Bearing Basics

An Overview

Summary

This article provides a basic introduction to plain and rolling element bearings by outlining issues of friction, load, bearing life, lubrication, and maintenance. The remainder of the article discusses plain bearing and rolling element bearing components, construction, and materials.

RB02002
SKF
24 pages
April 2002
Revised: January 2004

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1 Introduction

Bearings are designed to overcome friction to provide ease of rotation. Friction is a force that resists the relative motion of two bodies in contact. There are a couple of ways to reduce friction between two surfaces. One way is to change the contact environment by adding lubricant or changing to a material with a lower coefficient of friction. The other way to overcome friction is utilizing rolling elements. Rolling elements change sliding friction to rolling contact friction. Friction is reduced as things roll easier than they slide. The ancient world discovered the benefits of rolling elements thousands of years ago. During the construction of the pyramids, Egyptian builders used tree logs as rolling elements between the massive stones and the ground.

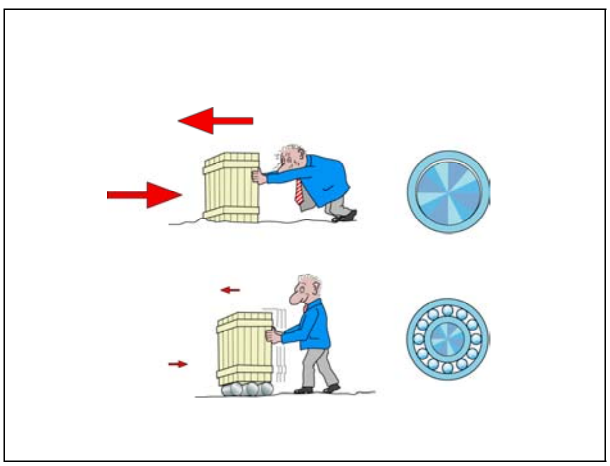

Figure 1. Bearings Reduce Friction.

This article provides a basic understanding and appreciation of plain and rolling element bearings. Part of this article comes from selections of SKF's general catalogue.

2 Bearing Load

Bearings are designed to support shafts and allow free rotation on applied loads. There are three basic types of load:

- *Radial* loads are applied perpendicular to the shaft (the bearing's axis of rotation).
- *Axial* (thrust) loads are applied parallel to the axis of rotation.
- *Combination* load is encountered when the bearing simultaneously experiences a radial and axial load.

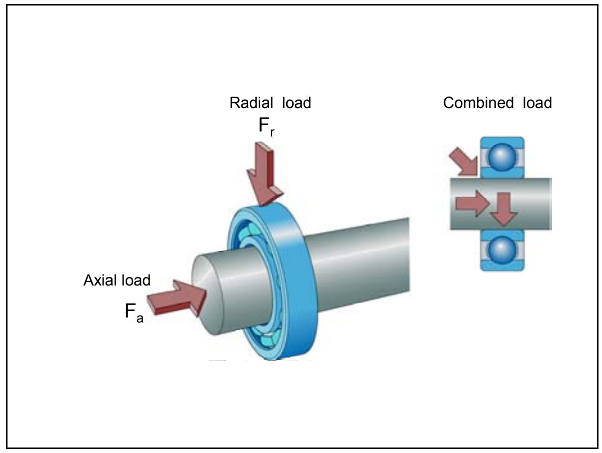

Figure 2. Bearing Loads.

3 Plain Bearings

Also referred to as *journal* or *sleeve* bearings, the plain bearing is cylindrical in shape and designed to fit tightly in the housing and on the shaft.

A plain bearing is constructed of material with a low coefficient of friction, which means the material structure and the smooth surface texture ensures low frictional losses. This results in low pressure drops and low resistance on sliding surfaces. The advantages of plain bearings include: smaller outside diameter (as opposed to rolling element bearings), quiet operation, absorption of shock loads, enduring oscillating motion (repetitive movement back and forth), and low cost.

3.1 Plain Bearing Designs

Based upon the performance envelope, plain bearings are divided into two basic designs:

Hydrodynamic

Hydrodynamic (Fluid Film Bearings) – These bearings are used in large machine applications. Lubrication is drawn into the region between the bearing's moving parts. When there is relative motion, the viscosity, combined with the bearing surface shape, generates pressure to keep surfaces separated.

