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Emerging Trends in Bearing Technology

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Abstract:
This paper aims at consolidating the tri-biological problems of fiction and lubrication. Different mechanics of wear and the measures or approaches for wear reduction are briefly discussed in the introductory part. Subsequently the areas for improvement of operational characteristics are identified. Thereafter, the emerging trends of bearing technology like hybrid and ceramic bearing and son are discussed. Application each category and the level of research have been covered.

1. Introduction

Any type of machine or equipment, be it as simple as a toy or a hi-tech sophisticated aero-engine will have relative moment between its moving parts or components. This movement could be of sliding, rotatory, oscillatory or any other type. There would be some fiction resistance offered to the movement depending upon certain factors like the factors like hardness or ductility in contact , loads, type and speed of relative movement , temperature ,environment conditio0ns etc. The friction obviously besides having the adverse effect of increased power consumption and lower efficiency, over a period of time will result in wear and tear of the surfaces, which will affect the operational capability of the equipment due to increased clearance and also reduce its effective life .ways means are therefore required to be devised to having relative movement between then. This is done by providing a special type of bearing most suitable for the application. It will obviate or minimize all the above listed problems and provide an efficient, reliable and trouble free equipment with prolonged life.

When we talk of bearing, the most common type of bearing that bearing that come to our minds is the ball bearing. However, we must bear in mind that even a piston reciprocating inside a cylinder is an example of a bearing due to sliding movement between the two. There can be many criterion for classification of bearing like type of relative movement, type of load, type of lubrication etc. Selection of a particular type of bearing is the discretion of the designer though it depends upon factors like speed, load, temperature, application, environment, etc. Amongst the two broad categories we have the sliding friction bearing like journal bearing and rolling its friction bearing like ball & roller bearing.

2. Technology of Wearing Reduction

It is understood that the purpose of bearing is not only to permit smooth movement but also to minimize wear, if possible reduce it to zero level. Hence, before we think of for new design concepts, we need to fully understand the mechanism of wear. Study of this subject has identified four types of wear mechanisms adhesive wear, abrasive wear, surface fatigue wear and corrosive wear. What makes study of wear phenomenon complex is the fact that firstly, at any point of time wear may be taking place on account of more than one type of above listed mechanism in varying degree or proportions, and secondly, at any stage the type of above can change from one to another form. Very commonly wear phenomenon starts with adhesive type and sub subsequently with hardened wear particle in circulation, the wear change to abrasive type.

Adhesive wear can be reduced by adopting the following measures:

2.1. Use of Dissimilar Metals

Adhesive wear occur due to localised welding at the asperities under high stress conditions and their subsequent breaking away due to movement. Since cohesive force in general is greater than adhesive force, the tendency to form junction by welding at the asperities will be less in case dissimilar metal used. This consideration is used to have the journal or shaft of a harder material and the bearing bush of a softer material, which can be replaced conventionally and economically on getting worn out beyond permissible limits. However, as far as removal or transfer of material does get transferred from the harder to softer ones also. Experimental trials have established that a soft polymer like Teflon can remove quite sizeable amount of material from materials as strong as carbon steel. This is because there exists local regions of low strength within the harder material. At a junction if these coincide with local region of high strength of softer material, the harder surface leads to fragment formation.

2.2. Increasing Surface Hardness

Harder metal will not undergo plastic deformation and will not get welded. If metals are already at their maximum hardness, they can't get welded as no further work-hardening is possible. Hence in such cases similar metals can be used for both elements, as in case of steel for roller bearings. Hardness can be increased by two methods- heat treatment and alloying.

2.3. Use of Alloys

In engineering applications, various types of cast-iron and steels are used. The properties of these materials including wear resistance vary considerably depending upon the percentage of ingredients, most significant being carbon. Amount of carbon present in the form of free carbon determines its quality which in turn affects the wear resistance. Elements such as chromium, copper, nickel, molybdenum, vanadium, titanium, silicon etc. are added to CI and steels. Silicon determines the relative proportion of graphite and combined carbon. Dissolved silicon adds to the strength and wear properties. Copper, titanium and vanadium improves the wear resistance, shock resistance, hardness, tensile strength and corrosion resistance. Hardness at the surface can also be achieved by depositing very hard coating by the process of plasma spraying or by sputtering (An expensive process). The major problem in this adhesion of the coating to the base material.

2.4. Heat Treatment

Heat treatment processes of induction hardening, nit riding, and cyaniding, carburizing and shot peening are adopted to increasing the resistance to fatigue wear.

