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Effect of Counter Surface Roughness on the Wear Mechanism of PTFE and PTFE Based Composites Liners in Aqueous Medium

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Abstract: For the past years bearings that use a self-lubricating PTFE-based liner material which replace standard metal-to-metal greased bearings in many aerospace, marine, and hydroelectric applications. When designing a bearing all of the operating parameters including radial and axial loads/pressures, rotational velocity, frequency, operational cycles, and environmental conditions are evaluated and taken into account Polytetrafluoroethylene (PTFE) is an important engineering material. When rubbed or slid against a hard surface, PTFE exhibits a low coefficient of friction but a high rate of wear. These unique properties of the polymer have encouraged many mechanistic and physical examinations of the processes involved in the friction and wear of this polymer. When rubbed against a hard surface, the PTFE chain undergoes scission, creating active groups which chemically react with the counterface. This results in strong adhesion and a coherent transfer film. Experimental work has been carried out considering loads varying at a constant velocity against mirror finish and polished surface. The test has been carried out for four materials of PTFE and its composites in water lubricated condition against EN-24 Steel plates. Duration of each test conducted is one hour. To improve resistance to wear property of PTFE, Glass Fiber is added as a filler material by varying its percentage. Tests were carried out for investigation of tribological properties such as wear rate and coefficient of friction against different surface roughness of counter surface. The results are used to generate friction and wear maps of different value of roughness of counterface of different loads and a relationship between a loads, Surface texture and behavior of PTFE and its composites.

Keywords: Surface Texturing, Tribology, Dimples, Polyamide, HDPE, Wear, Friction, Aqueous medium.

I. INTRODUCTION

Sliding machine elements made of plastics co-operates mostly with metallic material and subject to different processes involved with friction and wear.during the friction of polymer material on steel, several process like mechanical and adhesion interaction, trio- chemical and tribo-electical etc are presents. A share of these interaction in the process of friction is dependent upon the loading of the friction pair with the normal loads, sliding velocity, surface roughness and waviness o the co-operating metal element, mechanical properties of the rubbing element, adhesion characteristics of the sliding pair and other operating element as well as film stability to regenerate is also great importance.

1.1 Mechanical interaction-

Surfaces of mechanical elements, even those machined to the highest grade of finish,are never ideally smooth. Their geometric features are defined by the surface roughness, waviness, deviation in shape, and orientation of irregularities. The contact of two real surfaces subject to friction is done on the irregularity asperities. Many historical theories assumed that friction results from mechanical interactions of the contacting surfaces irregularities. In the so-called Coulomb model, the action of the wedge-shaped asperities causes the two surfaces to move apart as they slide from one position to another and then come close again. Work is done in raising the asperities from one position to another and most of the potential energy stored in this phase of the motion is recovered as surfaces move back.

Nowadays, it is generally acknowledged that apart of local adhesion contacts of the asperities of micro-irregularities, the energy of friction is required for microscale deformation of contacting surfaces during relative motion. If asperities of one surface (harder of the two, if dissimilar) plough through the other via plastic deformation, energy is required for this macro-scale deformation (grooving by ploughing).Macro-scale deformation can also occur by particles trapped between the sliding surfaces. A situation of this type is common during the friction of polymer materials on metals as the two co-operating materials feature a marked difference in hardness. Hard micro-irregularities of the metal element dig into a relatively soft surface of the polymer material causing ploughing, grooving or micro-machining during sliding Friction [**1 2 3]**

1.2 Creation of the polymer film

The polymer film, i.e. a thin layer of polymer forms on the surface of the co-operating metal element. It reduces the roughness of the steel surface influencing thus, among others, the friction and wear processes. Additionally, thanks to this layer, friction develops between two polymer layers and not between the polymer and metal layers. The rate of the film creation, its structure, durability and lubrication properties depend on forces of adhesion between the metal and the polymer, and, above all, on the properties of the very polymer material. The first layer of the polymer adheres strictly to the surface of the metal and is practically not removable during the whole friction process. The next layers of the polymer material may be easily removed and these very layers convert into wear products of the adhesion wear process. These products may also be created as a result of mutual abrasive interactions between the asperities of microirregularities of the metal surface and the surface of the polymer material. They fill gradually cavities between the asperities. Not all of the wear products are bound, however, to the surface of friction. In a further stage of the friction process these particles are compressed by the mating surfaces creating a layer of different thickness.[4 5 6 7]

1.3 Asperity melting

The wear of polymer materials that results in the melting of asperities is prevalent mostly at the stage of run-in, i.e. during the initial stage of their rubbing against steel. At an appropriate loading (in terms of pv) of a rubbing pair and an appropriate roughness of the metal element, the melting of asperities of the polymer material starts.