Hydrostatic

Hydrostatic – Offering very low coefficients of friction at all speeds, the main characteristic of hydrostatic plain bearings is a high load capacity. The load is carried by fluid pressure, which creates decreased friction.

3.2 Bushings

Bushings are cylindrical plain bearings suitable for oscillation movements and, to an extent, linear and rotational movements. Cylindrical bushings are used in applications where misalignment does not appear.

3.3 Spherical Plain Bearings

Spherical plain bearings are standardized, ready to mount, mechanical components that are self aligning to enable multi-directional alignment movement. The forces acting on the bearing may be static or may occur when the bearing makes oscillating or recurrent tilting and slewing movements at relatively slow speeds.

Figure 3. Spherical Plain Bearing (Example).

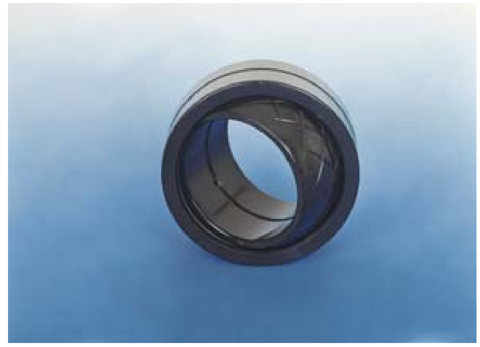

Figure 4. Spherical Plain Bearing (Example).

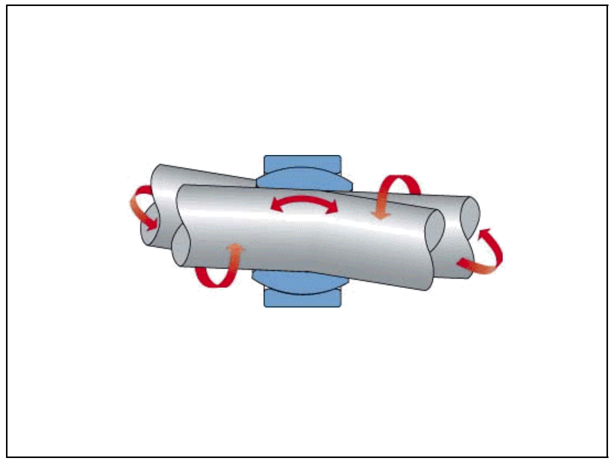

Figure 5. Spherical Plain Bearing Movement.

Rod ends are spherical plain bearing units that consist of a bearing fitted into a housing equipped with a male or female thread or a welding shank. They are primarily used on the ends of piston rods or together with hydraulic and pneumatic cylinders to join the cylinder to associated components.

3.4 Plain Bearing Materials

Plain bearing materials are grouped into two categories:

Lubricated

- Aluminum Based Alloys
- Copper Based Alloys
- Whitemetal

Dry

- Sintered Bronze
- PTFE
- Nylon

Bronze, Babbitt, oil Impregnated Sintered bronze, Teflon©, and Ultra-High Molecular Weight Polyethylene (UHMV-PE) are all low coefficient materials used in plain bearing construction. Although these materials possess low friction coefficients, lubrication between rotating and stationary parts assists in minimizing overall friction.

In addition to the advantages previously mentioned, plain bearings are used in many applications where rolling element bearings are not effective. For example, some applications in the food industry require bearings to resist contact with detergents and caustics on a continual basis. While sealed rolling element bearings do an excellent job keeping water and contaminants out, only plain bearings stand up to the rigorous environment found in these harsh applications.

4 Rolling Element Bearing Components

Rolling element bearings are far more complex than plain bearings and require much more consideration for any given application. However, rolling element bearings satisfy a greater variety of complex mechanical requirements; thus, it is easy to justify their additional cost.

Basic element bearing design is broken down into the sum of its components: outer ring, inner ring, and rolling elements. These three components are all required for a rolling element bearing to function. The cage is added to maintain even spacing between each rolling element, and to ensure equal load distribution. Seals (or shields) keep lubrication in the bearing and keep contaminants out.

