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Research Article

Study the Tribological Properties of PEEK/PTFE Reinforced with Glass Fibers and Solid Lubricants at Room Temperature

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Abstract

Investigations of tribological properties of polymers and polymers with filler materials, the present work has been carried out by using pin on disk. Normal load, velocity and atmospheric temperature these parameters were considered for tests. The friction and the wear mechanisms of PEEK based composites under dry condition was studied for non lubricated reciprocating compressor piston rings.. Base polymeric materials poly-ether-ether-keton (PEEK) containing fillers (PTFE) and solid lubricants like MOS2, Bronze reinforced with Glass were investigated. Composite Pins of (1)PEEK+ PTFE (wt15%) + glass fibers (wt15 %), (2) PEEK+PTFE (wt15%) + glass fibers (wt15 %)+Mos2(wt 5%), (3) PEEK+ PTFE (wt15%) + glass fibers (wt15 %)+Mos2(wt 5%), +Bronze (wt15%), (4) PEEKPTFE (wt15%) + glass fibers (wt15 %)+Mos2(wt 5%), +Bronze (wt 20 %). were tested against disk of grade EN-8 with an initial surface roughness of 0.4 micron. In all tests, conducted on pin-on- disk and wear data collected by machine analyzed, the following conclusion can be drawn: friction and wear in polymers are fundamentally different from the mechanism which occurs in metals. A very important conclusion on wear resistance of polymers and composites is its strong dependence on the atmosphere and normal load. It is observed that wear rate of PEEK+PTFE (wt15%) +glass fiber(wt 15% shows very high, it was $9.44x10^{-11}mm^3/NM$ and friction coefficient 0.133. but adding 5% MoS2 in PEEK/PTFE reinforced with glass fibers shows wear rate $3.31x10^{-11}$ mm^3/NM and friction coefficient 0.015.By adding bronze15%wt in PIN-3, 20% wt in PIN-4, wear rate was $2.98x10^{-9}$ mm^3/NM and $8.075x10^{-11}$ mm^3/NM respectively. It means by increasing the percentage of bronze in PEEK/PTFE reinforced with glass fibers, it minimize the wear. Among the tested of materials, the PEEK with fillers like PTFE, glass fibers, MoS2, Bronze have shown the greatest sliding wear resistance.

Keywords: *PEEK/PTFE , Glass fiber , solid lubricants, Tribological properties*

1. Introduction

PEEK based composite are new crovaline material and made by adding different filler material like PTFE, glass fibers, and solid lubricants like MOS2 and bronze. So thus maintaining the case of manufacturing and lower cost. The above fillers are common , they enhancing tribological as well mechanical chemical stability. These PEEK composites are suitable for various applications like self lubricant bearings, bushings, mechanical seals, bearing cages, gears and pulleys, piston rings etcThese materials are intelligent material for tribological application could reply to stimulate the tensile stress in deforming and improve its ability to resist wear or reduce friction.

In many decades solid lubrication has been considered one of the most promising materials used to achieve better tribological properties (B.J. Brisco *et al*). PEEK, PTFE these are the properties of high temperature thermoplastics can improve certain modification by or combination with other materials. PEEK is a high performance semi crystalline thermoplastic polymer, has received significant attention due to its strength and class modules properties. High melting temperature, chemical, inertness, toughness, easy processing and wear resistance. PTFE is one of a major class a engineering. Polymers with good combination of thermal chemical, mechanical and tribiological properties. Unal *et al*. reported that PEI+10%, PTFE, PEEK, UHMWPE polymer and glass fiber reinforced PTFE composite tested, the friction coefficient and wear rate decreases PTEF + 20% GFR composite showed the lowest wear rate. (E. Donnet *et al*).(Avanzini *et al.*) in willing contact fatigue testing of PEEK based composites reported that 30% glass fiber reinforced specimens shows high fatigue resistance and wear rate. Bijwe et al. has reported that 30% PIFE blend in PEEK shows excellent combination of co-efficient of friction and wear rate. Unfilled PEEK shows good wear resistance but exhibited high coefficient of friction.(Theiler *et al.*) tested MOS2 filled PEEK/PTFE composite in vacuum environment and get coefficient of friction 0.03, MOS2 film exhibit extremely low friction, but in presence of humid air, friction and wear rate increase.(J.R.Vail *et al.*). reported that 10% vol. of PTFE in PEEK dramatically reduced were rate and coefficient of friction wear rate of as $K= 7x10^{-8}$ mm^3/Nm. Transfer films were brown thin,

