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The Tribological Properties of PTFE Composites Filled with Carbon Fiber, MOS2, Bronze Reinforcement

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Abstract: *PTFE that is Polytetra fluoroethylene has wide increasing demand because of its unique properties like low coefficient of friction, high chemical resistivity, and high temperature stability. However, PTFE exhibits poor wear resistance, especially abrasion. The wear resistance of PTFE can be significantly improved by addition of suitable reinforcement (filler) materials. Among the most common filler materials are glass fibres, MoS2 and bronze. In this paper, it is presented a review of tribological properties of composite materials with PTFE matrix and above-mentioned filler materials. Now a day there has been a significant growth in the large-scale production of polymers and polymer matrix composites. Polymer composites mostly used as structural components that are very often subjected to friction and wear loadings under use. In some situations, the coefficient of friction is of the highest importance, but mostly the mechanical load-carrying capacity and the wear life of components that determine their acceptability in industrial applications under different operating conditions*

Keywords: Turbo-Ventilator, Electric Generator, permanent magnet, Axial Flow, Wind Energy, Ventilation

I. INTRODUCTION

Tribology is defined as the science and technology of interacting surfaces in relative motion, having its origin in the Greek word ‘tribos’ meaning rubbings with a view of understanding surface interactions in . It is the study of the friction, lubrication and wear of engineering surface detail and then prescribing improvements in given applications. Since World War II the rapid rate of technological advancement has required great expansion in research on what to do about surfaces that rub. One of the important objectives in Tribology is the regulation of the magnitude of frictional force according to whether we require a minimum or a maximum. This objective can be realized only after the understanding of the frictional process is obtained for all conditions of temperature, sliding velocity, lubrication, surface finish and material properties (1).

Many polymers and polymer-based composites are widely used for sliding couples against metals, polymers andother materials. However, when the contact is there, the problem of friction and wear is there. The friction between polymers can be attributed to two main mechanisms, deformation and adhesion. In this case, the deformation mechanism involves complete dissipation of energy in the contact area while the adhesion component is responsible for the friction of polymer and is a result of breaking of weak bonding forces between polymer chains in the bulk of the material. In fact, tribologists often classify thermoplastic polymeric materials into three distinct groups according to their friction and wear behaviour. These are: the normal polymers such as low-density polyethylene (LDPE), (PMMA);and the smooth molecular profile polymers such as Polytetrafluoroethylene (PTFE) and ultra-high molecular weight polyethylene (UHMWPE). Among them, the better frictional performance of the smooth molecular profile polymers can be explained by the easiness with which the long chain molecules shear across each other. Numerous nano particlesused as oil additives have been investigated in recent years. Results showed that they deposit on the rubbing surface and improve the tribological properties of the base oil, displaying good friction and wear reduction. Results showed that wear rates and friction stability were affected by the relative amounts of solid lubricants in the friction composites.

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There are very good effect of using graphite as a solid lubricant with the increase of graphite content wear rates were decreased significantly(2)

II. DEVELOPMENT PROCESS

Bearing Lubrication-

Most of the bearings operate with a fluid film of oil, liquid, or gas. The largest numbers of bearings are oil lubricated. The oil film can be maintained through pumping by a pressurization system in which case the lubrication is termed as hydrostatic. Or it can be maintained by a squeezing or wedging of lubricant produced by the rolling action of the bearing itself termed hydrodynamic lubrication. If loads are too high or speeds are too slow, the hydrodynamic action begins to break down a condition referred to as boundary lubrication.

Lubrication of Sugar Cane Mill Bearings-

In cane crushing sugar mills the highly smooth and polished split type journal bearing shown in fig. 2.1 is commonly used because mills runs at very low speed, rollers exert very high pressure on bearing which need substantial area to support the load. The material used for these bearings are brass or gunmetal.

Fig. 2.1 One halve of split type journal bearing [2].

The hydrostatic type of lubrication is provided through the lubricator driven by sprocket filled on pintle end of top roller shaft as shown in fig. 2.2. The hydraulic pressure of 775 psi to 900 psi is acting on the bearing side of hydraulic piston of 300 mm diameter in the cylindrical chamber. At the start of the mill and when sudden heavy load exerted by roller on the bearing the condition of lubrication is boundary lubrication.