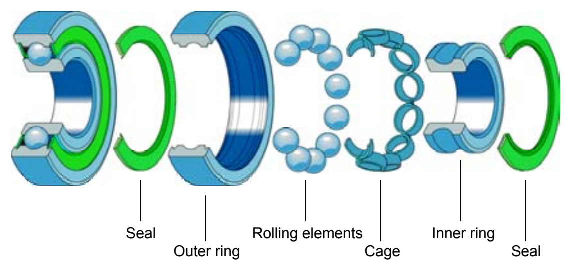

Figure 6. Rolling Element Bearing Components.

4.1 Rolling Elements

While increasing the size and quantity of the rolling elements increases the overall load carrying capabilities of the bearing, changing the type of rolling element can accomplish the same task. There are six basic types of rolling elements: ball, spherical roller (symmetrical), spherical roller (asymmetrical), cylindrical roller, needle roller, and tapered roller.

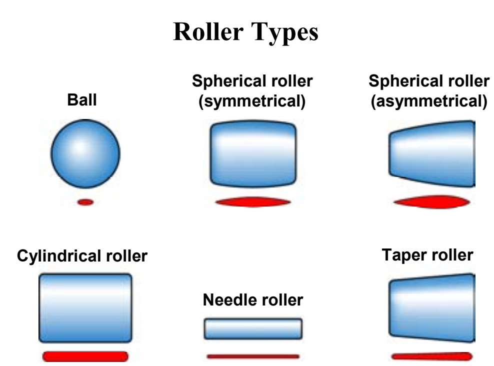

Figure 7. Rolling Elements.

Representative of each rolling element type is its ability to transmit loads through contact with the inner and outer rings. A ball rolling element transmits load through "point" contact. Point contact refers to the transfer of the entire load through the ball rolling element to the ring's raceway at a single point. Point contact (as with all rolling elements) has advantages and disadvantages. While ball elements are capable of running at higher speeds and adjust for minor misalignment, their load carrying capacity is limited.

"Line" contact rolling elements distribute the load across a larger surface between the ring's raceway. The ability to disperse the load across a larger surface allows for heavier loading than that of a ball rolling element. In addition, the dispersed area permits impact loading. The main disadvantage of line contact rolling elements is diminished speed caused by increased friction and heat generation.

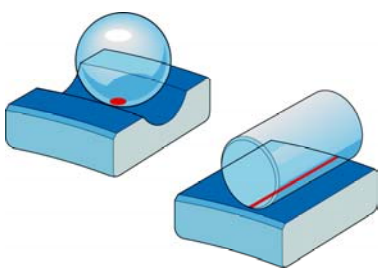

Figure 8. Rolling Element and Raceway.

4.2 Rings

The inner and outer rings provide a raceway for rolling elements to circulate. Each raceway is ground and polished to ensure the least amount of friction. The inner ring's bore serves as the interface between the rolling element and the shaft, while the outer ring's outer diameter interfaces with the housing.

4.3 Rolling Bearing Materials

Through-hardening steels

The most common through-hardening steel used for rolling bearings is a carbon chromium steel that contains approximately 1% carbon and 1.5% chromium. For bearing components with large cross sections, steel alloyed with manganese and molybdenum is used.

Case-Hardening Steels

Case-hardened rings are used when tough rings are necessary in combination with hard raceway surfaces. They are typically used in highly loaded applications. Chromium-nickel and manganese-chromium alloyed steels with a carbon content of approximately 0.15% are those case-hardening steels most commonly used for rolling bearings.

4.4 Cage

The cage performs many functions in a rolling element bearing. It prevents immediate contact between rolling elements to minimize friction and heat generation, guides rolling elements, provides space for lubricant, and retains the rolling elements when bearings of separable design are mounted or dismounted.

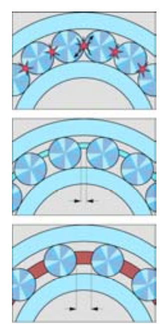

Figure 9. Cage Ball Spacing.

Depending on bearing series and size, ball bearings are fitted with one of the following cage types:

- pressed steel
- pressed brass
- machined brass
- polyamide (fabric reinforced synthetic resin)

Figure 10. Cage Variants.

Polyamide cages, especially in high-volume standard series bearings, replace steel and brass cages. In the case of low-volume, specialized bearings, brass cages are often used. Use bearings incorporating pressed steel or brass cages for bearing arrangements operated at continuously high temperatures or under arduous conditions. Before ordering cages, it is advisable to check availability.

