TRIBOLOGICAL COMPONENTS AND APPLICATIONS

Common tribological components which are used in industrial applications include sliding contact and rolling-contact bearings, seals, gears, cams and tappets, piston rings, electrical brushes, cutting and forming tools. More recently, micro/nano-electromechanical systems (MEMS/NEMS) also called micro/nano devices or micro/nana components are being produced using micro/nano-fabrication techniques.

COMMON TRIBOLOGICAL COMPONENTS

Tribological components that operate at low to moderate contact stress (on the order of 5 MPa) include sliding-contact bearings, seals, piston rings and electrical brushes. The components that operate at high Hertzian stresses (on the order of 500 MPa) include rolling-contact bearings, gears, cams and tappets.

1. Sliding Contact Bearings

The machine elements that support a moving shaft against a stationary housing are called bearing. Bearing can be classified as either sliding contact or rolling contact in sliding-contact bearings also known as sliding or plain bearings or brushings, the load is transmitted between moving parts by sliding contact.

The motion can be a planar motion or a rotational motion. Sliding bearings can be lubricated with a film of air, water, oil, grease or the process fluid. Thrust and journal bearings are perhaps the most familiar and most widely used of all bearings types. Thrust bearings are used to support thrust (or axial) loads in rotary machinery. These consist of multiple pads. Journal bearings are used to support radial (or normal loads). The bearings are generally lubricated with a liquid lubricant or grease.

2. Rolling Contact bearings

Rolling-contact or rolling-element or antifriction bearings employ a number of balls or rollers between two surfaces known as inner and outer races or rings. The inner race is carried by the rotating shaft or journal and the outer race, mounted on the machine casing or bearing housing, is often stationary. The balls or rollers also called rolling elements are held in an angularly spaced relationship by a cage, also called a retainer or separator. The rolling elements accommodate relative motion between the surfaces primarily by the action of rolling with a small slip (sliding) rather than pure sliding so that the frictional forces acting between the surfaces are primarily due to rolling resistance. Rolling bearings have much less friction than sliding bearings and therefore, are also called antifriction bearings. The loading capacity and stiffness of rolling bearings is much larger than that of sliding contact bearings. Because of the use of balls or rollers, the actual area of contact is reduced to near zero; therefore contact stresses are very high (Hertzian stresses), typically on the order of 500MPa or more. There are many kinds of bearings including radial ball bearings, angular contact ball bearings, cylindrical roller bearings and tapered roller bearings. Rolling bearings are generally lubricated with a liquid lubricant or grease via elasto-hydrodynamic lubrication. Some bearings for operation in vacuum and high temperatures must be self-lubricated. The classic rolling bearing failure mode is fatigue spalling, in which a sizeable piece of the contact surface is dislodged during operation by fatigue cracking in the bearing metal under cyclic contact stressing.

3. Seals

The primary function of seals, called fluid seals, is to limit the loss of lubricants or process fluid (liquid or gas) from systems and to prevent contamination of the system by the operating environment. Seals are divided into two main classes: static and dynamic seals. Static seals are gaskets, O-rings joints, packed joints, and similar devices used to seal static connections or openings. A dynamic seal is used to restrict fluid flow through an aperture closed by relative moving surfaces. Dynamic seals include fixed clearance type (labyrinth seals, floating ring seals and ferro-fluidic seals) and surface- guided type (mechanical face seals, lip seals and abradable seals).

Lubrication of the sealing interface varies from hydrodynamic to no lubrication (e.g. in gas-path components such as turbine or compressor blade tips). Adhesive wear is the dominant type of wear in well-designed seals. Other wear modes are abrasive wear, corrosive wear, fatigue wear and blistering.

4. Gears

Gears are toothed wheels used for transmission of rotary motion from one shaft to another and a change in rotational speed. There are different types of gear including spur, helical, bevel and worm gears. Spur gears are used to transmit rotary motion between parallel shafts. Helical gears are used to transmit rotary motion between parallel and non-parallel shafts. The smaller of the two mating gears is known as a pinion and the larger as a gear. To transmit motion at a constant angular velocity ratio, an involute tooth profile is used. In spur gears, the teeth are straight and parallel to the axis of rotation whereas in helical gears, teeth are not parallel to the axis of rotation. In the case of bevel gears, the rotational axes are not parallel to each other. Although gears are usually made for a shaft angle of 90^0, they can be produced for almost all angles. Pair of straight bevel gears is used to transmit motion between intersecting shaft. Worm and worm bears are used to transmit motion between non-parallel, non-intersecting shafts. Gear teeth may operate under boundary, mixed and fluid-film (elasto-hydrodynamic) lubrication regimes. Typical failure modes of for well lubricated gears are surface, scoring, pitting, scuffing (severe form of adhesive wear when elasto-hydrodynamic lubricating fluid is not sufficiently thick, metal to metal contact occurs leading to scuffing), corrosive wear and tooth breakage.

