International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
©2015 INPRESSCO®, All Rights Reserved
Available at http://inpressco.com/category/ijcet

Research Article

Prediction of Specific Wear rate of Glass and Bronze Filled PTFE Composites

Swati Prashant Patil†* and E.R.Deore†

†SSVPS, COE Dhule, North Maharashtra University, Jalgaon, India

Accepted 01 Dec 2015, Available online 30 Dec 2015, **Vol.5, No.6 (Dec 2015)**

Abstract

PTFE and its composites are steadily gaining ground over metals in the field of engineering applications in tribology. 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+15% bronze ,PTFE + 25% glass and PTFE + 30% bronze composites. Wear behavior of the specimen was investigated by using the Pin ON Disc apparatus at ambient condition. Parameters are set for three different levels and in optimum possible combination by Taguchi experimentation design array. The results of experiments are presented in tables and graphs which show that the addition of bronze and glass filler to PTFE decreases wear rate significantly and there is marginal increase in coefficient of friction. Wear rate is obtained as a response of experimentation and then further analyzed in design expert software. At the end all three materials are compared on the basis of wear rate and coefficient of friction.

Keywords: *Composites, Design Expert, ANOVA, PTFE, Taguchi OA friction, wear*

1. Introduction

Nowadays, there is very intensive growth in the large scale production of the fibre reinforced polymer composites since they possess certain advantage over the metals. The advantages include lower density, less need for maintenance and lower

Cost[5].PTFE is a high performance plastic, which is used in a broad range of industries. This plastic is also known by trade names such as Teflon® Dyneon™ or Fluon. PTFE is based polymer compound with white or grey in colour. PTFE has all qualities of bearing alloy like compatibility, conformability embed ability, load capacity, fatigue strength, corrosion resistance and hardness. It is a crystalline solid with good stability from -195°C to +260°C (Harshal Deshmukh *et al*).

But PTFE exhibits poor wear and abrasion resistance, leading to early failure and leakage problem in the machine parts. To minimize this problem, various suitable fillers added to PTFE. Generally, reinforcements such as glass fibers, carbon fibers, bronze and solid lubricants are added internally or incorporated into the PTFE. 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. The aim of the present study was to investigate the tribological behaviour of Pure PTFE and its composite ON Pin ON Disc apparatus. The wear model for the tested materials was developed based on the applied load, Sliding speed and sliding distance.

*Corresponding author **Swati Prashant Patil is a M.E. Scholar and E.R.Deore** is working as Assistant Professor

2. Factors affecting PTFE and PTFE composite wear

- Normal Load:-In order for a PTFE composite to function as a solid lubricant it must be able to support the load, as well as the tangential stresses induced by sliding.
- Sliding Velocity:-The high sliding speeds can produce high temperatures due to friction heating. This may cause the polymer or the polymer composite additives to degrade.
- Sliding Distance:-sliding distance is one of most important parameters which influence wear rate Thus it is important to choose sliding distance for each particular polymer to ensure the optimum performance.

3. Literature survey

Luigi Mazza *et al* investigate tribological behaviour of PTFF composite using two standard tribological tests approach i.e., pin-on-disc and thrust washer measurements, have been compared with sliding tests performed on composite. The obtained results indicate the different testing methods continuous rotation vs. reciprocating linear movement for the pin-on-disc/thrust washer and sliding tests, respectively, the different techniques provide highly comparable data within the adopted experimental conditions.

Hongxiang Teng Fluoropolymers have come a long way in the past 70 years. No doubt many new fluoropolymer materials will be developed and new applications will be found for old fluoropolymers. The importance of the fluoropolymer industry will not be destabilized before the emergence of new substitute materials.

Prasad M Patare studies the effects of filler on the friction and wear properties of 15% glass fibre and 30% glass filled PTFE composites under dry friction conditions were studied. The influence of filler content, sliding duration, test speed and load were also investigated. Experimental results shows that wear rate of PTFE reduced by addition of glass fiber and tribological properties also improved.