4.5 Seals

Bearing seals are found mainly on single and double row ball bearings. Seals are made of rubber with steel reinforced backing. Affixed to the outer ring, the rubber lip of the seal rides tightly on the surface of the inner ring. This seal keeps contaminants out of the bearing assembly while keeping the lubrication from leaving the raceway area. Yet, due to the friction of the lip seal contacting the inner ring, the sealed bearing is limited to slower operating speeds.

Two types of seals are normally used in conjunction with rolling bearings: non-rubbing (without contact), and rubbing (contacting) seals.

Non-Rubbing Seals

The effectiveness of non-rubbing seals depends in principle, on the sealing action of narrow gaps between rotating and stationary components. The gaps may be arranged radially, axially, or a combination of axially and radially.

Non-rubbing seals generate almost no friction and do not wear. They are generally not easily damaged by solid contaminants and are particularly suitable for high speeds and high temperatures. Pressing grease into the gap(s) can enhances their sealing efficiency.

Rubbing Seals

The action of rubbing seals depends on the seal exerting a certain pressure on its counter-face, usually by a relatively narrow sealing lip or surface. The penetration of solid lubricants or moisture and/or the loss of lubricant are prevented by this pressure. The pressure may be produced either by the resilience of the seal, which results from the elastic properties of the sealing material and the designed interference between the seal and its counter-face, or from a tangential force exerted by a garter spring incorporated in the seal.

Rubbing seals generally provide very reliable sealing, particularly when wear is kept to a minimum by producing an appropriate surface finish for the counter-face, and by lubricating the sealing lip / counter-face contact. The friction of the seal on its counter-face and the subsequent rise in temperature is a disadvantage; therefore, rubbing seals are only useful for operation up to certain peripheral speeds. They are also susceptible to mechanical damage as a result of improper mounting or solid contaminants. To prevent damage by solid contaminants it is customary to place a non-rubbing seal in front of the rubbing seal for protection.

Shields

Bearing shields are made of steel. They too are affixed to the bearing's outer ring but unlike the seal, the shield does not make contact with the inner ring. Shields allow for larger particulate contaminant protection, and tolerate higher bearing operating speeds.

5 Rolling Element Bearings

The combination of rolling elements and rings form the complete rolling element bearing. There are eight basic types of rolling element bearings: deep groove, angular contact, self-aligning ball, cylindrical roller, tapered roller, needle, spherical, and toroidal.

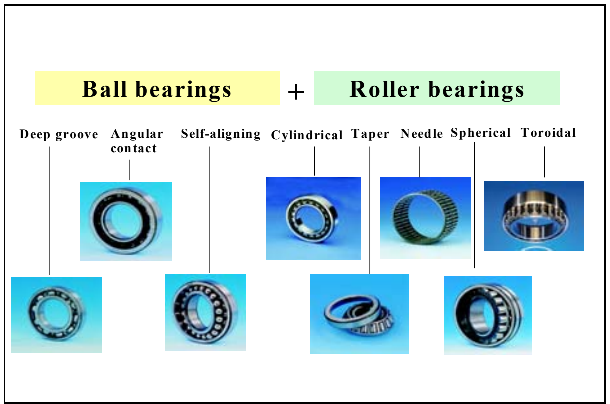

Figure 11. Completed Rolling Element Bearing.

The assorted rolling element bearing types are specifically designed to handle varying loads and speeds. Bearing loads are determined by how much weight needs to be supported and where that load is transmitted.

5.1 Deep Groove

Deep groove bearings have one or more rows of balls as rolling elements. These balls run in grooves in the inner and outer ring. Ball bearings make point contact, as opposed to line contact, thus they generate lower friction than roller bearings. The deep groove raceways allow the radial bearing to withstand a certain amount of axial load.

