Friction and Wear Behaviour of PTFE & Its Composites: A Review

Prashant B Patil[1], Prof E R Deore[2]
Dept. Mechanical Engineering[1,2]
S S V P S Bapusaheb Shivajirao Deore College of Engineering, Dhule [1, 2]
Email: patil.prashant411@gmail.com[1]

Abstract- When filler materials like carbon, graphite, glass fibres are added in the PTFE, a composite is formed which improves mechanical & thermal properties of that composite. It increases hardness and wear resistance, while the coefficient of friction is slightly affected and remains low. In this survey, we study various papers in which various methods & experiments were carried out for calculating friction & wear resistance of various compositions of polymers. So it is easy to understand properties & behaviour of polymers under various test conditions.

Index Terms- Composites, PTFE, friction, wear.

1. INTRODUCTION

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.

The development of the fluoropolymer industry began with the discovery of the polytetrafluoroethylene (PTFE) by Dr. Roy J. Plunkett (1910-1994) at DuPont in 1938 and introduction as a commercial product in 1946 [10]. Polytetrafluoroethylene (PTFE) is a high performance engineering plastics which is widely used in industry due to its properties of self-lubrication, low friction coefficient, high temperature stability and chemically resistant. While PTFE exhibits poor wear and abrasion resistance, leading to early failure and leakage problem in the machine parts. To minimise this problem, various suitable fillers added to PTFE. Generally, reinforcements such as glass fibres, carbon fibres and solid lubricants are added internally or incorporated into the PTFE. Its relative softness and poor heat conductivity limit its suitability as a bearing material to applications involving low speeds and low unit pressure, the tribological behaviour of polymers is affected by environmental and operating conditions and by the type, size, amount, shape and orientation of the fibres. A relationship between the wear of the polymers and operating parameters is desirable to obtain the better understanding on the wear behaviour [1, 2].

In 1953, a new fluoropolymer, polychlorotrifluoroethylene (PCTFE) was commercialized by M. W. Kellog Company under the trade mark Kel-F. PCTFE is produced by the free radical polymerization of chlorotrifluoroethylene (CTFE) with a linear polymer chain structure [10].

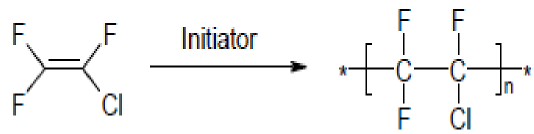


Figure 1: Polymerisation of CTFE

1.1 Test Conditions:

- Load: Load is important factor when we consider friction & wear. As we know, Friction & wear is directly proportional to the applied load.
- Velocity: When it’s deal with friction and wear testing machine, it is very necessary to consider the velocity of the specimen. Generally, frictional resistance decreases with increasing velocity.
- Temperature: Environmental temperature also affects the accuracy of the experiment.
- Contact Area: Contact area between mating parts is important. Contact area in all conditions must be same.

1.2 Properties to Study:

PTFE & CTFE has good properties such as low coefficient of friction, low wear rate, heat resistance, electrical insulation properties and chemical inertness**.**

PTFE + Carbon Composite, PTFE + Bronze Composite, CTFE may show excellent properties.

1.3 Parameters in Wear Testing:

Load, Velocity, Temperature, Contact Area, Surface Finish, Sliding Distance, Environment, Material, Hardness of counter face. The 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.

1.3.1 Coefficient Of Friction

The coefficient of friction is generally depends on the Load, sliding speed. Material should possess low coefficient of friction.

1.3.2 Wear rate

Wear is the removal of material from either or both of the contacting surfaces. Material should have improved wear resistance under load and permanent deformation.

1.3.3 Dielectric Properties

Teflon has high dielectric strength over many different frequencies, low dissipation factor and surface resistivity.

