Applications of Industrial Tribology

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Abstract - *The aim of the article is to study the tribological characteristics of different mechanical components. It has been observed that if mechanical losses are reduced by 10% in automobiles, the fuel consumption will be reduced by 1.5%. Development of new materials with better tribological properties is one of the promising solutions. The study of tribology has also helped in developing lubricants which are eco-friendly and sustainable. The research has shown that the use of bio lubrication in different industrial applications can protect the environment. Developments of bio lubricants as cutting fluids have also been suggested. Various vegetable oils as lubricants for automobiles have also shown promising results. Moreover, the paper also presents a summary of the various industrial applications of tribology.*

Key Words: **Tribology, Materials, Lubrication.**

1. INTRODUCTION

The tribological study of different components in the industrial applications has been a study of interest over many years. Tribology is the study of friction, wear and lubrication between the surfaces moving relative to each other. The tribology does not include the study of tribological properties of surfaces if they are not in relative motion. The interacting surfaces in relative motion are accompanied with friction. Friction between the surfaces leads to the dissipation of energy resulting in the loss of resources [1]. The main cause of friction is the adhesion and deformation [2]. In the adhesive friction, the interacting surfaces are held together by the molecular binding force. The friction due to the deformation is caused when harder surface gets in between the asperities of softer surfaces and deforms it. The main consequence of friction is wear. The wear leads to the degradation of materials performance and wastage of materials also takes place. Excessive wear eventually causes the materials to fail.

Different types of wear mechanisms include abrasive wear, adhesive wear, corrosive wear, erosive wear, fatigue wear [3]. Abrasive wear is caused when impurities like hard particles, dust, sand etc are in between the interacting surfaces. The result is that when the bodies move, these hard particles remove the material from the softer surfaces. Adhesive wear occurs because of the interaction of surfaces with each other. The surfaces in motion get attracted to each other due to the molecular force of attraction resulting in sticking with each other. This type of wear is very common in metals. Corrosive wear occurs when there is a chemical reaction between a corroding medium and the material, which is a strong function of operating conditions [4]. The erosive wear is similar to the adhesive wear where hard particles remove the materials from the softer ones. The difference being that there is a fluid present in between the surfaces. Fatigue wear occurs when there is cyclic loading. The cyclic loading causes the defects to grow due to the multiple reversals. The study of friction and wear can help us in conserving the energy and resources.

The friction and wear can be prevented by either providing a lubricating film between the surfaces or by developing new materials which are wear resistant [5]. The lubricating film can be solid or fluid. There are different types of lubrication which can be classified into a) Hydrodynamic lubrication b) Hydrostatic lubrication c)Elasto-hydrodynamic lubrication(EHL) and d)Boundary layer lubrication [6]. In Hydrodynamic lubrication, the surfaces are completely separated by thick lubricating film developed by wedge action of oil. There is no contact of asperities. Hydrostatic lubrication is actually a form of hydrodynamic lubrication difference being that in hydrodynamic lubrication pressure is self-generated where as in the hydrostatic lubrication, the surfaces are spaced by oil which is pumped by an oil pump. Since in this lubrication pressurized oil film is produced due to the external means, therefore a complete film is produced at all the time even at zero speeds [7]. EHL plays an important role where the applied load is large and the surfaces in motion does not match i.e their surfaces are different. The contact between such surfaces is called as counter formal contacts [8]. As a result of this, there will be elastic deformation of the surfaces. Due to this elastic deformation, the lubricant is pulled in between the surfaces which increase the pressure and this increase in pressure supports the load [9]. Boundary layer lubrication also known as the thin film lubrication. In this type of lubrication, the interfaces are separated by a very thin layer of lubricant. Here the oil film is so thin that under the motion, asperities come in contact with each other [10].

2. INDUSTRIAL APPLICATION OF TRIBOLOGY

The common industrial tribological components include: Bearings , cams , gears , automobile engines and cutting tools.