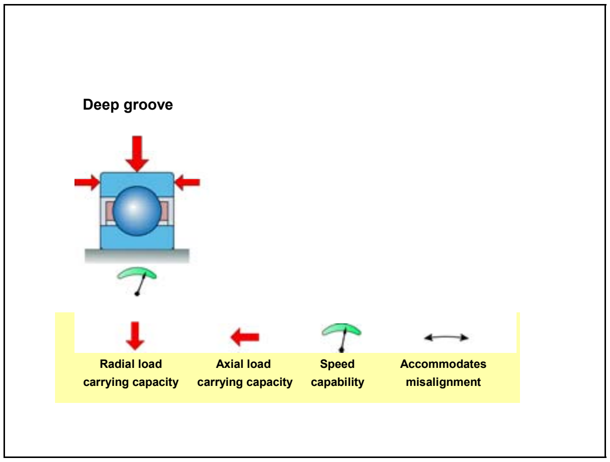

Figure 12. Deep Grove Ball Bearing.

5.2 Angular Contact

Angular contact bearings have inner and outer ring raceways that are displaced with respect to each other in the direction of the bearing axis. This bearing is particularly suitable for accommodating simultaneous radial and axial loads depicted in what is known as the contact angle. The axial load carrying capacity of angular contact ball bearings increases with an increasing contact angle. This is defined as the angle between the line joining the points of ball and raceway contact in the radial plane, and a line perpendicular to the bearing axis. For single row angular contact ball bearings, the magnitude of the contact angle is given by a suffix in the bearing designation. Normal contact angle for an angular contact bearing is 30 degrees, but this contact angle can be changed to coincide with application demands.

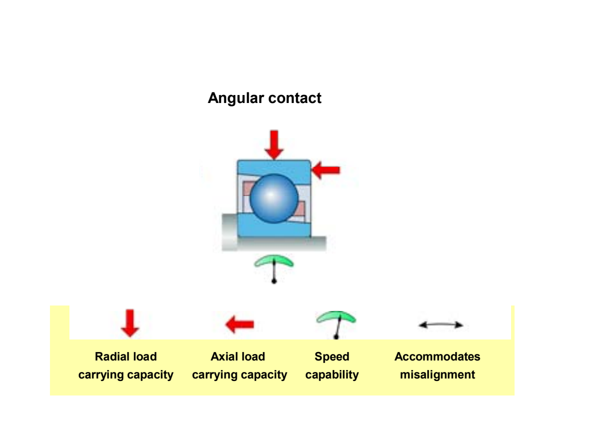

Figure 13. Angular Contact Bearing.

5.3 Self-Aligning Ball

The inside surface of the outer ring of a self-aligning ball bearing is part of a sphere. This means the bearing is self-aligning and adapts to shaft misalignment. SKF was founded on Sven Wingquist's revolutionary invention of the double row self-aligning ball bearing.

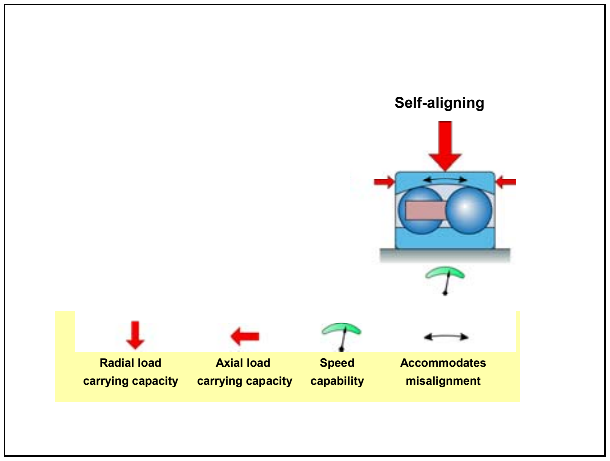

Figure 14. Self-Aligning Ball Bearing.

5.4 Cylindrical Roller

Cylindrical roller bearings are bearings with cylindrical rolling elements. These bearing variants have the highest load and speed capacity as compared with other line contact rolling elements (needle, spherical, and tapered). The load carrying capacity advantages of cylindrical roller bearings over ball bearings is sacrificed in its sensitivity to misalignment.

Another advantage to cylindrical roller bearings is their ability to deal with axial displacement (movement in the axial direction). NJ design (see Figure 15) cylindrical roller bearings and some full complement designs are used to compensate for axial displacement. These bearings permit roller axial displacement with respect to one of the raceways so both inner and outer rings can be mounted with interference fits. The cylindrical rollers are guided between two integral flanges on the inner ring, whilst the low flange on the inboard side of the outer ring holds the bearing together until it is mounted. Values for the permissible axial displacement within the bearing are given in the manufacturer's product tables.