This leads to a quick smoothing of its surface and with a more uniform distribution of pressure at the contact surface (reduction in the stress concentration at the peaks of microirregularities). A precondition, however, is that abrasive wear at this stage of the friction process is not too intensive.

Smoothing goes together with the working (hardening) of the upper layer of the polymer material. At a further stage, the asperity melting process terminates, the sliding surface of thermoplastic materials becomes lustrous and smooth. It may be assumed that the asperity melting wear is actually a beneficial part of the run-in process [8 9 10]

1.3 Aqueous medium (Water lubrication)

When a water droplet is interposed between two hydrophilic plates which are just separated, it sticks them together. This is because the plates easily become wet. In the world of a small-sized machine (micro-machine) the gap between the machine parts, which are usually hydrophilic, are so small that water acts as a glue of the parts and prevents them from sliding.

As a result, it interrupts the normal operation and sometimes causes a complete failure of the whole system. As the size of the machine becomes smaller, the water droplet effects become larger. On the contrary a water droplet on the hydrophobic surface does not stick to the surface and actually drops down from the surface, which can be commonly observed on the grass or leaves. The droplet has a spherical shape and rolls/ slides like a ball. So if it is utilized as a ball bearing between two plates, it will greatly reduce the friction force.

In the sliding test, a water droplet slides on the new surface. This means that the water droplet adheres to a new surface at the front end and is separated from the surface at the rear end. On the other hand in the loading/unloading test, the water droplet spreads out to extend the contact area in the loading process followed by the decrease in diameter in the unloading process. The loading/unloading process is equivalent to the sliding process from the viewpoint of changing the contact area. [11, 12]

II. EXPERIMENTATION DETAILS AND INVESTIGATION

To analysis wear property of PTFE, Glass Fiber composite material by varying the roughness of the disk. For this study 15%, 25%, and 40% Glass Fiber is added in PTFE.

Tests were carried out for investigation of tribological properties such as wear rate and coefficient of friction against different surface roughness of counter surface. These tests were carried out on Pin-on Disc Tribometer.

For this the disc are made of EN-24 of surface roughness Ra = 0.06, 0.1, 0.14μm (mirror finish &polish finish).
Test were conducted as follows,

1. Sliding speed V=2.5 m/s
2. Average pressure P=0.22,0.77,1.44,2.22 Mpa
3. Duration T=60 Min.
4. Polymer material-pure PTFE ,15% glass fiber, 25% glass fiber, 40% glass fiber
5. Water lubrication temperature = 20°c

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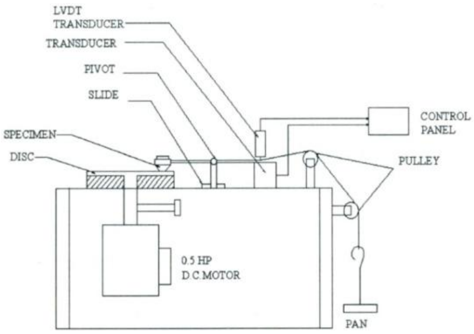
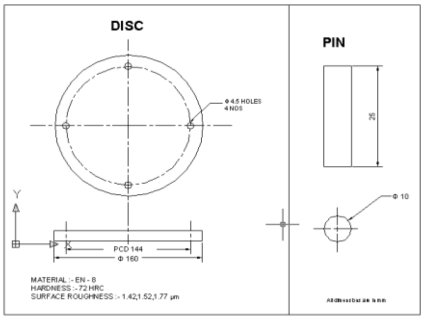
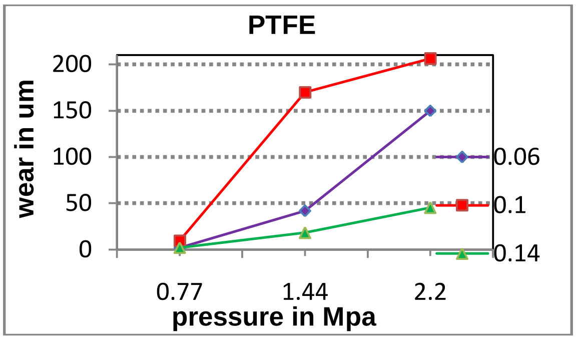
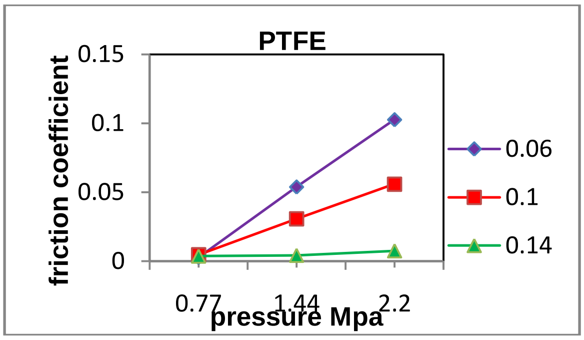
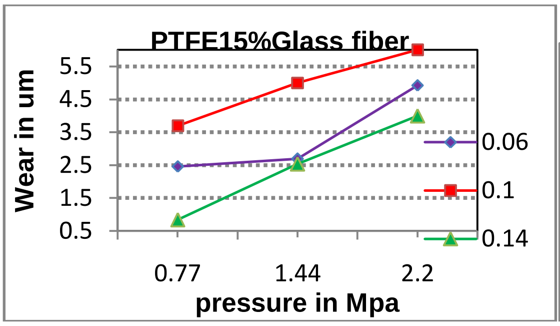