S.M.Gujarathi showed that the incorporation of carbon particles in the PTFE matrix as a secondary reinforcement increases the wear resistance of the material. The smearing of the carbon and formation of protecting layer between the pin and the counter face enables in reducing the wear volume loss.

Deepak Bagle has studied the tribological behavior of PTFE and its composites with filler materials as carbon and bronze under dry conditions. He found that addition of filler materials such as bronze and carbon to PTFE causes an increase in wear resistance.

Sandip Chaudhari has done wear analysis of PTFE and its composites under wet conditions. The results of experiments shows that the addition of bronze, glass and carbon filler to the virgin PTFE decreases wear rate significantly

Harshal Deshmukh, Navneet Patil has studied three different composites of semi-metallic brake pads for wear rate under dry conditions. Conclusions of the work are, as load and sliding distance increases wear rate also increase.

Jaydeep Khedkar *et al* studied the tribological behavior of polytetrafluroethylene (PTFE) and PTFE composites with filler materials such as carbon, graphite 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.

4. Experimental Procedure

A. Specimen Preparation

Materials used for experiment to analyze comparative tribological behaviour, wear and coefficient of friction of 25% glass filled PTFE, 30% bronze filled PTFE and 15% bronze filled PTFE under load of 1 kg, 2 kg, 3 kg and sliding velocity 3.77 m/s, 5.03 m/s and 6.28 m/s under dry friction condition The sample specimen has been prepared by performing necessary turning and facing operations on the respective rods. Then respective codes has been assigned to the specimen as follows,

Table I: Assigning codes specimens

Material Name	Chemical Composition in Wt.%
I	30%Bronze filled PTFE
II	25% Glass filled PTFE
III	15%Bronze filled PTFE

B. 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.

C. Introduction to Design Expert

Design-Expert, version 9.05 software 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.

D. Taguchi Approach

Taguchi approach is significant analysis tool for the influence of control variable on performance output. It provides a simple, efficient and systematic approach to optimize design of performance, quality. The method is valuable when design parameters are qualitative and discrete. Taguchi Parameter design can optimize the performance to source of variation parameter. Taguchi approach is consist problem definition, choice of response, selection of factors and levels, selection of orthogonal array, enter factor and level value in selected array chart, perform experimentations per chart value, analysis and interpretation of result. The design of experiment process made up of three main phase: the planning phase, the conducting phase and analysis interpretation phase. The planning phase is the most important phase one of must give a maximum importance to this phase. The data collected from all the experiment in the set are analyzed to determine the effect of various design parameters.

Fig.1 An outline Procedure for Taguchi Approach

E. Statistical Regression Analysis

Statistical regression analysis is the study of the relationship between two or more variables, used to establish the empirical equation relating input-output parameters, by utilizing least square method. The following steps are to be considered for carrying out statistical regression analysis of a process.

1. Identifying the important process control variables and finding their upper and lower limits.
2. Developing the design matrix (Statistical design of experiments).
3. Conducting the experiments as per the design matrix and recording the response parameters.
4. Developing the models and calculating the regression coefficients.
5. Checking the adequacy of the models.
6. Testing the significance of coefficients and arriving at the final models.
7. Presenting the direct and interaction effects of the process.
8. Analysis of Results.

F. Analysis of Variance (ANOVA)

The adequacy of the models is tested using the analysis of variance (ANOVA) technique. It is a statistical tool for testing null hypothesis for designed experimentation, where a number of different variables are being studied simultaneously. ANOVA is used to quickly analyze the variances present in the experiment. The ANOVA allows analyzing the influence of each variable on the total variance of the results.

G. Design of test runs

The To ensure the optimum interaction of all the parameters L9 (3^4) Method of Taguchi Orthogonal array is used which have nine test runs, 3 levels of factors, and maximum 4 factors, we identified 3 factors.

Table II: Test run parameter

	Levels		
	low	medium	high
Load(kg)	1	2	3
Disc Speed(rpm)	600	800	1000
Sliding Distance(km)	2	3	4

If the parameter given in Table I are put in Design expert software it will generate a following Run sheet of parameters for pin-on-disc setup shown in Table II which can be further utilized as Observation table to note wear rate as response.