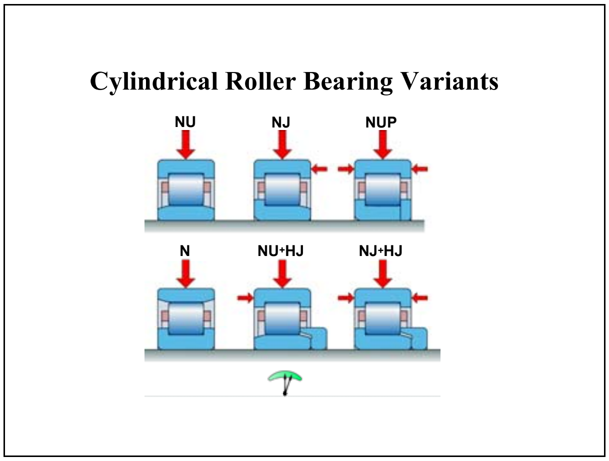

Figure 15. Cylindrical Roller Bearing.

5.5 Tapered Roller

Tapered roller bearings are a four-part bearing assembly consisting of: tapered rolling elements, outer ring or *cup*, inner ring or *cone*, and cage. Designed for combination loads, tapered roller bearings are available with steep and shallow angles to accommodate larger thrust and radial load combinations respectively.

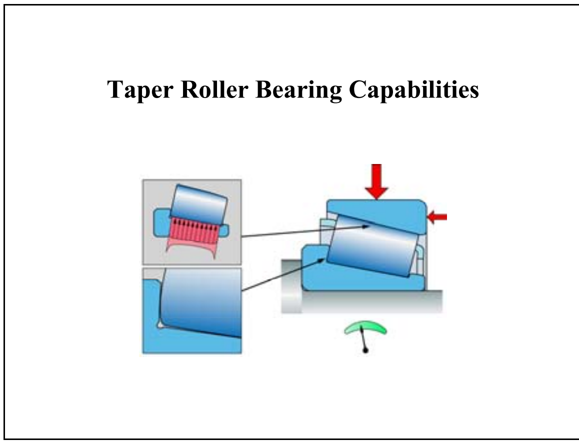

Figure 16. Tapered Roller Bearing.

5.6 Needle

Needle bearings are similar to cylindrical roller bearings, but have long, thin cylindrical rollers with a small length-to-diameter ratio. A hardened shaft or sleeve acts as the inner race / ring for the needle bearing, which allows for an overall lower bearing profile that requires little space. Caged needle bearings are available for higher speed applications.

Figure 17. Needle Bearing.

Figure 18. Needle Bearing.

5.7 Spherical

Spherical bearings are roller bearing where the inside surface of the outer ring is part of a sphere. This means the bearing is self-aligning to adapt itself to shaft misalignment. Because the spherical bearing is internally self-aligning, it is well suited for heavy-duty applications. There are many different designs on the market, which results in large performance differences.

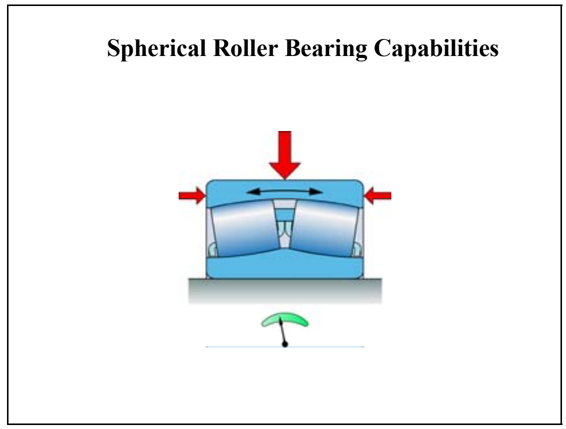

Figure 19. Spherical Roller Bearing.

5.8 Toroidal

The CARB is a toroidal roller bearing - a completely new type of radial roller bearing. This compact, self-aligning roller bearing was developed by SKF as a single row toroidal roller bearing with long, slightly crowned rollers. The raceways of both inner and outer rings are concave and symmetrical. This optimum combination of raceway profiles guarantees a favorable load distribution and low friction.