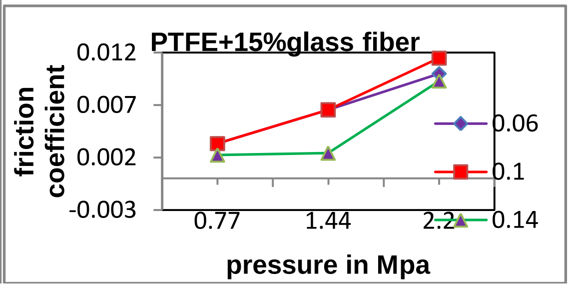


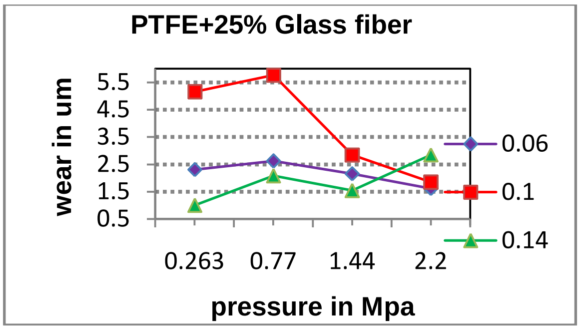
2 Results : wear and friction coefficient mechanism for three surfaceroughness

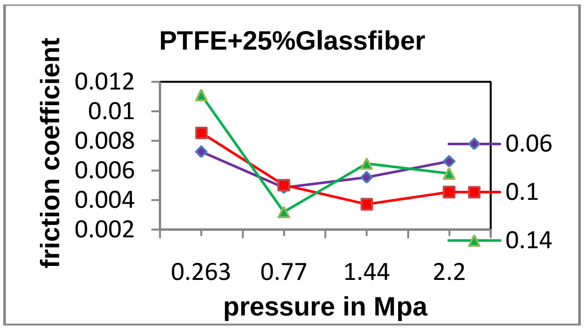


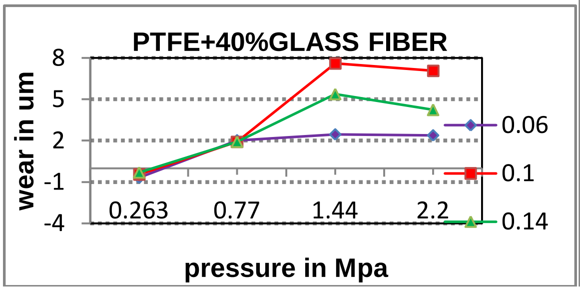


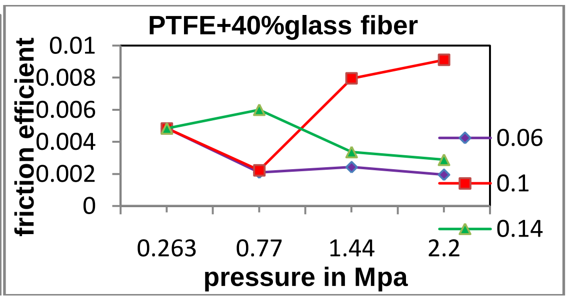












IV. CONCLUSIONS

- Highest friction levels were provided by PTFE and these were considerably higher thanthose of the PTFE-based materials.
- In general the coefficient of friction during operation decreased for all of the materials with increased loading at the starting after some time it is reduced.
- Pure PTFE provided variation in friction through both variations in surface roughness and pressure.
- Contact pressure and temperature were found to influence the friction independently of each other for PTFE as well as composites, i.e. there was no significant interaction between temperature and pressure effects.
- Significant polishing effect of the steel counter-surface is observed in the cases of both PTFE materials and its composites at all pressures. Measurable polishing is not observed on the counter-surfaces of the other materials.
- PTFE has the highest value of this parameter but also the poorest tribological behavior under tested conditions

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