Table III: Layout of L9 orthogonal array for experimentation

Run	Load (kg)	Speed(rpm)	Sliding Distance (km)
1	1	600	2
2	1	800	3
3	1	1000	4
4	2	600	3
5	2	800	4
6	2	1000	2
7	3	600	4
8	3	800	2
9	3	1000	3

The arrangement to set sliding distance is not provided on test setup instead the time of run can be calculated and can be monitored using stopwatch. The final test run and parameter combination is shown in Table IV. The Pin on Disc Friction & Wear Testing Machine designed and developed by MAGNUM ENGINEERS is primarily intended for determining the tribological characteristics of wide range of materials under conditions of various normal loads, sliding speeds & temperatures (optional).

Fig.2 Pin on disc Test-Rig

Table IV: Final test run design

Run	Load(kg)	Disc Speed(rpm)	Time (min)
1	1	600	8.84
2	1	800	9.94
3	1	1000	10.62
4	2	600	13.26
5	2	800	13.25
6	2	1000	5.31
7	3	600	17.68
8	3	800	6.63
9	3	1000	7.96

H. Testing

Experiments are conducted as per the design matrix Table IVand response is recorded in terms of wear by weight loss method. Weight of pin before run and weight of pin after run is noted and calculated to obtain wear rate. Weighing scale with minimum capacity of 10 mg is used for the same. For the analysis and to find correlation all factors should be in same unit therefore while filing the data in software Disc speed and Run time is converted in Sliding Velocity (m/s) and Sliding Distance (Km) as shown in Table V.

Table V: Final test run data for software

Run	Load(kg)	Velocity(m/s)	Sliding Distance(m)
1	1	3.77	2000
2	1	5.03	3000
3	1	6.28	4000
4	2	3.77	3000
5	2	5.03	4000
6	2	6.28	2000
7	3	3.77	4000
8	3	5.03	2000
9	3	6.28	3000

5. Results and discussion

Analysis of Variance (ANOVA) for Wear Rate is done for all three Material compositions and checked if the model is significant or not, when all models were significant the following effects are shown in fig.

- For Material I (PTFE + Bronze 30 %)

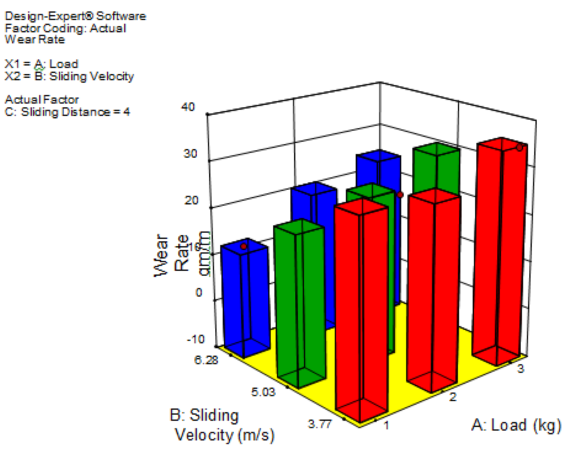

Fig.3: Interaction effect of load and velocity of sliding on wear at maximum sliding distance 4 km

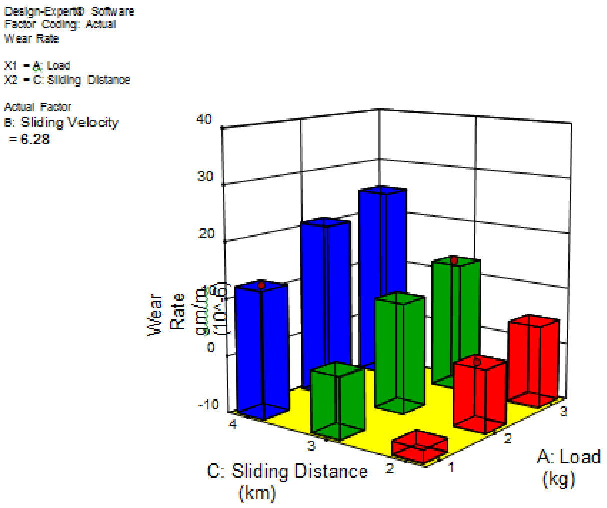

Fig.4: Interaction effect of load and sliding distance on wear at maximum velocity 6.28 m/s