The CARB rollers are self-guiding (i.e. they always adopt a position to evenly distribute the load over the roller length) irrespective of whether the inner ring is axially displaced and/or misaligned with respect to the outer ring. The load carrying capacity of the CARB is very high even when it has to compensate for angular misalignments or axial displacements. This results in operationally reliable bearing arrangements with long service life.

Figure 20. Toroidal Bearing.

Figure 21. Toroidal Bearing.

More information and a demonstration can be found in the SKF General Catalogue.

6 Load Capabilities

While rings and rolling elements carry the bearing load, the type, size, and number of the rolling elements directly influence the bearing's overall *load capacity*. By increasing the size or the quantity of rolling elements, the overall load capacity increases. Total load capabilities also increase by changing the rolling element style.

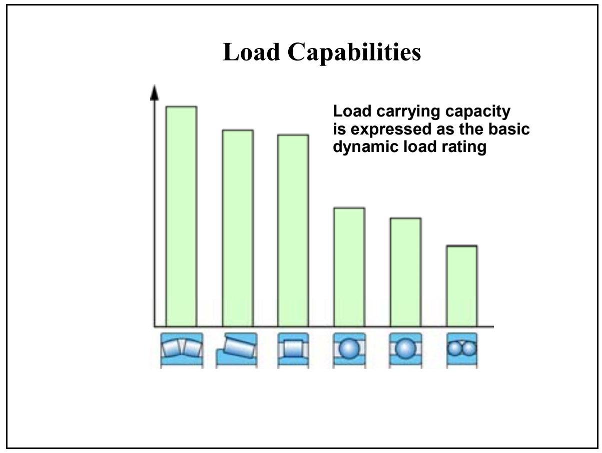

Figure 22. Load Capabilities by Type.

6.1 Minimum Load

To guarantee satisfactory operation, deep groove ball bearings, like all ball and roller bearings, must always be subjected to a given minimum load, particularly if they operate at high speeds, high accelerations, or rapid changes in load direction. Under such conditions, the inertia forces of the balls and cage, and the friction in the lubricant, can have a detrimental influence on the rolling conditions in the bearing arrangement and may cause damaging sliding movements between the balls and raceways.

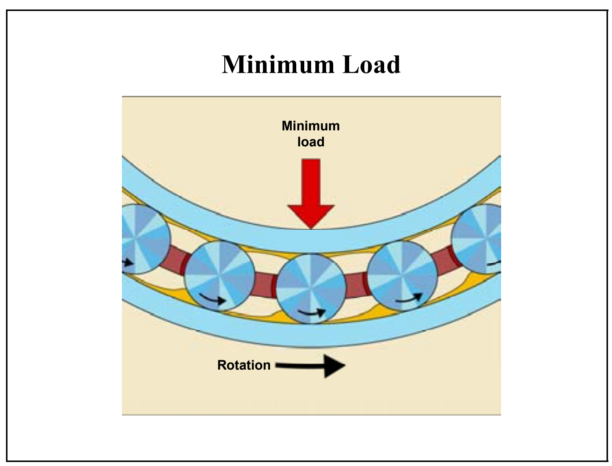

Figure 23. Minimum Load.

When starting up at low temperatures or when the lubricant is highly viscous, even greater loads may be required. The weights of the components supported by the bearing, together with the external forces, generally exceed the requisite minimum load.

6.2 Load Carrying Capabilities and Life

Initially select the bearing size on the basis of its load carrying capacity in relation to load, life, and reliability requirements. Numerical values termed basic load ratings are used to express load carrying capacity. Values for the basic dynamic load rating C and the basic static load rating C_0 are quoted in the manufacturer's product tables. The SKF Formula for Rolling Bearing Life is an excellent article on theory and calculations of bearing life.

6.3 Basic Load Ratings

The basic dynamic load rating C is used for calculations involving dynamically stressed bearings, or bearings that rotate under load. It expresses the bearing load as an ISO (International Organization for Standards) basic rating life defined under Life (Load Carrying Capability and Life) of 1,000,000 revolutions. It is assumed that the load is constant in magnitude and direction and is radial for radial bearings, and axial (acting centrically) for thrust bearings.

