

Bearings

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ME 201

Definition

- Whenever two parts have relative motion, they constitute a **bearing** by definition, regardless of their **shape** or **configuration**.
- **Lubrication** is required to reduce friction, wear and remove heat.
- Bearings may **roll** or **slide** or do **both simultaneously**.
- A **sliding contact bearing** is formed by any two materials rubbing on one another. Example - sleeve around a shaft or flat surface under a slider. It has high starting friction.
- A **rolling contact bearing** has hardened steel **balls or rollers** captured between hardened steel raceways to provide very low friction. It has comparatively lower starting friction.
- Rolling contact bearings can support radial, thrust or a combination of these loads.

Rolling Contact Bearing

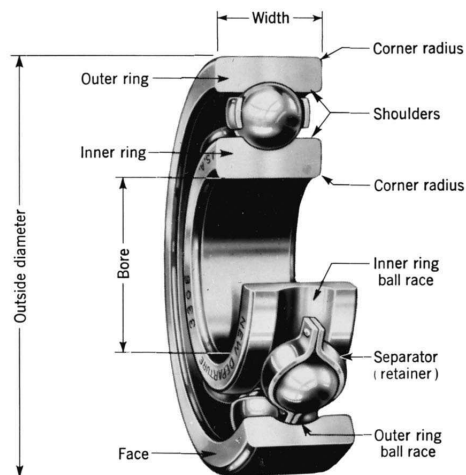


Figure: Nomenclature of a ball bearing.

Rolling Contact Bearing



Figure: A roller bearing.

Rolling Contact Bearing

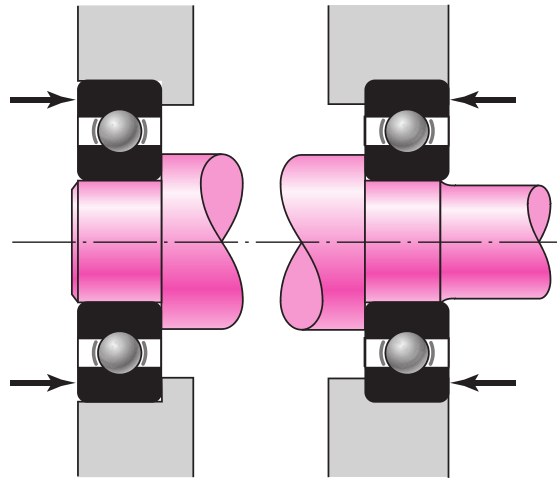


Figure: How bearings are mounted.

Material combinations

- **Babbitt:** Alloy of lead and tin.
- **Bronze:** Alloy of copper.
- **Gray Cast Iron and Steel**
- **Sintered Materials:** Made of powdered materials, microscopically porous after heat treatment.
- **Nonmetallic Materials:** Graphite , Thermoplastics.

Ball Bearing Types

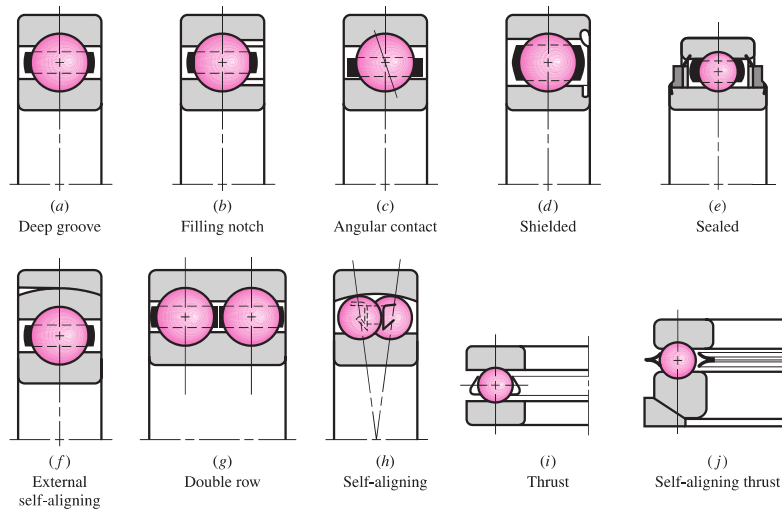


Figure: Various types of ball bearings.

Classification of Ball Bearings

Here, we include a selection from the many types of standardized bearings.

Single-row Deep-groove Bearing

The single-row deep-groove bearing will take radial load as well as some thrust load. The balls are inserted into the grooves by moving the inner ring to an eccentric position. The balls are separated after loading, and the separator is then inserted.

Filling Notch Bearing

The use of a filling notch in the inner and outer rings enables a greater number of balls to be inserted, thus increasing the load capacity. The thrust capacity is decreased, however, because of the bumping of the balls against the edge of the notch when thrust loads are present.

Angular-contact Bearing

The angular-contact bearing provides a greater thrust capacity.

Shielded Bearing

All these bearings may be obtained with shields on one or both sides. The shields are not a complete closure but do offer a measure of protection against dirt.