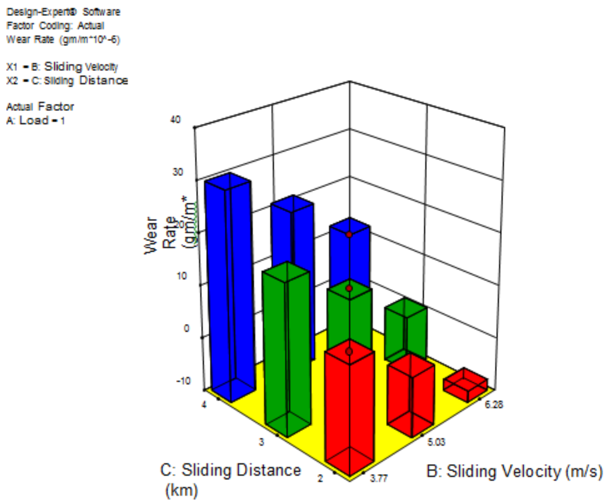

Fig.5: Interaction effect of load and velocity of sliding on wear at minimum load1 kg

- For material II (PTFE + Glass 25 %)

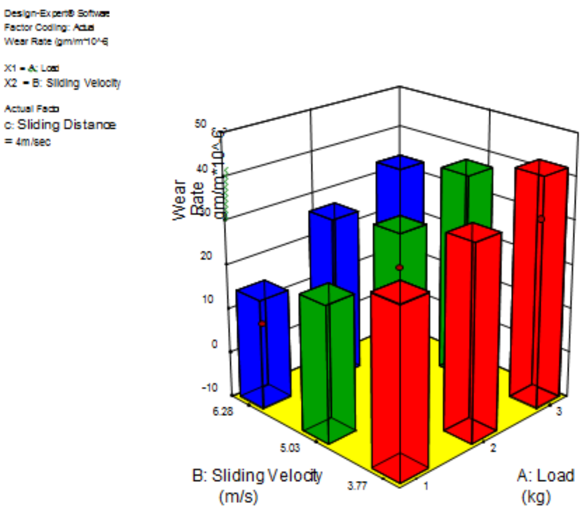

Fig.6: Interaction effect of load and velocity of sliding on wear at maximum sliding distance 4 km

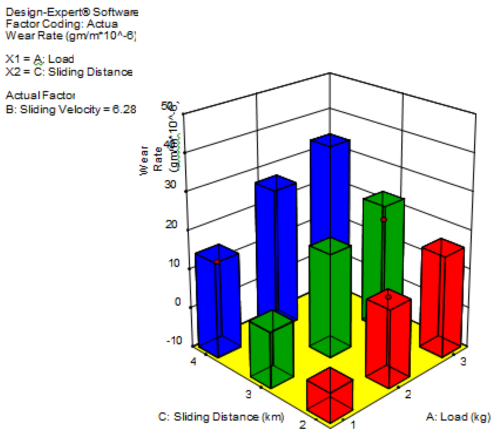

Fig.7: Interaction effect of load and sliding distance on wear at maximum velocity 6.28 m/s

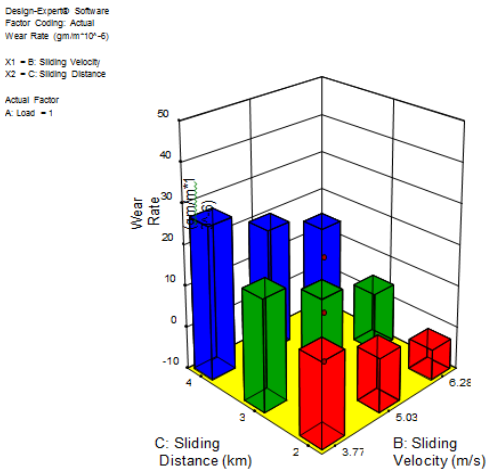

Fig. 8: Interaction effect of load and velocity of sliding on wear at minimum load1 kg

