

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 12, December 2017

## Effect of Graphite on Tribological Behaviour of PTFE Composites

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**ABSTRACT:** This paper provides a PTFE/Graphite self lubricating composite that shows very low wear rate and friction coefficient. In this work, the tribological behaviour of PTFE filled graphite composites is investigated. Four compounds of PTFE with Graphite (0~30 wt. %) were prepared using injection molding machine and test is carried out on Pin on disc friction and wear tester. The wear tests were conducted at a nominal load of 50 N and a sliding speed of 0.8m/s. The result showed that increase in the addition of graphite into PTFE, reduced the coefficient and wear rate. The highest wear resistance was found for composites containing 30% Graphite. Scanning electron microscopy (SEM) was utilized to study the mating surface and worn surface of PTFE/Graphite composites. The images of SEM show that the presence of transfer film on the surface of mating which act as lubricant is responsible for the low friction and wear rate.

**KEYWORDS:** Friction and wear, PTFE/Graphite composite, transfer film, scanning electron microscope.

### I. INTRODUCTION

Polytetrafluoroethylene (PTFE) polymer is one of the most commonly used solid lubricants in bearing applications, which exhibits low friction coefficient, excellent chemical and thermal Stability [1, 2]. PTFE bearings are frequently used on various machines due to their low friction coefficient in boundary lubrication conditions. These are also used in the suspension of a modern front wheel–drive automobile because it provides low friction and wear under both static and dynamic conditions. The major problems involved in designing polymer bearings are to decide the optimal dimensions and material type for long life and for obtaining lower friction and wear losses. However, PTFE exhibits very poor thermal conductivity, poor wear and abrasion resistance, leading to early failure and leakage problems in the seals [3]. Due to bad conductivity of PTFE during working condition, heat gets accumulated at meeting surface which leads to increase in temperature at meeting surface and it loses mechanical strength at elevated temperature. Some research studies show that, addition of suitable filler materials to PTFE can significantly improve the wear resistance of PTFE [4]. Besides the type, the shape and size of the materials added also influence the tribological properties [5].

### II. LITERATURE SURVEY

In the past, research work has been confined to the PTFE filled with filler materials like glass fibers, carbon fibers, molybdenum sulphide (MoS<sub>2</sub>) etc. Lancaster et al. [6] proposed that addition filler materials (carbon fibers, glass fibers) to PTFE can improve its wear resistance due to load supporting action of these fibers. There have also been some reports on the use of particulate filler materials like MoS<sub>2</sub> and graphite to modify the tribological properties of PTFE [7–9]. Tanaka et al. [10] have studied the effect of addition of glass fibers and MoS<sub>2</sub> fillers on the friction and wear properties of PTFE. It was also observed that the addition of MoS<sub>2</sub> alone does not impart a good wear resistance to PTFE, during sliding [8].

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Zang et al.[11] studied the friction and wear properties of metal powder filled PTFE composite under oil lubrication and reported that copper (Cu), lead (Pb) and nickel (Ni) increased the load bearing capacity and reduced the wear of PTFE composite. A traditional way to improve the properties of polymers is to addition of fibers (glass or carbon) or filler material (organic, inorganic and metallic particulates). The addition of filler materials to polymers can enhance the mechanical, thermal, impact, electrical and tribological properties [12]. However, graphite which has high thermal conductivity and low cost can be used with polymer for bearing to increase conductivity and to reduce lubrication. Even though some filler materials are added to the polymers, their effects on tribological properties are not clearly known.

### III. OBJECTIVE AND METHODOLOGY

From the literature study, it has been observed that the main purpose of developing composite is to reduce wear rate and lubrication by using graphite as solid lubricant. For this purpose, a composite specimen is developed using pre-determined percentage of graphite powder filled into PTFE using twin screw extruder and injection molding machine. Due to the four levels which affect the performance of wear is applied and wear test is carried out using pin-on-disc wear testing technique and wear rate and microstructure of specimen is found out.

### IV. EXPERIMENTAL RESULTS

#### Materials

Pure PTFE and three PTFE based composite materials were studied in the present work. The compositional details of



Fig.1 PTFE



Fig. 2 Graphite powder

each material are presented in Table1. A commercially available PTFE in granular form and having density 2200 kg/m<sup>3</sup> used as matrix material as shown in Fig.1. The melting temperature of PTFE is 327°C. It has low thermal conductivity and high linear thermal expansion coefficient. Graphite powder with an average particle size of 45µm and having density of 2.2 g/cm<sup>3</sup>, was used as reinforcement material as shown in Fig.2. The graphite has good thermal conductivity of 125 W/m-K and has melting temperature above 3500°C.

