Tribology
Module6: Application of Tribology

Q.1. What are the criteria on which bearings can be classified?

Ans: Bearings can be classified based on relative motion (rolling contact, sliding etc.), direction of load (radial, thrust etc.) and on lubrication system (dry, hydrostatic, aerodynamic etc).

Q.2. Is there any method to predict/estimate the life of the bearing?

Ans: We can estimate the operational life of the bearing using Lundberg Palmgren Approach and correction factors (i.e. impact factor, reliability factor, material factor, etc.). Lundberg Palmgren formulae require the effective load imposed on the bearing, relative rotational speed, and dynamic load rating provided by bearing manufacturers.

Q.3. How one calculates/finds the load bearing capacity of a roller bearing and what is the maximum rpm till which roller bearing can be safely operated?

Ans: Load bearing capacity of roller bearing depends on dynamic load capacity, relative speed, material properties, appropriate lubrication and effective bearing load. Maximum relative speed depends on the rate of heat generation and rate of heat dissipation. For example, liquid lubricants, with proper lubrication mechanism, may be operated at higher speed compared to same bearings operated with grease lubrication. Similarly ceramic rolling bearings due to lesser rate of heat generation may be able to operate at higher speed compared to similar bearing made of metals.

Q.4. What are the most common causes of bearing failure?

Ans: In ideal case, bearings fail by surface-fatigue. In practice, bearings fail due to misalignment which causes additional load and negative clearance (which increases coefficient of friction) at one end of bearing.

Q.5. What factors significantly contribute to the load on the bearing?

Ans: The prime consideration in calculating bearing loads is the magnitude and direction of the bearing load or loads. This load is affected by one or more of the following factors:

- Weight of components such as shafting, flywheels, sheaves, pulleys, gears, etc.
- Tension resulting from belt or chain drives.
- Tangential, separating and axial loading developed by gears.
- Inertia resulting from acceleration or deceleration.
- Centrifugal forces developed in rotary or out of balance motion.

Q.6. Why grease is preferred as compared to oil to lubricate rolling bearings?

Ans: Grease has the advantage over oil that it is more easily retained in the bearing arrangement, particularly where shafts are inclined or vertical, and it also contributes to seal the arrangement against contaminants, moisture and water. In other words, grease is employed to a much greater extent than oil by reason of its convenient form and its ability to assist greatly in sealing the housing.

Q.7. In the space available for lubrication how does one decides the right required amount of lubricant (especially grease)?

Ans: Where bearings are to operate at very low speeds and must be well protected against corrosion, it is advisable to completely fill both bearings and housings with grease. In moderate to high speed applications, greater amount of grease increases friction losses, while smaller quantity causes bearing dryness and increase in noise. Often 30 to 50% of available free space is recommended as grease volume.

Q.8. Why preloading is required in rolling bearings?

Ans: Negative clearance is created between rolling elements and bearing rings in order to preload the bearing. Preloading of bearings is required to prevent/suppress shaft run out/vibration/noise. Preloading improves the running accuracy and increases the bearing stiffness. But preloading increases the friction loss and so running temperature. With increase in temperature, viscosity of grease/oil decreases which further increases the metallic friction. Therefore preloaded bearings must be designed with care.

Q.9. Explain bearing misalignment and what are its causes?

Ans: The misalignment of the outer ring with respect to the inner ring is known as bearing misalignment. If a bearing is misaligned such that this angle is exceeded than permissible limit, then damage and premature failure of bearing may occur. Common causes of bearing misalignment are bent shafts, out-of-square spacers, and out-of-square clamping nuts etc.

Q.10. What is the pressure angle with respect to two mating gears and what is its significance?

Ans: Pressure angle is the angle formed between the line drawn between the centers and a line drawn $\perp$ the "line of action" which is tangent to both base circles and includes the pitch point. Pressure angle used today is 20^0, a good compromise for power and smoothness. Lower pressure angle has the advantage of smoother and quieter tooth action because of larger profile contact ratio. Higher pressure angle provide higher strengths and a lower tendency to experience tooth-tip interference, but are susceptible to noise and higher bearing loads.

Q.11. What is gear backlash? What is the significance/ purpose of backlash?

<u>Ans</u>: Backlash with respect to gears, also known as lash or play, is the clearance between the mating gear teeth. It is the amount of lost motion due to clearance or slackness when movement is reversed or contact is re-established. Theoretically backlash should be zero but practically some positive value should be allowed to prevent jamming. Desirability of backlash depends upon the application. Some of the reasons for which backlash is required are: allowing for lubrication, manufacturing errors, deflection under load and thermal expansion.

Q.12. What methodology is adopted for reducing friction in mating gears?