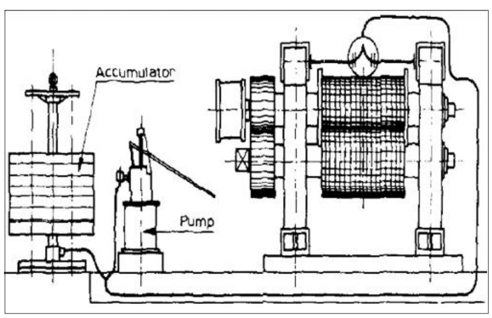


Fig. 2.2 Hydraulic pressure system [10]

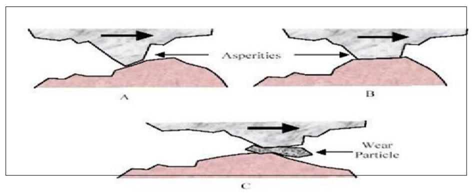
Average oil consumption is 30 liters / hour for the sugar factory of 2500 tonnes of crushing capacity per day. This oil should have a viscosity of 3000 – 3200 centipoises at 40^0c and contain the additives: 4.5% of a mixture of sulphur and phosphorus 0.5 % of an anti-foaming agent, 0.01% of a lubricant agent. Cooling water for the six bearings of a slowly rotating three roller mills required is 700 to 1000 liters/hour.

Wear-

Wear occurs when two surfaces with a relative motion interact with each other. Wear is a mechanism of removal of material from its surface when it moves to relative to other surface. The mechanism of wear is very complex and is a progressive deterioration of the surfaces with loss of shape often accomplished by loss of weight and creation of debris. The real area of contact between two solid surfaces compared with the apparent area of contact is very small, and limited to points of contact between surface asperities. The load applied to the surfaces will be transferred through these points of contact and the localised forces can be very large. Factors governing the wear are material surface properties such as hardness, strength, ductility, work hardening, surface finish, lubrication, load, speed, corrosion, temperature and properties of the opposing surface etc. Adhesive wear, abrasive wear, liquid erosion, cavitation erosion, fretting wear, fatigue failure and are the types of material wear.

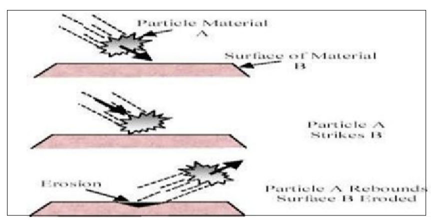
Adhesive Wear-

Adhesive wear is also known as scoring, galling, or seizing. It occurs when two solid surfaces slide over one another under pressure. As shown in fig. 2.3 surface projections, or asperities, are plastically deformed and eventually welded together by the high local pressure. As sliding continues, these bonds are broken, producing cavities on the surface, projections on another surface, and frequently tiny, abrasive particles, all of which contribute to future wear of surfaces. Therefore ahesive wear is produced by the formation and subsequent shearing of welded junction between two sliding surfaces. Surfaces which are smooth and held apart by lubricating films, oxide films etc. reduce the tendency of adhesive wear.



Erosive Wear-

The integrity of the material may be destroyed by the erosion caused by the high pressure moving liquids may be containing solid particles. The solid particles present in liquid causes the strain hardening of the metalsurface leading to localised deformation, cracking and loss of materials.



Abrasive Wear-

As shown in fig. 2.4abrasive wear occurs when material is removed by contact with hard particles (either of any surface or loose foreign particle existing between surfaces). These particles either may be present at the surface of a second material (two-body wear) or may exist as loose particles between two surfaces (three-body wear). Two body abrasive wear occurs when one surface (usually harder than the second) cuts material away from the second, although this mechanism very often changes to three body abrasion as the wear debris then acts as an abrasive between the two surfaces. Abrasive wear is common in machineries like scrubber blades, crushers, lapping machines and grinders to remove materials. In dampers, gears, piston and cylinders, abrasive wear occurs(7).

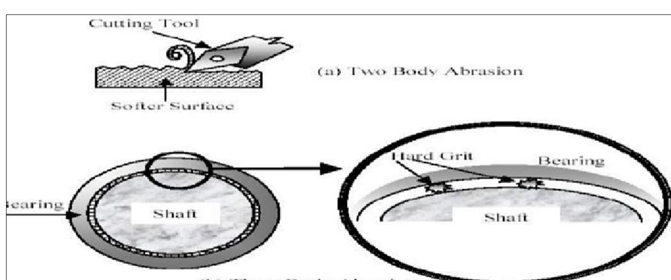


Fig. 2.4 Schematic of abrasive wear process [2].