2. LITERATURE SURVEY

H. Unal et al [1] "Sliding friction and wear behaviour of polytetrafluoroethylene and its composites under dry conditions" in Materials and Design 25 (2004) 239–245 presented the influence of test speed and load values on the friction and wear behaviour of pure polytetrafluoroethylene (PTFE), glass fibre reinforced (GFR) and bronze and carbon (C) filled PTFE polymers under ambient conditions in a pin-on-disc arrangement concluded that The friction coefficient of pure PTFE and its composites decreases when applied load increases also pure PTFE is characterised by high wear because of its small mechanical properties. Therefore, the reinforcement PTFE with glass fibres improves the load carrying capability that lowers the wear rate of the PTFE.

Ayman A. Aly, et al [2] "Friction and Wear of Polymer Composites Filled by Nano-Particles: A Review", World Journal of Nano Science and Engineering, 2012, 2, 32-39 has reviewed about friction & wear effects on nano particles filled composites. The survey showed that there is a significant improvement in mechanical properties of the composite due to the addition of the nano-particles. Many types of nanofilling martials, including SiC, Si3N4, SiO2, ZrO2, ZnO, CaCO3, Al2O3, TiO2, and nano-CuO, have been used to different types of polymers such as PEEK, PMMA, PTFE and epoxy. The mechanical properties which have been improved include fatigue resistance, fracture toughness, tensile strength, wear resistance, and friction coefficient.

David L. Burris et al [3] "A low friction and ultra-low wear rate PEEK/PTFE composite", Science Direct, Wear 261 (2006) 410–418 presented PEEK filled PTFE composite that exhibits low friction and ultra-low wear by using laboratory designed linear reciprocating tribometer and states that this composite material has a friction coefficient & wear rate lower than unfilled PTFE and PEEK for every sample tested.

Li Chang et al [5] "Enhancement effect of nanoparticles on the sliding wear of short fiber-reinforced polymer composites: A critical discussion of wear mechanisms" Tribology International 43 (2010) 2355–2364 investigated the wear mechanisms of the hybrid SFRPs filled with nano particles on pin on disc arrangement. It was found that the load-carrying capacity of the SFRPs is mainly determined by the properties of the fibers. However, the tribological performance of SFRPs can be significantly improved by using nanoparticles due to their friction reducing abilities, especially under extreme loading conditions.

N.V. Klaas, et al [6] "The tribological behaviour of glass filled Polytetrafluroethylene", Tribology International 38 (2005) 824-833 has tested glass filled PTFE by using reciprocating wear tester apparatus under and concluded that The wear rate of PTFE composites was an order of two magnitude higher in water than under dry sliding conditions.

W. Gregory Sawyer et al [7] "A study on the friction and wear behavior of PTFE filled with alumina nanoparticles", Science Direct, Wear 254 (2003) 573–580. In this paper composites were tested against a polished stainless steel counterface on a reciprocating tribometer. The friction coefficient & wear rate of as received PTFE powder & jet milled composite PTFE powder were compared. After result, he concluded that composite has slightly increased friction over unfilled samples. Also the wear resistance increased monotonically with increasing filler concentration.

Deepak Bagle et al [8] "Wear Analysis of Polytetrafluoroethylene and its Composites under Dry Conditions using Design-Expert", International Journal of Scientific and Research Publications studied the effects of load, velocity of sliding and sliding distance on sliding friction and sliding wear of PTFE & it's composites under dry testing by using pin-on-disc apparatus and conclude that, addition of filler materials such as bronze and carbon to PTFE causes an increase in wear resistance, while the coefficient of friction is slightly affected.

Jaydeep Khedkar et al [9] "Sliding wear behavior of PTFE composites", wear 252 (2002) 361-369. In this paper the tribological behavior of polytetrafluroethylene (PTFE) and PTFE composites with filler materials such as carbon, graphite, E glass fibers and poly-*p* phenyleneterephthalamide (PPDT) fibers has studied. In this work, unidirectional sliding friction and wear tests were carried out in the laboratory using a computer controlled pin-on-disc type tribometer. He concluded that, addition of filler materials such as carbon, graphite, glass fibers and PPDT to PTFE causes an increase in hardness and wear resistance, while the coefficient of friction is slightly affected and remains low.