<u>Ans:</u> Friction between gear pair occurs due to sliding between meshed teeth and churning of lubricant. To reduce friction in mating gears, interface shear strength must as low as possible. One way to achieve this is to coat gear surfaces with anti-friction coatings. Shear strength of such coatings is far lesser than that of the base material of gears. Often such coating materials are supplied with carrier fluids so that during the gear operation after rubbing off of these coatings, reformation of coating happened immediately. They thus protect the surface of the base material from excessive wear and subsequent destruction. Following two coatings (as solid lubricants) are used to reduce friction:

- Phosphate layers, few microns.
- Graphite or molybdenum disulphide, 1-2 μ thin coating.

Q.13. What is gear efficiency and how it is calculated? What are the sources of power loss in gear operation?

<u>Ans:</u> Dears are used to transmit power. Any loss in power transmission in gear-meshing is accounted by gear efficiency. The efficiency (in percentage) of a gear system is simple calculated as the [output shaft power /Input shaft power]*100. Power losses in gear systems are associated primarily with tooth friction and lubrication churning losses. Churning losses are relatively independent of the nature of the gears and the gear ratios - they are primarily related to the peripheral speed of the gears and level of fluids. To minimize tooth friction anti-friction additives play important role, while to reduce churning losses, level of lubricant is to be maintained at desired level.

Q.14. What is gear pitting and what are the various causes of pitting?

<u>Ans:</u> Gear pitting is formation of pits on the tooth surface during gear-operation. Pitting occurs when fatigue cracks (due to rolling contacts, abrasive particles, etc.) are initiated on the tooth surface or just below the surface. Pits may occur due to fatigue of metal-to-metal contact of asperities or due to progress of subsurface cracks to the surface. These cracks may start at inclusions in the gear materials or due to fatigue generated nucleus, and propagate parallel to the tooth surface. Pits are formed when these cracks break through the tooth surface and cause material separation. A number of pits join together and make a larger pit (or spall).

Q.15. What guidelines can be adopted to reduce pitting in gears?

Ans: The following guidelines should be adopted to minimize the onset of pitting in gear units:

- Reduce contact stresses by optimizing gear geometry.
- Proper heat-treatment (very high hardness increases brittle with low hardness reduces surface strength) of gears. Carburizing is preferable from economics point of view.
- Gear teeth should have smooth but hard surfaces to reduce chance of generation of surface cracks.
- Use proper quantities of cool and clean lubricant with desired additives.

Q.16. Explain mechanisms gear lubrication mechanisms.

Ans: Following two types of lubrication mechanisms are commonly used for gear lubrication depending on the power transmitted by the gears:

- Splash lubrication, when power transmitted is less than 100 kW.
- Pressurized lubrication (by oil jets) for large gear train transmitting power greater than 100 kW.

Too much or too less lubricant is harmful for gear operation.

Q.17. What are porous bearings? How are they manufactured and what are the common applications of porous bearings?

Ans: Porous bearing are modified form of “hydrostatic bearings with orifice compensators”. Oil flows due to capillary action through the pores in the unloaded region. The oil flows back through pores in the loaded part of bearing shell. Porous bearing are of powdered metals which are pressed in dies. After compression, they are sintered at a high temperature in a reducing atmosphere. Sintering causes powdered metal to fuse into a strong compact. After sintering, bearings may be submerged in oil for impregnation. Voids may vary from 15% up to 35% of the volume of the bearing. Bearings are finish-sized in punch press to close tolerances. These bearings are often known as economic mean to feed lubricant to the bearing. These bearings work satisfactory for light load and moderate speed. Operating temp puts a limit on working of porous bearing as heat is dissipated through bounding solids and cause deterioration of mineral oils. Therefore these bearings are recommended for small electric motors, household appliances, automotive accessories, etc.

Q.18. What mechanism is used for the lubrication of journal bearing?

<u>Ans:</u> Lubrication in journal bearings can be achieved by continuously feeding lubricant (as pressure greater than ambient pressure) through oil groove arrangement. Bearings are provided with feed hole and oil grooves to get lubricant. Oil can be supplied to bearing by oil hole, partial groove or full groove arrangement depending on required quantity of oil and load direction. If applied load changes its direction then partial to full groove arrangement is essential to avoid starvation. Very rarely submerged bearings (without feeding groove arrangement) are also used.

Q.19. What are the main criteria for designing of journal bearing?

<u>Ans:</u> Bearing is designed with bearing clearance and length which often is decided based on bearing bore diameter. Increasing bearing length increases load capacity of the bearing. Upper limit on bearing length is decided based on space limitation. Increasing radial clearance decreases load capacity and increases lubricant flow rate.

Q.20. What are the guidelines for material selection for journal bearing?

<u>Ans:</u> Idealy bearing material does not affect bearing performance, so every material is suitable for journal bearing operation. But in practice journal bearings must be made from a material that is durable, low friction, low wear to the bearing and shaft, resistant to elevated temperatures, and corrosion resistant. In addition bearings must be able to embed dirt particles and able to conform as per the shaft surface.