Classification of Ball Bearings (contd.)

Sealed Bearing

A variety of bearings are manufactured with seals on one or both sides. When the seals are on both sides, the bearings are lubricated at the factory. Although a sealed bearing is supposed to be lubricated for life, a method of relubrication is sometimes provided.

Self-aligning Bearing

Single-row bearings will withstand a small amount of shaft misalignment or deflection, but where this is severe, self-aligning bearings may be used.

Double-row Bearing

Double-row bearings are made in a variety of types and sizes to carry heavier radial and thrust loads. Sometimes two single-row bearings are used together for the same reason, although a double-row bearing will generally require fewer parts and occupy less space.

Thrust Bearing

The one way ball thrust bearings are made in many types and sizes.

Roller Bearing Types

(a) straight roller; (b) spherical roller, thrust; (c) tapered roller, thrust; (d) needle; (e) tapered roller; (f) steep-angle tapered roller. [Courtesy of The Timken Company.]

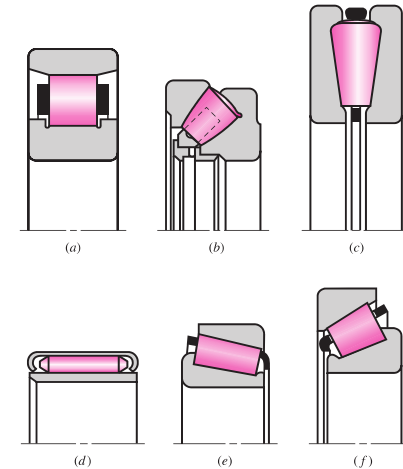


Figure: Various types of roller bearings.

Classification of Roller Bearings

Straight Roller Bearing

Straight roller bearings will carry a greater radial load than ball bearings of the same size because of the greater contact area. However, they have the disadvantage of requiring almost perfect geometry of the raceways and rollers. A slight misalignment will cause the rollers to skew and get out of line. For this reason, the retainer must be heavy. Straight roller bearings will not take thrust loads.

Helical roller Bearing

Helical rollers are made by winding rectangular material into rollers, after which they are hardened and ground. Because of the inherent flexibility, they will take considerable misalignment. If necessary, the shaft and housing can be used for raceways instead of separate inner and outer races. This is especially important if radial space is limited.

Spherical-roller thrust Bearing

The spherical-roller thrust bearing is useful where heavy loads and misalignment occur. The spherical elements have the advantage of increasing their contact area as the load is increased.

Classification of Roller Bearings (contd.)

Needle Bearing

Needle bearings are very useful where radial space is limited. They have a high load capacity when separators are used, but may be obtained without separators. They are furnished both with and without races.

Tapered roller Bearing

Tapered roller bearings combine the advantages of ball and straight roller bearings, since they can take either radial or thrust loads or any combination of the two, and in addition, they have the high load-carrying capacity of straight roller bearings. The tapered roller bearing is designed so that all elements in the roller surface and the raceways intersect at a common point on the bearing axis.

Special Bearings

Many special-purpose bearings are manufactured, and bearings are also made for particular classes of machinery. Typical of these are:

Instrument Bearing

Instrument bearings are high-precision and are available in stainless steel and high-temperature materials.

Nonprecision Bearing

Nonprecision bearings, usually made with no separator and sometimes having split or stamped sheet-metal races

Ball bushings

Ball bushings permit either rotation or sliding motion or both.

Bearings with flexible rollers

Typical bearings, but with flexible rollers.

Bearing Life

- When ball or roller of rolling-contact bearings rolls, **contact stresses** occur on inner ring, rolling element, and on outer ring.
- If a bearing is clean and properly lubricated, is mounted and sealed against the entrance of dust and dirt, is maintained in this condition, and is operated at reasonable temperatures, then metal fatigue will be the only cause of failure.

Common quantitative **bearing life** measures are-

- Number of revolutions of the inner ring (outer ring stationary) until the first tangible evidence of fatigue.**
- Number of hours of use at a standard angular speed until the first tangible evidence of fatigue.**

Tangible Evidence of Failure

- The life measure of an individual bearing is defined as the total number of revolutions (or hours at a constant speed) of bearing operation until the failure criterion is developed. Under ideal conditions, the fatigue failure consists of spalling of the load carrying surfaces.
- The American Bearing Manufacturers Association (ABMA) standard states that failure criterion is the first evidence of fatigue.
- The fatigue criterion used by the Timken Company laboratories is the spalling or pitting of an area of 0.01 in^2 .**
- The **rating life** of a group of nominally identical ball or roller bearings is defined as the number of revolutions (or hours at a constant speed) that **90 percent** of a group of bearings will achieve or exceed before the failure criterion develops.

Lubrication & Journal Bearing

- The purpose of lubrication is to reduce friction, wear, and heating of machine parts that move relative to each other. A **lubricant** is any substance that, when inserted between the moving surfaces, accomplishes these purposes.
- Lubrication** is required to reduce friction, wear and remove heat.