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Table 1: PEEK composite

Details of composite Details of PEEK	Designation of composite pin	blend in % by wt
PEEK+PTFE+GF	P1	70%+15%+15%
PEEK+PTFE+GF+MOS2	P2	65%+15%+15%+05%
PEEK+PTFE+GF+MOS2 + Bronze	P3	50%+15%+15%+05%+15%
PEEK+PTFE+GF+MOS2 + Bronze	P4	45%+15%+15%+05%+20%

and contained carbon oxygen and fluorine at the surface. (H Vass *et al*) reported that on the wear behavior short fiber reinforced PEEK composites. 18% GFR shows good wear resistance. (Sean Benjamin) reported in wear analysis of PEEK composites, he concluded that wear rate increased when carbon fiber 18% and glass fiber 5% and wear rate decreases when Carbon fibers 5% increased to a maximum before decreasing the glass fiber 18% did the opposite,. The effects of fillers on the mechanical and thermal properties of polymers are interrelated with those on the frictions and wear properties. Addition of glass fiber increases strength and hence load carrying capacity but also increases the coefficient of friction and thus reducing the sliding speed. Some solid lubricant reduces though the load carrying capacity but also reduces the co efficient of friction. Wear properties of different materials depend on the sliding as well as on the type of material (Z.P.Lu *et al*). Solid lubricant like Bronze improves mechanical properties it is harder, better wear, friction and chemical resistance. It is high thermal conductivity better creep resistance.

The objective of the present work is to develop self lubricating PEEK composites material for the application piston rings of compressor. This work is helpful for dry friction and wear behavior between PEEK composite against steel in room temperature.

2. Experimental Details

2.1 Materials Selected

Neat PEEK (unfilled) 450G fine powder with average diameter of 100 µm supplied by victrex. Polytetrafluoroethylene(PTFE) supplied by PCEE textile Kanpur, Bronze powder with 10% tin was supplied by pometon India Pvt., Mumbai, MOS2 diameter 100 µm supplied by Vishal Pharmachem Mumbai.

Fig 1: Granules of PEEK composite and injection molded pins

The composite were prepared by compression as well as injection molding. The PEEK; PTFE, Glass fibers, MOS2, Bronze were mixed before melt blending on twin screen extruder in temperature range from 343^{o} C to 400^{o}C. The extruded strands were quenched in water followed by chopping into granules. There were dried for 44 at 150^{0}c for injection molding (J.J.Rajesh *et al*). The Sample we get in the form of bars was supplied for tribological studies.

2.2. Tribological studies

The pin on Disc discussed elsewhere was selected for this work. The composite pin (4x4x30 mm^3) oscillated against counter face of steel EN-38 Disc with dimension 165x8mm thickness.

Fig.2: Pin on Disc

Following operating parameters were selected for the studies.

Load: 1N
Temperature & environment selected: room temperature
Frequency -50 Hz
Duration: 3 hrs.
Sliding velocity:1.8 m/s to 3.4 m/s.

Specially this test was conducted for the non lubricated reciprocating compressor piston rings. The aim of these studies is to minimize wear rate. The content pressure ranges from 1 to 4 mpa. The value of contact pressure was selected with non lubricating air compressor application which works on working pressure at 4 mpa. Sliding velocity were 3.4m/s.

Co-efficient of friction (µ) was recorded on the chart paper as a function of ; in Data equation system and wear also get in micron. Wear was calculated as a loss in weight of the polymer pin. Specific wear rate was calculated using following equation.

$$K = \frac{\Delta m}{\rho L F_N}$$

Where K = sp. Wear rate in m^3/N.m.
Δ m = weight loss in kg
ρ = Density of sample in kg/m^3
F_N = the applied normal load in N
L = sliding distance in m.

3. Discussion

3.1 Wear

Due to filler material in PIN-1- PEEK as base material and PTFE and GRR are filler materials. Initial period of test means in 1st 60 min. wear was very low 0.82 micron. Resulting in a thin brown film layer deposited on the disc initially during formation of transfer film the frictional force also very low it was 1.5 N. At the end test that is 180 min. the total wear of pin material was 39.94 micron. The specific wear rate has found to be 9.44x 10^{-11} mm^3/Nm .It is also observed from. Fig.2 and fig 4

Table 2 Wear of composite pins in 3hrs

Composite	Wear1 in 60 min	Wear2 in 120 min	Wear3 in 180min
p1	2.82	24.92	39.94
p2	-1.33	-1.25	-1.49
p3	61.68	68.17	70.99
p4	10.71	14.98	15.01