2.1 Tribology of Bearings

In mechanical systems, bearings are used for supporting the various rotating elements like shafts etc. Journal bearings are used for supporting the cylindrical rotating shafts. A special feature of journal bearings is that it makes metal to metal contact only in two conditions, one at the start of rotation and other at the end of rotation. Only in these two conditions, wear of journal bearings takes place. At all other instants, there is a hydrostatic lift between shaft and bearing which is created by pressurised fluid which we supplied externally. In Hydrostatic lift, shaft is slightly lifted from its original position and it rotates at its new position and does not make any contact with bearing so no wear of bearing takes place. But at the start and end of rotation, large amount of wear occurs so we have to find the remedies to such wear [11]. The prevention of this wear is very important as in today's world we have to save energy, so by reducing the wear, we can achieve the energy saving.

The main reason for this type of wear at start up and end is the low turning speed. Various analysis and observations shows that there is a very thin lubricant film at low turning speed. Due to thin film, wear occurs. So, film thickness can be increased by increasing speed which in turn reduces wear. In some cases, lift pump systems are used for providing hydrostatic support which increases thickness of film of lubricant. But in spite of this lift pump system, wear can occur [12]. Wear always occur when thickness of film is less than the 10 times of surface finish. Even wear can occur in thick film if debris is present in the lubricant. So, for reducing the wear at start up condition we have to increase the oil thickness and reducing the contamination in lubricants.

Another reason of wear is the rapid increase in temperature of bearing pads during start-up which causes the deflection of pads which in turn breaks the oil film. This can be avoided by preheating the pads. From various researches, it was found that at the start-up, fluid film builds quickly. For bronze bearings, friction coefficient does not change and remains constant between 0.16 and 0.20 [13].

2.2 Tribology of Gears

Gears are very important for transmitting the power from one shaft to other shaft and used in large number of applications. So, we have to investigate various tribological aspects of gear like reasons for failure and methods of preventing these failures. As, we know that maximum deterioration of gears takes place on surface of gears as teeth are responsible for power transmission. So, we have to do some surface modifications so that failure of gears can be avoided to some extent. Gear failure takes place when teeth losses its shape. Major causes of gear failure are friction, scuffing i.e. scratching, and rust. For preventing these failures on surfaces, we can use the various surface coatings of some harder materials on gear profiles. Diamond like carbon (DLC) coatings is one of them. For enhancing the wear resistant properties of these coatings, we can add tungsten to these coatings. When we compare the WC/C coated gears lubricated with low viscosity oil to the case-carburised gears lubricated with conventional gear oil, it was founded that WC coated gears possess good wear resistant properties [14].

In case carburised gears, failure of gears takes place due to scuffing i.e. scratching or wear when two mating surfaces comes in contact with each other. But in WC coated gears, failure takes place due to thinning of coating not due to wear. This shows that WC coating improves tribological properties of gears. From various experiments, it was found that by using WC coatings on surfaces of gears, surface roughness of gears was reduced by 40% than that of uncoated gears. Also, the temperature of lubricant oil used in tungsten coated gears was less than the temperature of oil in uncoated gears which in turn reveals that there is less friction in coated gears.

Micro pitting i.e. formation of pitting takes place on the surface of gears due to high surface roughness and poor lubrication. It may cause breaking of surface at the scratch if stress is applied on the pit or scratch which ultimately leads to failure of gear. As surface roughness is reduced by using WC coatings, these coatings also prohibit the micro pitting action which prevents the failure of gears [15].

For transmitting power in precise applications and for high safety, polymer gears can be used for power transmission. Polymer gear is a wheel made up of some polymer material having teeth on its surface and manufactured by injection moulding process. Polymer gears are self-lubricating gears and can be used without external lubrication. But at high temperature which can be developed in high power transmission applications, they have low life due to large wear of surfaces. Their life can be improved by decreasing the running temperature of gears by reducing the friction by using some solid lubricant coatings. Following coatings can be used: Molybdenum disulphide ($MoS2$), Graphite flake, Boron nitride and Polytetra fluoro ethylene (PTFE). PTFE provides maximum improvement in life by decreasing the running temperature up to 30 deg. celsius and reduce the wear up to 90%. As temperature decreases near pitch line of gear surface, it reduces the possibility of pitch line fracture [16].

In polymer gears, wear always takes place and it is permissible up to a certain limit after which it is unacceptable. But when we use solid lubricant coated gears at high speed, large wear takes place and wear exceeds the thickness of coatings, then coatings losses its effectiveness. Despite of this, solid lubricant coatings are preferred because of its low cost and high effectiveness in decreasing the running temperature of polymer gears.