- For material III (PTFE + Bronze 15%)

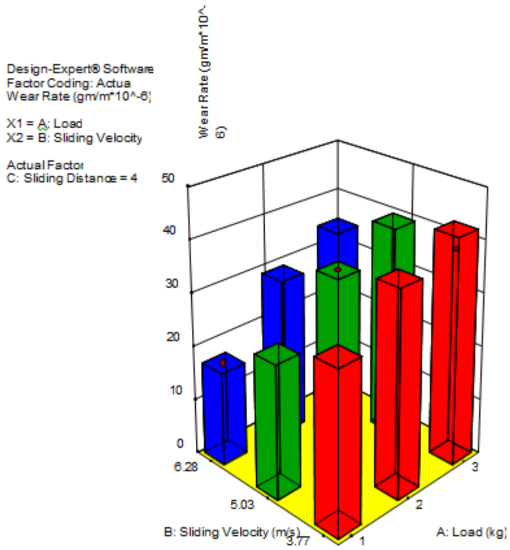

Fig.9: Interaction effect of load and velocity of sliding on wear at maximum sliding distance 4 km

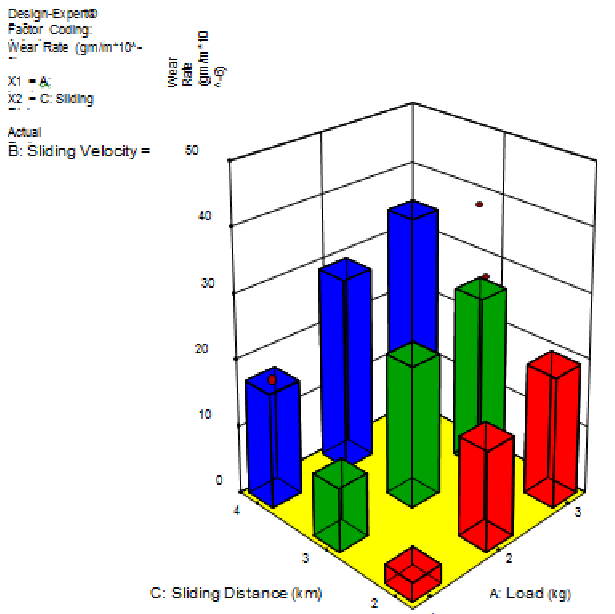

Fig.10: Interaction effect of load and sliding distance on wear at maximum velocity 6.28 m/s

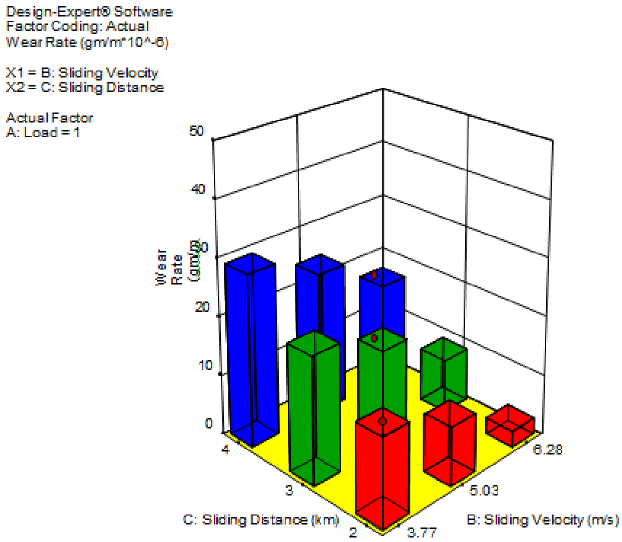

Fig.11: Interaction effect of load and velocity of sliding on wear at minimum load1 kg

It is clearly seen from above results that as load and sliding distance increases wear rate of all three PTFE Composite also increases whereas velocity of sliding increases wear of PTFE Composite materials decreases.

Specimen Name	Wear Rate (gm/m)
PTFE + BRONZE 30 %	1.583 * 10^ -5
PTFE + GLASS 25 %	2.046 * 10^ -5
PTFE + BRONZE 15 %	2.481 * 10 ^ -5

6. Comparative wear data of all material

Following correlations are obtained for three materials.