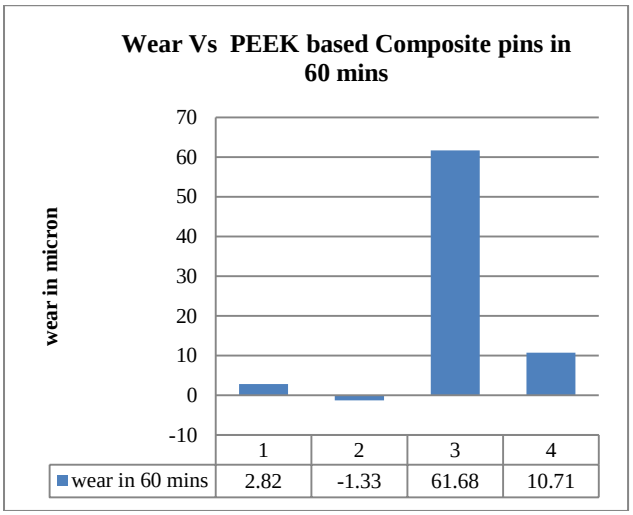

Fig.2 Wear for PEEK based composite in 60 min

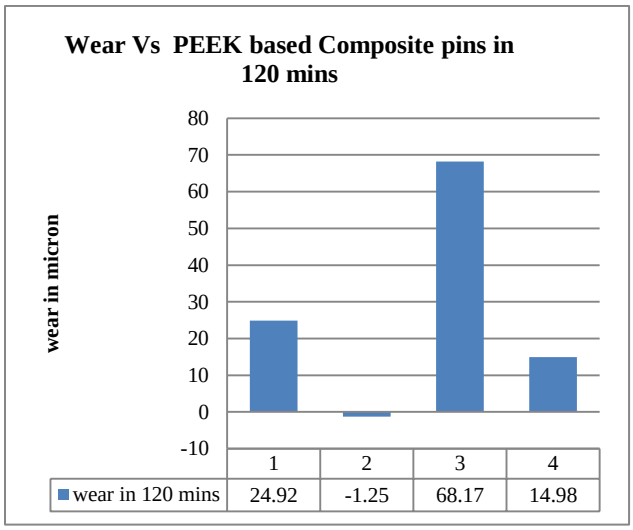

Fig .3 Wear for PEEK based composite in 120 min

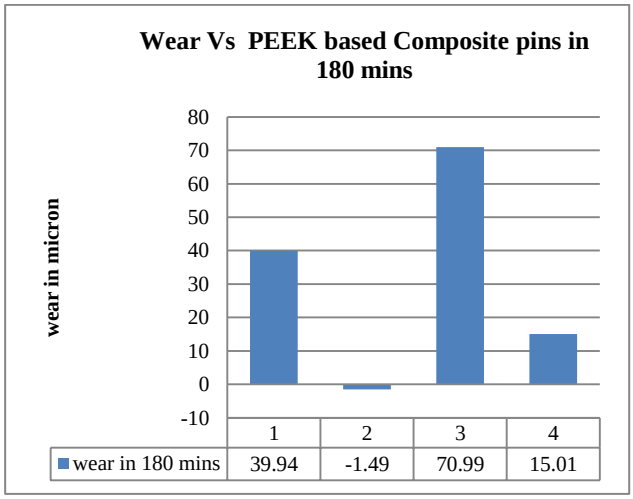

Fig.4 Wear for PEEK based composite in 180 min

In PIN 2 the filler material was PTFE, GF and MOS2 with PEEK as a base material. This pin also shows same characteristic, but wear rate of PIN-2 is less as compared to PIN 1 after forming thin film with black gray layer i.e. transfer film formation on disk it almost stabilized wear found after 60 min. initially wear was -8.80 micron and after 180 min wear was -1.49 micron. It is shown in fig.1 and fig 4 Wear goes increasing and then stabilized. The frictional force initially low and at the end of test it was 2,28N.The specific wear rate has found to be 3.31x 10^{-11} mm^3/Nm.

In PIN 3 the filler material was PTFE, GF, MOS2 and Bronze. the percentage of filler material like MOS2 5% and Bronze 15%, glass fiber 15%, PTFE 15% by weight initially wear rate in first 60 min. was 61.68 micron, the transfer film on disc was brownish and smooth thicker then Pin-1 and Pin-2, frictional force was also 1.49N. After 180 min wear rate increased continuously. After that wear rate was 70.99 micron but friction force was less as 1.04 N. here wear increases and frictional force decreases. It is shown in fig1 and fig 4 .The specific wear rate has found to be 2.98x 10^{-9} mm^3/Nm .This wear is more than above PIN-2 and PIN-3.