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TABLE 1 COMPOSITION OF PTFE/GR COMPOSITES

Specimen No	PTFE in %	Graphite in %
1	100	0
2	90	10
3	80	20
4	70	30

### Preparation of PTFE/Graphite composite

Initially, PTFE with varying amounts of Graphite powder viz 0, 10, 20 and 30% by weight were mixed manually then blended using a Twin screw extruder. The table 1 shows compositions of PTFE/Graphite composites. The specimens of PTFE and its composites were molded by using an injection molding machine. The specimens are prepared according ASTM G 99 standards. Table 1 presents the composition of each composite. Figure 3 shows the prepared specimens with different content of graphite in PTFE.

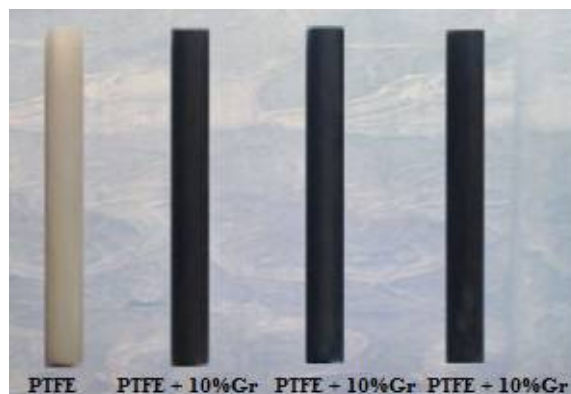


Fig. 3 Prepared specimens for wear test

### Friction and wear testing

Wear test was carried out with pin-on-disc wear tester usually under non-abrasive conditions. The test machine causes either the disc or the pin specimen to revolve about the disc centre.

During experiment composite specimens were firmly hold against rotating disc and a normal load was applied using standard weights to apply contact pressures. Each specimen was weighed to get the mass lost due to wear using highly reliable and a sensitive balance to an accuracy of 0.001 gm. The wear rate was calculated by using following equation:

$$\text{Wear rate} = \frac{\Delta m}{\rho L d} \times 10^3 \frac{\text{mm}^3}{\text{Nm}}$$

Figure 4 represents line diagram of Pin on disc wear test rig.

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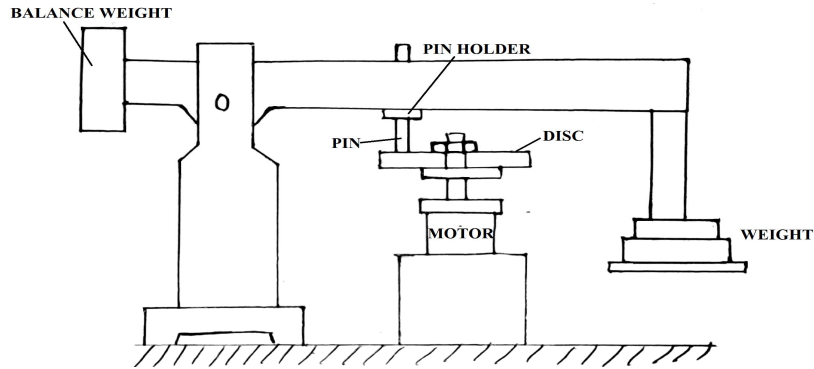


Fig. 4 Pin on Disc wear test rig

The observed response such as coefficient of friction and wear rate is shown in table 2. It is observed that addition of filler material such as graphite can improve the wear resistance of PTFE composites. This is due to presence of graphite which acts as solid lubricant.

Table 2 Observed Response

Content of Graphite in composite %	wear rate ( $10^{-4} \text{ mm}^3/\text{N m}$ )	Coefficient of friction $\mu$
0	44	0.119
10	7.29	0.092
20	3.75	0.1
30	1.21	0.09

It also observed that small fluctuations in coefficient of friction with increase in addition of graphite to PTFE composites. The highest wear resistance was found for composites having 30% of graphite. Figure 5 shows variations in the coefficient of friction (COF) and wear rate with respect to different graphite contents.