Hongxiang Teng [10] "Overview of the Development of the Fluoropolymer Industry", *Appl. Sci.* 2012, *2*, 496-512 has reviewed the development of the Fluoropolymer.

3. METHODOLOGY

Various test methods are available for friction & wear testing. Some of them are explained below,

[1] H. Unal et al presented the influence of test speed and load values on the friction and wear behaviour of pure polytetrafluoroethylene (PTFE), glass fibre reinforced (GFR) and bronze and carbon (C) filled PTFE polymers under ambient conditions in a pin-on-disc arrangement. Schematic Diagram of wear test rig is as shown in fig.

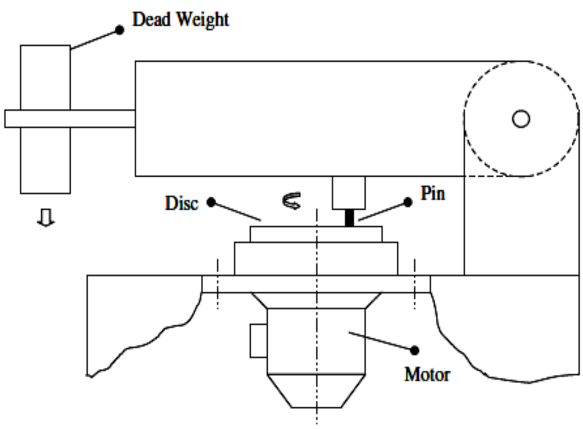
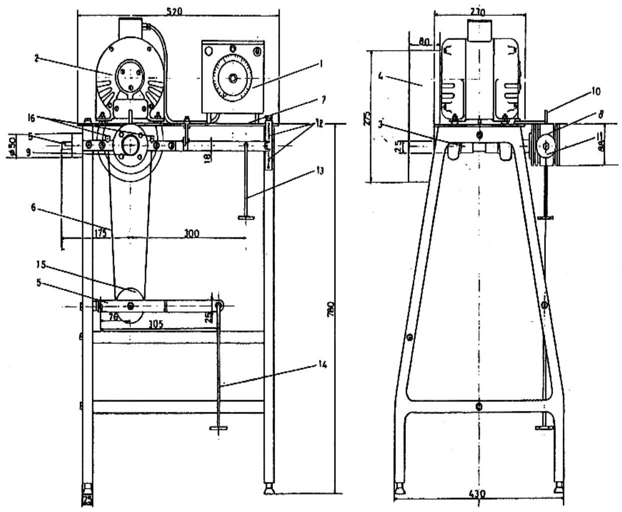


Figure 2: Wear Test Rig [1]

2] Talat Tevrüz done his experiment on the apparatus illustrated as in Fig 3 [4]. The system is rigid. Different pressures were achieved by different weights and different velocities were obtained by a rheostat which allows the speeds up to 1900 rpm. The temperatures of the friction surfaces were measured by a thermometer in a hollow in the bearing housing.



1.Control box with speed regulator. 2.D. C. shunt wound motor. 3.Shaft. 4.Belt-pulley device. 5.Bar. 6.Wire cable. 7.Lapboard. 8.Bearing housing. 9.Bearing. 10.Thermometer pocket. 11.Polse wight. 12.Damping sprigs. 13.Torque hanger. 14.Load hanger. 15.Ball bearing pulley. 16.Knife bearing. 17.Bolts. 18.Bolts.

Figure 3: Apparatus for Experiment [4]

3] Experiment by Li Chang, Klaus Friedrich. The wear tests were conducted on pin on disc apparatus [5]. During the test, the friction coefficient was recorded and calculated by the ratio of tangential force to normal load. The reduction in specimen's height was measured by a displacement transducer, which could be used to characterize the development of the wear process. An additional monitoring of the temperature rise during testing was carried out by an iron–constantan thermocouple positioned on the edge of the steel disk.