PIN 4 the filler material was same as above, pin composition was different PTFE 15% GF 10% MOS2 5% and Bronze 20%. Addition of Bronze increase the strength, initially wear was 3.91 microns in 60 mins and frictional force was 2.17N, after 180 mins Wear was 15.01 micron and frictional force 1.76N. as shown in fig 4. The wear was less as compared to the P3. It means that addition of filler materials like glass fiber, MOS2 and bronze, resist wear rate. The specific wear rate was found 8.075x 10^{-11} mm^3/Nm

3.3. Comparative study of PEEK based composites

Fig.5 show scatter diagram for the comparison of PEEK/PTFE/Glass Fiber/Mos2/Bronze wear curve.PEEK/PTFE reinforced with glass fiber shows higher wear rate but addition of inorganic filler material like Mos2 and Bronze decrease the wear rate and coefficient of friction. Addition of glass fiber with Mos2 increased wear resistance, compressive strength, reduced

cold flow, and increased rigidity. The percentage of MoS2 with Glass fiber and Bronze should be 5%.above this it loses its properties. Also with addition of Bronze, it was found that ware rate is very less as compare to pure PEEK. Wear value drastically enhanced by addition Bronze with Glass fiber and Mos2.It increases the hardness, wear resistance, and improve thermal conductivity. It was also observed that transfer film formed very soon as compared to pure PEEK material.

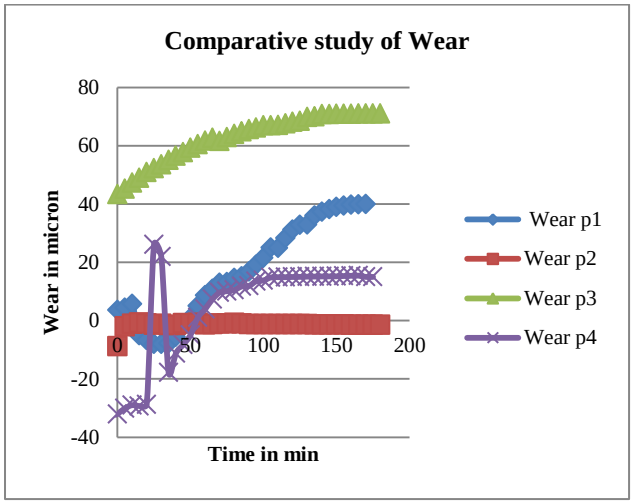

Fig.5 comparison wear of various PEEK based composites

3.2 Coefficient of friction

Figure 5 and table 3shows the variation between the friction of composites P1, P2, P3, P4. The coefficient of friction of P2 is 0.015 which less as compared to composite P1, P3, P4.

Table 3: Variation between the friction of composites P1, P2, P3, P4

Composite pin	Coefficient of friction
P1	0.133
P2	0.015
P3	0.182
P4	0.221

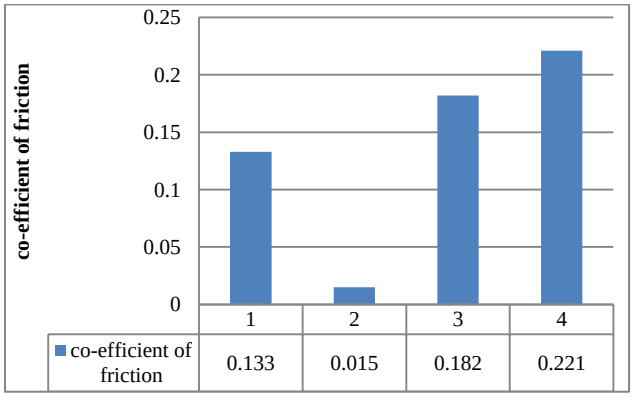

Fig.5 Coefficient of friction for various PEEK based composites

Conclusion

Based on experimental analysis of dry friction and wear tests presented above the following conclusions were made.

1. It was found that the 15% glass fiber reinforced with PEEK/PTFE shows higher wear rate but addition of MOS2 and Bronze enhance wear properties of PEEK reinforced with glass fibers.
2. It was found that the Composite P2 5%MOS2 with 15% glass fibers exhibited low coefficient of friction and high wear resistance It shows very less wear rate that is $3.331x10^{-11}$ mm^3/NM. This is because of proportion of solid lubricant
3. MOS2 and Bronze is widely used as solid lubricant material. These materials easily enter the roughness valley and stably stay on disk. It provides necessary lubrication during sliding. This is helpful to reduce the wear and increase wear life of component.
4. It is concluded that inorganic materials like MOS2, bronze power as fillers could effectively prolong the wear life of transfer film of PEEK based composites reinforced with Glass fiber.

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