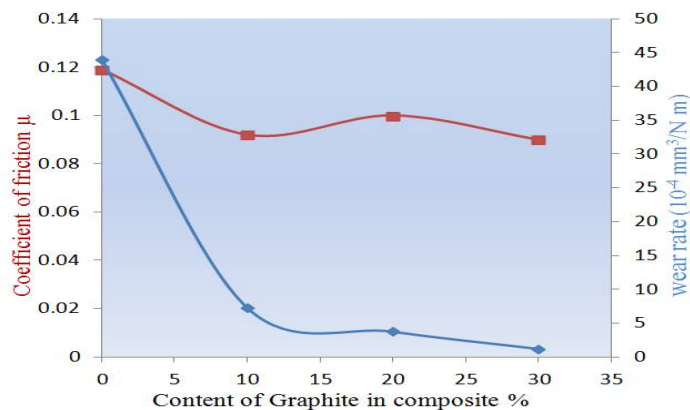


Fig.5 variations in the coefficient of friction (COF) and wear rate with respect to different graphite contents

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Worn out surfaces of PTFE/Graphite composites were examined in Scanning Electron Microscopy (SEM). Figure 6 shows wear mechanism of PTFE composites having graphite content in % i.e. 0, 10, 20, 30 respectively. SEM observations presents that, wear rate of PTFE composites is influenced by content of graphite present in composites. It is clearly shown that reduction in wear rate of composites is due to presence of transfer film on surface of disc.

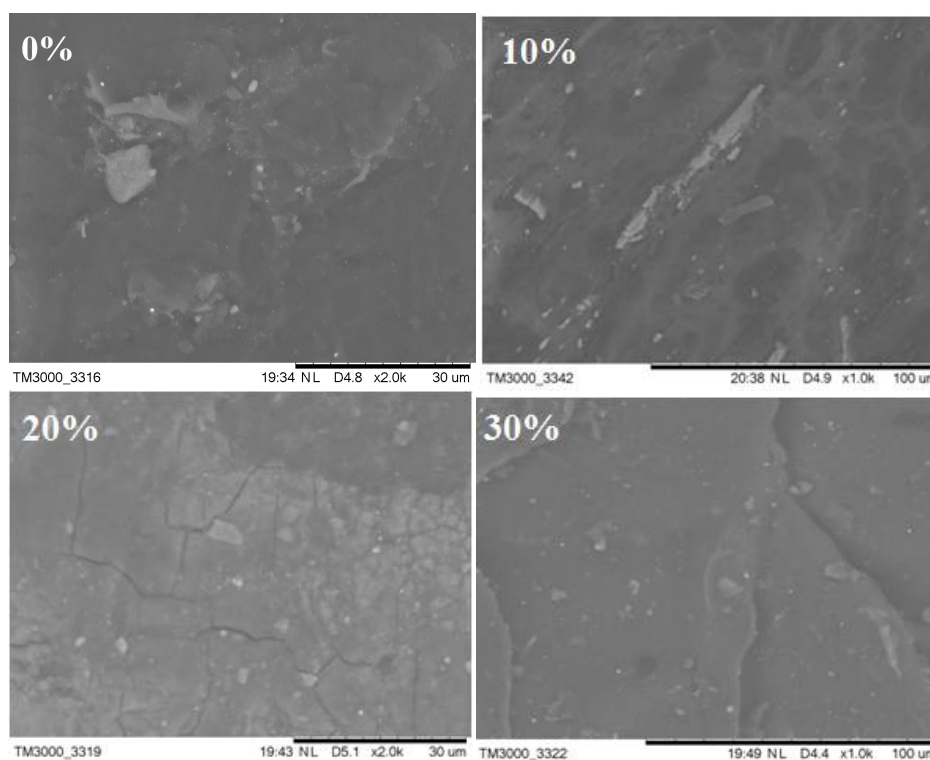


Fig. 6 Worn out surfaces of PTFE composites having graphite content in % i.e. 0, 10, 20, 30

### V. CONCLUSION

Based on the analysis of experiments and worn out surface images, it is concluded that, addition of graphite into PTFE matrix reduces the coefficient of friction and wear rate. Considering various factors in account, PTFE/Graphite composite shows best wear resistance properties. It can also be concluded that the tribological properties of composites such as coefficient of friction and wear rate depends on thermal conductivity, thermal stability and properties of filler materials.

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