2.3 Tribology in Cams

In internal combustion engines, Cam and Follower is an important component. As they perform their desired functions by making a continuous contact between themselves. So, due to this continuous contact, there are large chances of wear on surfaces which leads to failure of cams and follower before the predetermined life. We have to look on the various causes and factors which effect these types of failure. There are various reasons for this type of wear. Following are the some of the mechanisms by which failure takes place in cams and followers: 1) Accelerated wear 2) Scuffing 3) Pitting 4) polishing [17]. All these failure mechanisms depend mainly on the metallurgy of the component i.e. materials of which the components are made. Other factors which affect these wears are geometry of components and properties of lubricating oil. Common materials used for manufacturing camshafts are unalloyed cast iron, alloyed cast iron, hardened and case carburised steel, medium carbon steel and alloyed steels. These materials have great impact on the wear resistant properties. Nodular graphite irons are preferred over hardened cast irons as they provide good resistant to pitting. Also, chilled irons are very prone to pitting but good resistant to scuffing whereas hardened steel are prone to scuffing but resistant to pitting. So, materials are selected depending on the type of applications such as high speed or low speed applications. As cast iron is a brittle material, it is very prone to pitting as pitting is a fatigue mechanism and due to brittle nature of cast iron fatigue can take place [18].

The tendency of different materials towards wear resistant properties can be improved by some special surface treatments. Best surface treatment for improves wear resistant properties is some form of phosphating. In phosphating, some form of phosphate crystals are layered on the metal surface. Different types of wear resistance properties can be obtained by varying form and size of phosphate crystals as better wear resistance can be obtained by fine-grained coatings. Better scuff resistance can be obtained by the use of soft-nitriding treatments such as Tufftriding .

Some more factors which affect the cams and followers wear are rotational speeds, temperature and viscosity of the oil and operational conditions. In case of cast iron cam and follower, at the point of contacts the tensile stress developed in the surface exceeds the tensile strength of materials and thus causes the rupture of surface. By keeping all these factors in mind, the most preferred material for cams and followers is grey pearlite low alloyed cast iron containing elements such as Mo, Ni and Cu, which improves hardness of cast iron for cam and surface hardened, toughened and ionitrided steel for follower as this have large abrasive wear resistance to tribological wear [19].

2.4 Tribology in Automobile Engines

The most important tribological component in the automobiles is the engine. It is because maximum amount of fuel energy is lost in the engine. A part of the fuel energy is lost as friction. Almost 15% of the fuel energy is lost as mechanical losses. It has been seen that if mechanical losses are reduced by 10% in automobiles, the fuel consumption will be reduced by 1.5% [20-22]. The improvement in the mechanical efficiency can be made by the tribological evaluation of materials used and by providing efficient lubrication [23]. Most of the lubricants used today are petroleum based lubricants. These lubricants are responsible for emitting hazardous substances and corruptin the environment. Research has been done on replacing mineral by biodegradable and eco friendly lubricants [24-29]. Vegetable oils have emerged as suitable lubricants for replacing mineral oils. The vegetable oils are 90-98% biodegradable and have all suitable properties to act as lubricants [30].

2.5 Tribology of Metal Working Fluids

Metal working fluids are used for the providing cooling and lubricating effect in different cutting operations such as turning, milling, grinding etc. if the MWF's are not used there be wear of the interacting surfaces leading to the failure of operations. Recent researches have suggested that vegetable oils can also be used as MWF's [31-34]. The use of vegetable oils has been limited by the oxidation stablity of vegetable oils [35-37]. Improvements have been made in the oxidation stability of vegetable oils by adding anti oxidants to the oils or by chemically modifying the oils [38, 39].

3. CONCLUSIONS

The understanding of tribology is a great way of conserving the energy. By reducing the coefficient of friction and wear rate greatly saves our resources. Also the development of eco friendly materials and biodegradable lubricants can help in the sustainability. This reduces the emissions to a greater extent and provides a source of renewable energy. Further researches are going on the development of new materials and overcoming the difficulties in biodegradable lubricants so that they can be used widely.

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