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Wears in Sugar Mill Bearings-

The high rate of wear on top roller shaft journal is an important problem in sugar cane mill bearing. Milling operation using spilt bearing make possible that bagasse & mineral extraneous matter (MEM) in juice enters in the bearing when the top roll moves up & down during milling transients. In this condition the lubricant properties are degraded & its performance affected, additionally MEM causes a high abrasive wear because it contains silicate & other hard particles. Both high abrasive wear and deep grooves are present on the journal zone closer to the shell.

Due to temperature rise in bearing, degradation of the lubricant increases the adhesion between journal & bearing which tends to possible formation of oxides that remain in the system, acting as abrasive for further wear. So this abrasive particles and MEM are responsible for the journal wear and also diminishes the shaft service life. Therefore it is necessary to develop sealing system to diminish MEM entering in the bearing gap. Also it is needed to find out different materials & lubricants to obtain a better performance of the pair. Fig. 2.6 illustrates the magnitude of wear problem in sugar cane mill bearing.

Without significant changes in the design concept of cane crushing mills it is necessary to develop sealing systems to diminishes MEM entering in the bearing gap, but also it is needed applied research on different materials and lubricants to obtain a better performance of the pair which needs better understanding of friction and wear mechanism in bearings(8).

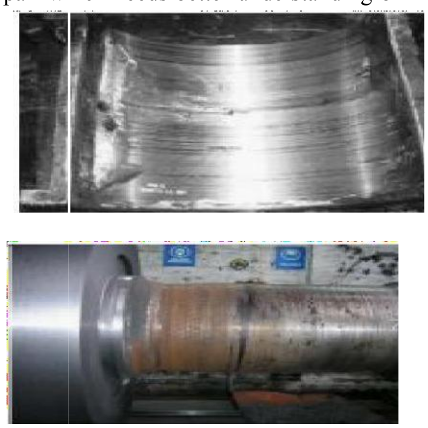

Fig. 2.6 Groove caused by abrasive wear and lost material by wear on journal [2].

Tribological Properties of Bearing Materials-

In general, the most important characteristics of bearing materials are

Score resistance –

A good bearing material should not damage the surface of journal under operating conditions of boundary lubrication. The anti-wear characteristics of bearing material are referred to as a score resistance.

- **Compressive strength -** This is the ability of the bearing material to carry imposed load without extrusion or disintegration, even if the load without extrusion or disintegration, is variable either in magnitude or direction or both.
- **Fatigue strength -** Bearings are usually exposed to fluctuating load, therefore bearing materials should have sufficient fatigue strength.
- **Deformability -** The bearing material should have an ability to yield and adapt in shape to that of the journal. This property is called conformability. When the journal is deflected under load the contact takes place only at the edges. Confirmable material adjusts its shape under these circumstances. The bearing material should also be able to accommodate any foreign body without scoring of journal. This property is called embed ability.
- **Corrosion resistance -** Bearing material should resist corrosion due to the lubricant and retain its shape.
- **Thermal conductivity** – Running bearings produce heat. This heat can make the lubricant unstable and hence breakage of oils films may happened. Hence, bearing materials should dissipate heat with higher thermal conductivity.

- **Thermal expansion -** Coefficient of thermal expansion should be low for bearing materials to prevent change in size and shape

III. POTENTIAL APPLICATION

PTFE and PTFE Composites-

Polytetrafluoroethylene (PTFE) resin is a paraffinic thermoplastic polymer that has some or all of the hydrogen replaced by fluoride. It is discovered in 1938 by a DuPont chemist, Mr. Roy J. Plunkettat DuPont's Jackson Laboratory in New Jersey. Upon examination, he learned that PTFE provided a combination of friction, temperature, chemical, mechanical and electrical resisting properties. PTFE is recorded the lowest coefficient ofstatic and dynamic friction as 0.02 - equivalent to wet ice on wet ice. PTFE revolutionized the plastics industry and, in turn, gave birth to limitless applications of benefit to mankind. PTFE is used extensively for a wide variety of structural applications as in aerospace, automotive, earth moving, medical, electrical, electronics, computer and chemical industries. PTFE has extended chain of linear repeating molecules of CF_2–CF_2. PTFE is a crystalline polymer with a melting point of about 327ºC. PTFE has useful mechanical properties from cryogenic temperature of − 260ºC to higher temperature of 280ºC. Pure PTFE has virtually universal chemical resistance, light and weather resistant, resistant against hot water vapor, excellent sliding properties, anti-adhesive behavior, non-combustible, good electric and dielectric properties, no absorption of water, physiologically harmless so as to use in food industry applications. But it has some adverse properties like cold flow behavior, relatively low wear resistance, low resistance to high-energy radiation, poor adhesive behavior and it cannot be injected.