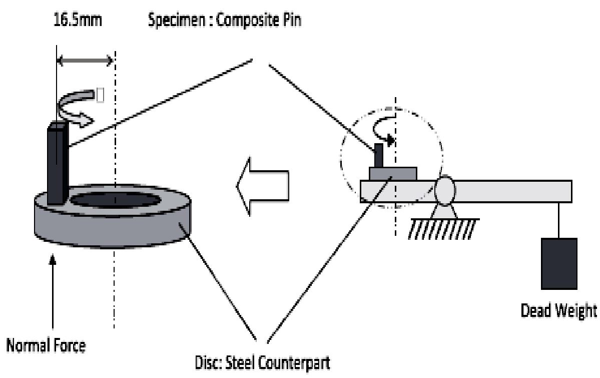


Figure 4: Pin-on-disc arrangement for wear tests[5]

4] N.V. Klaas et al in his experiments carried out the friction and wear tests on a reciprocating sliding wear rig which consists of a wear pin sliding perpendicular to the grinding marks on a flat counterface [6]. This is a standard wear rig used for friction and wears and is fully described elsewhere. Each test was performed on a new wear track covering a totalling sliding distance of 5 km. The linear reciprocating sliding wear rig reproduces the reciprocating motion typical of many real-world mechanisms, thus, the apparatus is frequently used to test wear performances of materials.

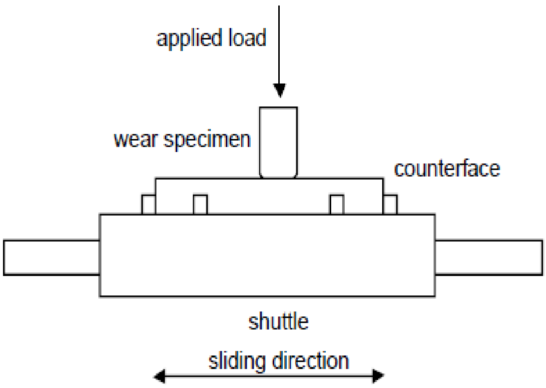


Figure 5: Reciprocating wear tester [6]

5] W.G. Sawyer et al in his experiment used reciprocating pin-on-disk Tribometer for wear testing. A schematic diagram is as shown in figure below [7].

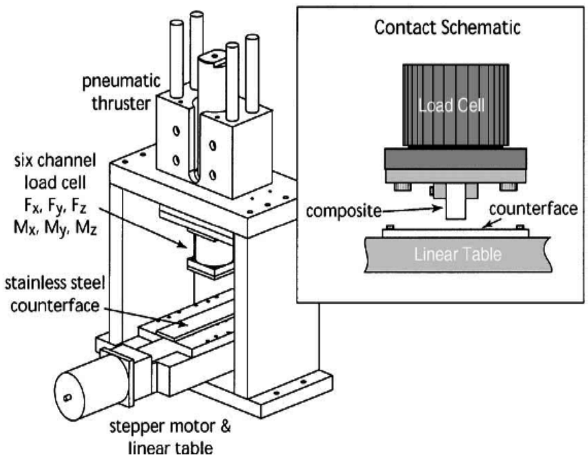


Figure 6: A schematic of the reciprocating pin-on-disk Tribometer [7]

6] Deepak Bagle et al in his experiment used pin on disc apparatus for wear testing of different composites sample. Experimental setup for of their work is shown in figure below [8].