2.5. Use of Plastics and Polymers

In the recent years plastics synthetic resins have been used where wear resistance and corrosion are the prime considerations. Common plastics used for this purpose are acetal, fluorocarbon, nylon, and thermo plastics resins.

2.6. Creating a protective coating

Lubricating oil used to reduce friction contains element like oxygen, sulphur, and phosphorus. Due to oxidation these elements help to form protective layer on the mating surfaces. If the rubbing cab be restricted to the coating of this low shear strength layer at the asperities, adhesive wear can be limited. Rubbing off and replacement of layer will keep taking place simultaneously, thus preventing direct metal to metal contact. However in case this layer is brittle, it will spall or breaks off and produce abrasive wear process. Measures to be taken to prevent corrosive wear are:

- Select the right type of lubricant which neither reacts chemically with the base metal, nor with the environment.
- Have the required additives in the lubricant which help forming a protective film or layer which adheres well to the metal surface or improves some other characteristics of the lubricant.

3. Emerging Trends

Further improvements to reduce wear and increase life, reliability, efficiency and performance characteristics of bearing could be looked into the following three areas:

3.1. Improvement in Materialistic Properties

This may relate to material properties like mechanical strength (shear, tensile and compressive), surface hardness , temperature, resistance, machinability, surface finish , coefficient of friction, adaptability of surface to chemical or polymer coating and so on. Thus new material could be developed in which the above mentioned properties are improved. This would also require improved manufacturing techniques-machining, surface finish, polishing, grinding, giving higher levels of surface finish and dimensional accuracy, better heat treatment processes, etc.

3.2. Improvement in Material Contact Surfaces

Whatever the condition of lubrication prevailing, whether thick or thin film or boundary layer, lubricant plays a vital role in reduction of wear and frictional losses and also heat dissipation to keep the operating temperature within permissible limits. Besides the basic requirement of viscosity and viscosity index, there are many other features that can reduce wear. Chemical action of the lubricant with the metal forms a protective oxide layer on the mating surface. Various additives added to the lubricant to impart desirable characteristics. For example, Extreme pressure (EP) additives improve the strength of the film to withstand higher loads. Thus improving the characteristics of the lubricant will help in reducing wear.

3.3. Improvement in Design

Changeover from sliding to rolling friction or hydrodynamic to hydrostatic friction is a change in design concept. Similarly, innovative ideas could be introduced in design which could result in reduction of friction and wear or enhance the capacity and performance characteristics of the surface. Two outstanding examples of this are use of controlled magnetic field for accurate positioning of shaft within the bearing, wherein it may also be possible to eliminate the use of lubricant if metal to metal contact could be avoided. Secondly, use of pre-stressed hollow rollers which improve the load carrying capacity of the bearing with reduced run-out. Development of different types of foil bearing is another example of innovative design. Here a thin metallic foil prevents direct metal to metal contact between the elements of bearing and thus permits operation at very high speed.