- For material I

Wear rate × 10-06 gm /m= - 16.57-5.74*load[1]+1.20*load[2]+6.20*sliding velocity[1]-1.57*sliding velocity[2]-4.54*sliding velocity[1]+0.74*sliding distance[2]-2.50*load[1]sliding velocity[1]-1.39*load[2]sliding velocity[1]

- For material II
-

Wear rate × 10-06 gm /m= -20.46-8.80* load[1]+0.65*load[2]+4.81*sliding velocity[1]-0.46*sliding velocity[2]-8.15*sliding velocity[1]+1.20*sliding distance[2]+1.67*load[1]sliding velocity[1]-1.39*load[2]sliding velocity[1]

- For material III
-

Wear rate × 10-06 gm /m= -24.82-8.43* load[1]+1.85*load[2]+4.35*sliding velocity[1]-0.74*sliding velocity[2]-7.13*sliding velocity[1]-0.46*sliding distance[2]+1.39*load[1]sliding velocity[1]-0.56*load[2]sliding velocity[1]

Conclusion

1. From the analysis on the results of dry sliding wear of the PTFE Filled with Bronze and glass, the following conclusions can be drawn from the study.

- Wear rate of PTFE Composites increase with the increase in normal load.
- Wear rate of brake pads decreases with increase in sliding velocity.
- Wear rate of brake pads increases with increase in the sliding distance.

2. Sliding distance is the wear factor that has the highest physical properties as well as statistical influence on the dry sliding wear and of the composites. The load, sliding speed and reinforcement, and the interaction sliding speed and sliding distance will contribute more and other interactions will influence very less.

3. Pure PTFE gives very high wear rate as compared to composite PTFE.

4. Composite PTFE has much good mechanical and tribological properties as compared to Plain PTFE.

5. Depending upon load, velocity of sliding and sliding distance, material used in this study can be ranked as 30 % bronze filled PTFE > 25 % glass filled PTFE > 15 % bronze for their wear Performance.

Acknowledgment

I would like to express my sincere thanks and appreciation to Mechanical Department of S.V.P.S.'s B.S.Deore College of Engineering, Dhule for valuable support and kind co-operation during experimentation work.

References

Luigi Mazza, Andrea Trivella , Roberto Grassi , GiulioMalucelli (2015), A comparison of the relative friction and wear responses of PTFE and a PTFE-based composite when tested using three different types of sliding wear machines , Tribology International 90,15–21

Harshal P Deshmukh, Navneet K Patil (October-2015), Experimentation and Analysis of Three Different Compositions of Semi-Metallic Brake Pads for Wear Rate under Dry Friction Condition International Journal of Engineering Research & Technology (IJERT), Vol 4 Issue 10.

Prasad M Patare, Dr G S Lathkar (Nov 2014), Effects of Filler Glass Fiber on the Properties of PTFE Composites ,vol 3 issue 11

S.M.Gujrathi (June 2013), Wear Studies on Polytetrafluroethylene (PTFE) Composites: Taguchi Approach vol3 2

Hongxiang Teng (29 May 2012), Overview of the Development of the fluoropolymer Industry

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

W. Brostow, V. Kovačević, D. Vrsaljko (2010), J.Tribology of polymers and polymerbased composites, Journal of Materials Education Vol. 32. No. 5-6, pp. 273-290.

Deepak Bagle, Sanjay Shekhawat, Jitendra Chaudhari (January 2013),Wear Analysis of PTFE and its Composites under Dry Conditions using Design-Expert, International Journal of Scientific and Research Publications, Volume 3, Issue 1, ISSN 2250-3153.

Sandip B. Chaudhari, Prof. S.P. Shekhawat (Jul. - Aug. 2013), Wear Analysis of (PTFE) and its Composites under Wet Conditions, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 8, Issue 2, PP 07-18.

Jaydeep Khedkar, Ioan Negulescu, Efstathios I. Meletis (2002), Sliding wear behavior of PTFE composites, Wear 25, 361-369.