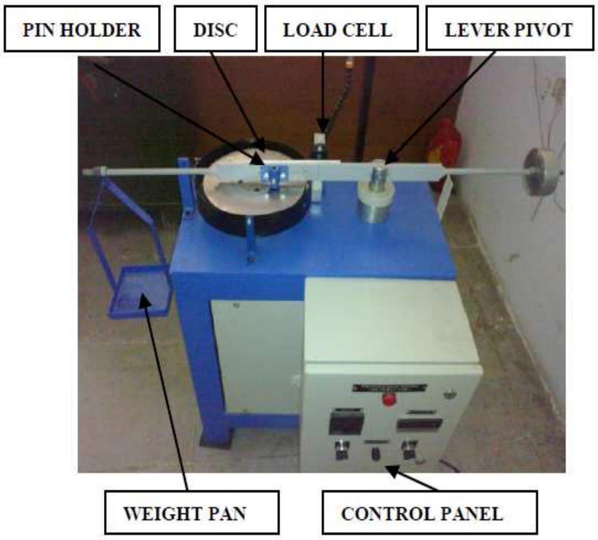


Figure 7: Experimental Setup of Friction and Wear test rig

4. CONCLUSION

From the overview of above study concludes that,

- Addition of filler materials such as bronze and carbon to PTFE causes an increase in wear resistance, while the coefficient of friction is slightly affected.
- The friction coefficient of pure PTFE and its composites decreases by increasing applied load, which can be improved by reinforcement PTFE with glass fibres.
- For the specific range of load and speed, the load has stronger effect on the wear behaviour of PTFE and its composites than the sliding velocity.
- Addition of filler materials such as carbon, graphite, glass fibers and PPDT to PTFE causes an increase in hardness and wear resistance, while the coefficient of friction is slightly affected and remains low. Filler materials in general are effective in impeding large-scale fragmentation of PTFE, thereby reducing the wear rate.

REFERENCES

[1] H. Unal, A. Mimaroglu, U. Kadıoglu, H. Ekiz, “Sliding friction and wear behaviour of Polytetrafluroethylene and its composites under dry conditions”, Materials and Design 25 (2004) 239-245.

[2] Ayman A. Aly, El-Shafei B. Zeidan, AbdAllah A. Alshennawy, Aly A. El-Masry, Wahid A. Wasel, “Friction and Wear of Polymer Composites Filled by Nano-Particles: A Review”, World Journal of Nano Science and Engineering, 2012, 2, 32-39.

[3] David L. Burris, W. Gregory Sawyer, “A low friction and ultra low wear rate PEEK/PTFE composite”, Science Direct, Wear 261 (2006) 410–418.
[4] Talat Tevrüz, “Tribological behaviors of carbon filled Polytetrafluoroethylene (PTFE) dry journal bearings”, Wear 221 (1998) 61-68.
[5] Li Chang, Klaus Friedrich “Enhancement effect of nanoparticles on the sliding wear of short fiber-reinforced polymer composites: A critical discussion of wear mechanisms” Tribology International 43 (2010) 2355–2364.
[6] N.V. Klaas, K. Marcus, C. Kellock, “The tribological behaviour of glass filled Polytetrafluroethylene”, Tribology International 38 (2005) 824-833.
[7] W. Gregory Sawyer, Kevin D. Freudenberg, Praveen Bhimaraj, Linda S. Schadler, “A study on the friction and wear behavior of PTFE filled with alumina nanoparticles”, Science Direct, Wear 254 (2003) 573–580.
[8] Deepak Bagale , Sanjay Shekhawat , Jitendra Chaudhari, “Wear Analysis of Polytetrafluoroethylene and its Composites under Dry Conditions using Design-Expert”, International Journal of Scientific and Research Publications, Volume 3, Issue 1, January 2013, ISSN 2250-3153.
[9] Jaydeep Khedkar, Ioan Negulescu, Efstathios I. Meletis, “Sliding wear behavior of PTFE composites”, Wear 252 (2002) 361-369.
[10] Hongxiang Teng, “Overview of the Development of the Fluoropolymer Industry”, *Appl. Sci.* 2012, *2*, 496-512.