Use of Sintered and Porous materials a new copolymer given the name "Micro-well" has been developed by Newport Research laboratories, New York. This may revolutionise lubrication method for ball bearing and other rolling and sliding element components. It is a precision structured porous elastomer having its chemical and mechanical characteristics similar to those of Urethane. It has 60 times the lubricant capacity materials such as cotton reinforced phenolic and felt, which are conventionally used for lubrication retention and transfer application. The unusual characteristics of new material results from the previous network of tiny reservoirs and capillaries through the material. Lubricant is stored in the reservoirs which are interconnected by capillaries. The lubricant is distributed from reservoir to reservoir through the capillaries and metered on the mating surface as needed. Thus, the material continuously maintains a regular oil film between the surfaces. The oil impregnation material provides complete wetting of metal surface, without voids.
Use Ceramic Material because metals and plastics are used so extensively as bearing material, the potential advantages of ceramics are often overlooked. Ceramic are particularly attractive for applications requiring high temperature, durability, high speed operation and corrosion resistance. Typically ceramics are hard materials that have high resistance to from abrasive particles. For example, a ceramic like Silicon Nitride has a hardness of Rockwell C75 to C80. However, ceramics are also brittle and hard to machine. Unlike metals or plastics, ceramics do not run in or deform plastically. Consequently components misalignment must be eliminated. Generally, ceramics exhibit behaviour right up to the point where material fails with little or no warning. Also, ceramics are susceptible to catastrophic failures due to material defects such as porosity, non- uniform density and trace impurities. Of all the ceramic materials tested, silicon nitride provides the best performance characteristics for bearing. Also, it can be manufactured with very smooth surface finish. Because of their low density, silicon nitride rolling elements reduce centrifugal forces at high operating speeds. Unlike steel. Silicon nitride does not flow plastically to redistribute local stresses over a large contact area. Consequently, for equal contact loads and geometries, stresses in silicon nitrides are higher than those in steel. Also silicon nitrides are higher than those in steel. Also silicon nitride has a Young's Modulus about 1.5 times that of steel.
Silicon nitride has a thermal expansion coefficient about one-fourth that of steel. Consequently this difference in thermal expansion must be accommodated in design if ceramic bearing are mounted on steel shafts or on steel housing. According to some tests, silicon nitride rolling elements appear to run cooler than steel rolling elements. Also silicon nitride shows promise as a dry bearing material. The ceramic when combines with conventional lubricant can provide elasto-hydrodynamic films similar to those occurring with steel bearing. The ceramic provide resistance against any chemical attack from the environment. Both hybrid and all ceramic bearing have been tested. Hybrid bearing have steel cages and rolling elements both of silicon nitride.
Elastomeric Bearing and lamination elastomeric bearings are particularly attractive where there are oscillating compressive and torsional loads, typically these bearings are designed to carry compressive and torsional loads while accommodating oscillating motion in shear. Generally, they exhibit compressive stiffness but low torsional or shear stiffness, Elastomeric bearings have alternate laminations of elastomer and metal. The elastomeric laminations are vulcanised and bonded to the metal laminations. The elastomer can be bounded to any metal including stainless steel, titanium or aluminium. Natural rubber is most commonly used elastomer which can operate in an ambient temperature ranging from -650F to 1600F without adverse effect on service life or bearing performance. Other synthetic elastomers can be selected to resist abrasive, petro chemicals, ozone, heat, moisture, etc. Elastomers are basically in-compressive laterally when loaded. Compressive load capacity increases significantly with shape factor, compressive load area to bulge area. Laminated elastomeric bearing eliminate the need for lubrication. Because these bearing wear gradually, they require only occasional inspection. Elastomeric bearing have exhibited service life of 20 to 400 million cycles. One noteworthy application of elastomeric bearings is in helicopter rotor system where they provide service life of 2000 to 3000 flight hours with minimum of maintenance and also eliminate considerable hardware that would be required with conventional bearings.
Foil bearings are basically designed with a thin, flexible surface that can deflect under changing loads to maintain a constant film thickness, damp out load fluctuation and minimise whirl. As a member of gas bearing family, foil bearing operate with low friction, are of simple construction and need no lubrication. In addition, foil bearing have an inherently long life, a capability of ultrahigh speed operation, can operate at high speed operation, can operate at high temperature, and are of potentially low cost. For example, foil bearing can operate at greater than 100000 rpm and at temperature greater than 10000F. Also they have high tolerance to dust particle passage. They can readily accommodate shaft misalignment and geometric shaft imperfections.
Basically there are two types of foil bearing configurations: tension dominated and bending dominated. Both types have about the same load carrying capacity and are usually self-acting. Tension dominated bearing have a foil strip, typically 1mil thick, wrapped around a journal and several guides. When tension is applied to free end of strip, the pre-loaded foil contacts the journal along the region of wrap. Then the foil strip is locked and clamped at the guides. When the journal rotates, torque overcomes the friction between the foil and journal and a gas wedge develops to float the journal on a thin film. Clearance increases with speed, thereby stretching the foil and further increase the tension. The simplified assembly of bending dominated bearing helps lowering manufacturing costs.
For many years, tension dominated foil bearings have been used in data processing equipment where they provide friction free support for magnetic tape traveling over guide and head recent development has concentrated on adapting these bearing to support the rotors in high speed turbo-machinery like blower motors, centrifugal compressors and pumps, turbochargers, etc.

4. Conclusion

A wide spectrum of operational requirements is experienced in varied engineering applications in terms of load, speeds, temperature, environment, etc. Selection of a particular type of bearing is to be made additionally keeping in mind factors like cost, reliability, life, maintenance, etc. there is a continuous need to enhance the performance characteristics of bearing to obtain these objectives. For this the trust areas are: material, lubrication and innovation design concepts. Ultimate selection of a bearing is decided by the designer based on operational requirements and his experience.

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