Applications-

- In a sleeve bearing, a shaft, or journal, rotates or oscillates within a sleeve, or bushing, and the relative motion is sliding.
- In an antifriction ¹ bearing, the main relative motion is rolling.
- Mating of two gears by combination of rolling & sliding.
- Pistons slide within their cylinders.

¹ a.k.a. rolling contact bearing

Journal Bearing: Formation of Film

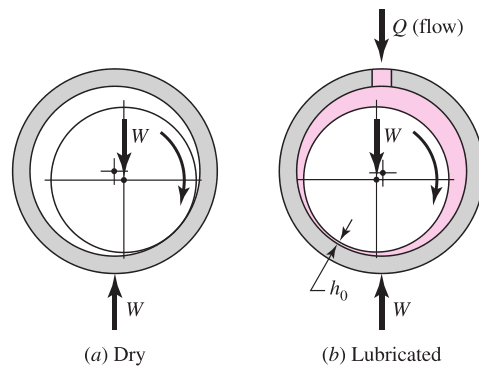


Figure: Formation of a film.

- A journal just **beginning** to rotate in a clockwise direction. Under starting conditions, the bearing will be **dry** and hence the journal will **climb or roll up the right side of the bearing**.
- Now suppose a lubricant is introduced into the top of the bearing. The action of the rotating journal will pump the lubricant around the bearing in a clockwise direction.
- The lubricant is pumped into a wedge-shaped space and forces the journal over to the other side.
- A **minimum film thickness h_0** occurs, not at the bottom of the journal, but displaced clockwise from the bottom.
- Film pressure in the converging half of the film reaches a maximum somewhere to the left of the bearing center.

Journal Bearing

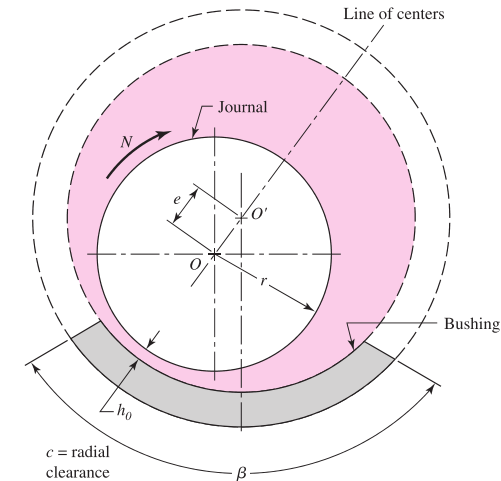


Figure: Journal bearing Nomenclature.

Classification of Lubricants

- **Liquid Lubricants or Lubricating oils:** Such as (i) Animal and Vegetables oils, (ii) Mineral or Petroleum oils and (iii) blended oils.
- **Semi-solid lubricants or Greases:** Combination of lubricating oil with thickening agents is termed as grease. The thickeners consist primarily of special soaps of Li, Na, Ca, Ba, Al, etc. Non-soap thickeners include carbon black, silica gel, polyureas and other synthetic polymers, clays, etc. Grease can support much heavier load at lower speed.
- **Solid lubricants:** Most common are graphite, molybdenum disulphide, tungsten disulphide and zinc oxide.

Classification of Lubrication

Five distinct forms of lubrication may be identified:

Hydrodynamic Lubrication

- Load-carrying surfaces of the bearing are separated by a relatively thick film of lubricant that prevents metal-to-metal contact.
- Explained by the laws of fluid mechanics.

Hydrostatic Lubrication

- The lubricant (air or water) is introduced into the load-bearing area at a pressure high enough to separate the surfaces with a relatively thick film of lubricant.
- Unlike hydrodynamic lubrication, motion of one surface relative to another isn't required.

Elastohydrodynamic Lubrication

- Occurs when lubricant is introduced between surfaces that are in rolling contact, such as mating gears or rolling bearings.
- Explained by Hertzian theory of contact stress and fluid mechanics.

Classification of Lubrication (contd.)

Boundary Lubrication

- When the following happens the buildup of a film thick enough for full-film lubrication is prevented- (i)insufficient surface area, (ii)drop in the velocity of the moving surface, (iii)reduction in the quantity of lubricant delivered to a bearing, (iv)increase in the bearing load, (v)increase in lubricant temperature resulting in a decrease in viscosity.
- In this case, the highest asperities may be separated by lubricant films only several molecular dimensions in thickness which is known as boundary lubrication.
- The change from hydrodynamic to boundary lubrication is not at all a sudden or abrupt. A mixed hydrodynamic and boundary-type lubrication occurs first, and as the surfaces move closer together, the boundary-type lubrication becomes predominant over time.
- The viscosity of the lubricant is not of as much importance with boundary lubrication as is the chemical composition.

Solid film Lubrication

- When bearings must be operated at extreme temperatures, a solid-film lubricant such as graphite or molybdenum disulfide must be used because the ordinary mineral oils are not satisfactory.