5. Cams and Tappets

Cams and tappets (cam follower systems) are extensively employed in engineering machines to transform rotary motion to reciprocating sliding motion or vice-versa. e.g. in automotive valve trains and textile machines. The cam follower can be a flat follower or a roller follower. The contact conditions are nominal points or line contacts which under load lead to elliptical and rectangular contact areas, respectively. There is always a rolling motion through the contact, accompanied by some sliding in the direction of rolling motion. The wear modes for cams and tappets are very similar to those of gears. Under heavy duty, cams and tappets suffer from burnishing (due to adhesive/abrasive wear processes), scuffing (due to severe adhesive wear processes) and pitting (due to fatigue wear processes). The wear can be reduced considerably by selecting hard materials combinations or by hardening the cam materials by heat treatments or thermo-chemical treatments or by applying coatings.

6. Piston Rings

They are mechanical sealing devices used for sealing pistons, piston plungers, reciprocating rods etc. inside cylinders. In gasoline and diesel engines and lubricated reciprocating-type compressor pumps, the rings are generally split-type compression metal rings. When they are placed in the grooves of the piston and provided with a lubricant, a moving seal is formed between the piston and the cylinder bore. Piston rings are divided into compression rings and oil-control rings. Compression rings, generally two or more, are located near the top of the piston to block the downward flow of gases from the combustion chamber. Oil rings, generally one or more, are placed below the compression rings to prevent the passage of excessive lubricating oil into the combustion chamber yet provide adequate lubrication for the piston rings. In typical lubricated situations, the piston skirt is in direct contact with the cylinder and acts as a bearing member that supports its own weight and takes thrust load. In unlubricated arrangement, it is necessary to keep these two surfaces separated because they are frictionally compatible. An ideal piston ring must meet the following requirements: low friction and wear losses, superior scuffing resistance tolerances for marginal lubrication and rapidly varying environments, good running-in wear behaviour, long-term reliability and consistency of performance, long maintenance-free life and low production cost.

7. Electrical Brushes

Machines that utilize electrical brushes can be broadly classified into two groups. In the first group, the machines require a commutator. In these machines, the brushes must be capable of transferring the load current to the external circuit as well as assisting the commutation function. Within this class of machines are DC motors and generators. In second class of machines, brushes are used only to transmit electric power from a stationary source to a moving component by means of a slip ring. Examples of slip ring applications are AC generators, motors and special applications. Brush wear is believed to be due to adhesion and particle transfer while fatigue has been identified in some circumstances.

8. MEMS/NEMS

Microelectromechanical systems (MEMS) refer to microscopic devices that have a characteristic length of less than 1 mm but more than 100 nm and combine electrical and mechanical components.

Nanoelectromechanical systems (NEMS) refer to nanoscopic devices that have a characteristic length of less than 100 nm and combine electrical and mechanical components.

In mesoscale devices, if the functional components are on micro-or nanoscale, they may be referred to as MEMS or NEMS, respectively. These are referred to as an intelligent miniaturized system comprising of sensing, processing, and/or actuating functions and combine electrical and mechanical components.

Another term generally used is micro-/nano-devices. MEMS/NEMS terms are also now used in a broad sense and include electrical, mechanical, fluidic, optical, and/or biological functions.

MEMS/NEMS Application and name are:

1. Optical – Micro/nanooptoelectromechanical systems (MOEMS/NOEMS)

2. Electronic – Radio Frequency-MEMS/NEMS or RF-MEMS/NEMS

3. Biological – BioMEMS/ BioNEMS

Other tribological components and fabrications are:

1. Material processing which include Cutting tools, Grinding and Lapping, Forming processes (wire, bar and tube drawing operation, extrusion, shearing (blanking, punching and slitting)).

2. Industrial applications – Automotive engines, Gas turbine engines, Rail roads, magnetic storage devices.

Review Questions

1. Mention the common tribological components.

2. Briefly discuss each of these components.

3. Differentiate between MEMS and NEMS.