PTFE is a high-performance engineering plastic which is widely used in industry due to its properties of self-lubrication, low friction coefficient, high temperature stability and chemically resistant. In fact, PTFE exhibits poor wear and abrasion resistance. To improve the wear resistance suitable fillers are added to PTFE. The most commonly used are glass fiber, carbon and graphite, in the form of powder intimately mixed with the PTFE, other fillers are molybdenum disulfide, metal powders, ceramics, metal oxides and mixtures of two or more additives (12).

3.1 Molecular structure of PTFE

PTFE is a completely fluorinated polymer manufactured by free radical polymerization of tetrafluoroethylene with a linear molecular structure of repeating–CF_2–CF_2– units. Molecular structure of Polytetrafluoroethylene is a crystalline polymer with a melting point of about 621ºF (327ºC). PTFE has useful mechanical properties from cryogenic temperatures (-260ºC) to 500ºF (280ºC).

The carbon-fluorine compound is one of the strongest compounds found in organic chemistry. The carbon chain is nearly completely covered by fluorine atoms, thus being protected against external influences. This results in the very high chemical resistance of PTFE .

Thermal Properties of PTFE

Thermal Resistance

The thermal resistance of PTFE has a range of -260°C to 300°C (i.e. stable in boiling helium at –269°C). No other standard industrial compound can have this temperature range.

PTFE may be exposed to temperatures ranging from– 200°C to 260°C.

Thermal Expansion

When designing components made of PTFE, the relatively high degree of thermal expansion must be taken into consideration

Thermal conductivity-

The coefficient of the thermal conductivity of PTFE does not vary with the temperature. It is relatively high, so that PTFE can be considered to be a good insulating material. The mixing of suitable fillers improves the thermal conductivity

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Specific heat –
The specific heat, as well as the heat content (enthalpy) increases with the temperature.

Manufacturing of PTFE Component –
Processing of PTFE is more difficult than that of standard thermoplastics. At high temperatures (340-380°C) PTFE will merely become highly viscous, which means that injectionmolding or regular extrusion is impossible. For this reason, semi-finished products are manufactured by means of compression sintering or ram-extrusion. PTFE can be turned, milled, drilled, pierced, broached, ground and polished.

Stages of manufacturing of PTFE components.
Resin in Granular Form
PTFE resins are supplied in granular form of uniform density particle and grade. This ensures continuity for allmaterial. This can be done by degradation of PTFE.

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Extrusion, Molding and Sintering of PTFE -
Traditionally, ram or paste extrusion, compression molding or isostatic molding processes PTFE and filled PTFE's. Pressing & Sintering is an extension of these processes and uses powder metallurgy techniques to produce custom sintered PTFE and PTFE filled components

Future Scope Of Work-
There are many variables that could be taken in wear testing such as load, velocity, temperature, contact area, surface finish, sliding distance, environment, counter face material, type of lubricant, hardness of counter face etc. In this present experimental investigation, variables like contact area, temperature, test duration (sliding distance), hardness of counter surface and surface finish were kept constant. But these can be varied to observe the wear rate of tested PTFE composites

1. Similar friction and sliding wear tests can be carried out for the PTFE composites filled with more percentage like 60 % and 70 % of Fiber particles.
2. For the PTFE composites selected for experimental investigation, comparable experimental research can be carried out with lubrication and lubrication additives.
3. The test can be conducted by considering effect of variables like temperature, and humidity on the friction and wear behavior of PTFE composites. Study of orientation, particle size of filler material like Fiber can be another area of research.

IV. CONCLUSION

The following conclusions, from the experiential investigation can be made about the friction and sliding wear be havior of PTFE composites filled with Fiber particles under the selected ranges of normal loads and sliding velocities. For the PTFE + up to 30% carbon fiber Fiber composites, initially wear is more & after certain sliding time wear curve shows very small wear with time or it gets stabilized. This may be due to formation of more & more uniform transfer film on the counter face.

1. Frictional coefficient initially increases with sliding time & later it remains almost constant due to more compact and uniform transfer film.
2. Wear increases with increase in applied load.
3. Fiber filled PTFE composites under experimental investigation register the stability in wear loss with time after the rapid initial wear.

4. The variation in normal load is more responsible for decrement in coefficient of friction.
5. From the investigation carried out, up to 30 % carbon Fiber particles filled PTFE composite material than glass fiber filled PTFE can be suggested as the best suitable self-lubricating material for sugarcane milling roller journal bearings to enhance the wear life of bearing.

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