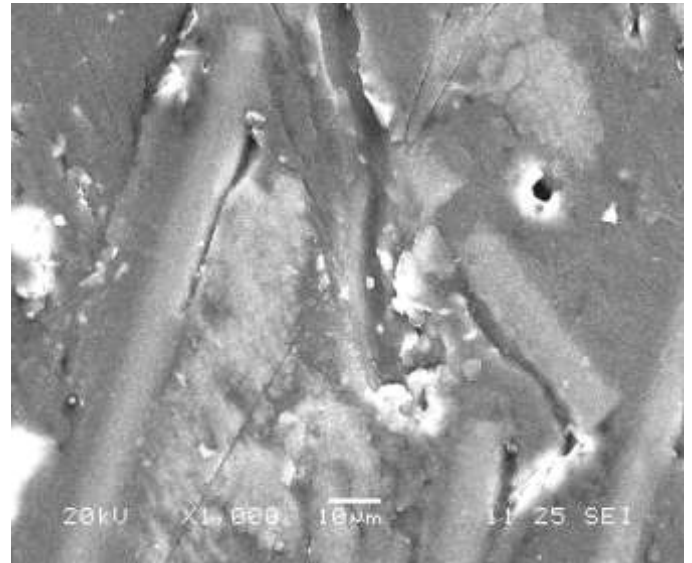


Fig 4.7 SEM of 15% Glass fiber + 5% MoS<sub>2</sub> filled PTFE sample before wear test

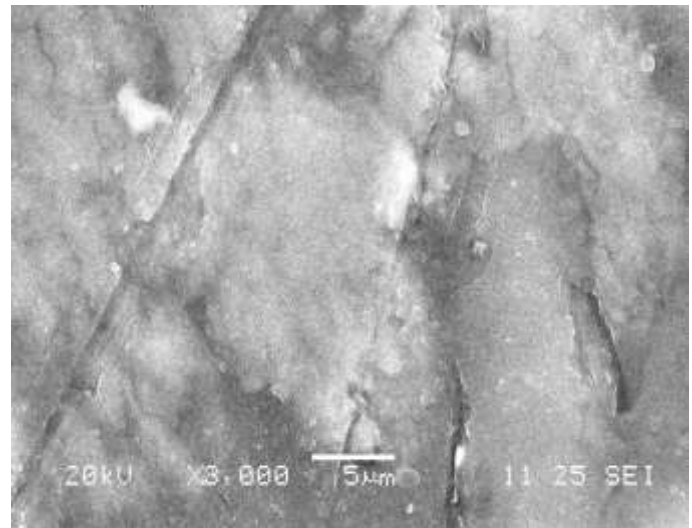


Fig 4.8. SEM of 15% Glass fiber + 5% MoS<sub>2</sub>PTFE sample after wear test at dry condition

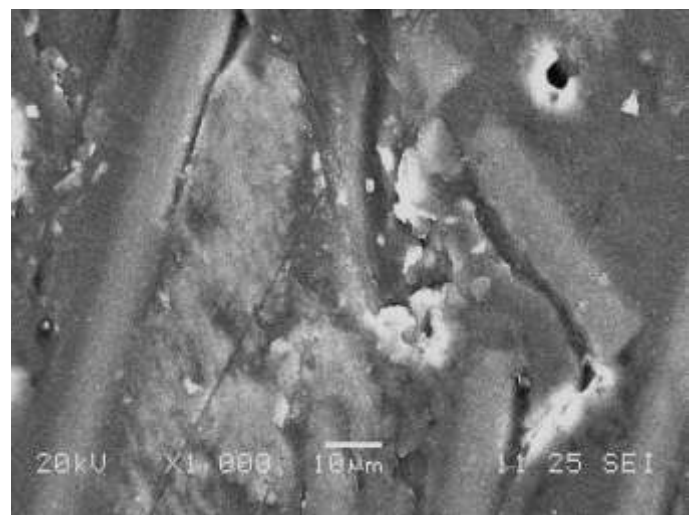


Fig 4.9 SEM of 15% Glass fiber + 5% MoS<sub>2</sub> PTFE sample after wear test at wet condition

## V. CONCLUSION

- All types of PTFE composites under experimental investigation register the stability in wear loss with time after the faster initial wear.
- For the selected range of normal load and sliding velocity, the wear increases with increase in load.
- The coefficient of friction decreases with increase in load for both dry and wet condition.
- At constant load the coefficient of friction is slightly increases with increase in sliding velocity.
- Material used in this study were ranked as follows for their wear performance.  
15% Glass fiber + 5% MoS<sub>2</sub> > 15% Glass Fiber > 40% Bronze > Pure PTFE.
- 15% Glass fiber + 5% MoS<sub>2</sub> exhibited best wear performance and can be considered as a good tribo-material between materials used in this study.

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