The basic static load rating C_0 is used in calculations when bearings rotate at very slow speeds, perform very slow oscillating movements, or are stationary under load for certain periods.

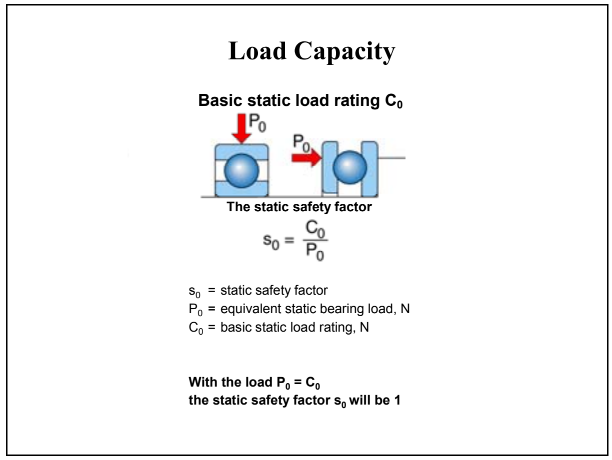

Figure 24. Load Capacity.

The basic static load rating is defined in ISO 76-1987 as static load that corresponds to a calculated contact stress at the center of the most heavily loaded rolling element / raceway contact of:

- 4,600 MPa for self-aligning ball bearings
- 4,200 MPa for all other ball bearings
- 4,000 MPa for all roller bearings

This stress produces a total permanent deformation of rolling element and raceway, which is approximately 0.0001 of the rolling element diameter. The loads are purely radial for radial bearings and centrically acting axial loads for thrust bearings.

6.4 Comparative Load Ratings

For rolling mills and similar applications, particularly when multi-row roller bearings are used, it is common practice to calculate using dynamic load ratings (determined by a method that deviates from that specified in ISO 281:1990 and is based on a rating life of 90 million revolutions - 3,000 operating hours at 500 rpm) instead of the 1 million revolutions specified by ISO.

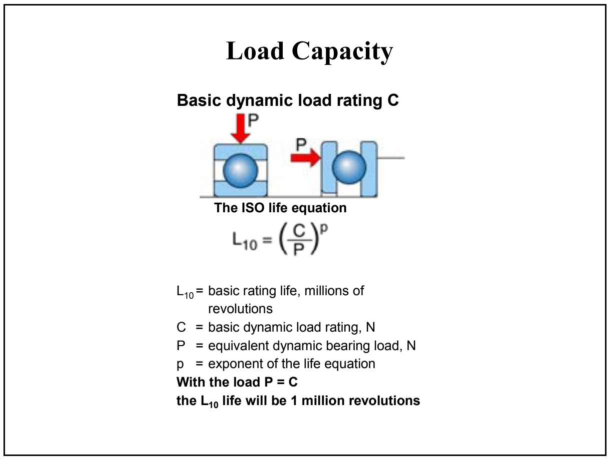

Figure 25. Load Capacity.

There are obvious differences in bearing load ratings quoted by different manufacturers for bearings, as load ratings depend on the use of materials, material quality, design details, number of rolling elements, etc.

6.5 Bearing Life

Practical experience and modern research shows that, under special conditions, bearings can attain a much longer life than predicted by standardized life calculation methods, particularly when loads are light. These special conditions apply when the surfaces in rolling contact (raceways and rolling elements) are effectively separated by a lubricant film and deterioration from contaminants is largely non-existent. Under ideal conditions it is possible to speak of infinite life.

It is well known that the calculated life is often longer than the service life actually achieved for large, multi-row bearings (i.e. heavily loaded rolling mill bearings). Therefore, a comparison of these bearings based solely on load ratings is questionable. The know-how of a bearing manufacturer in respect to typical operating conditions for a particular application is of considerable importance when satisfactory performance in that application is of concern.

The *SKF Life Theory* introduces the concept of a fatigue load limit P_u analogous to that used when calculating other machine components. This fatigue load limit represents the load below which fatigue will not occur in the bearing under ideal conditions.

The SKF theory represents an extension of the work of Lundberg and Palmgren, taking into account the fatigue load limit and several other factors related to lubrication and contamination. It is possible to predict a realistic bearing service life as referred to above with this theory. A precise prediction can only be made if the operating conditions are accurately known and if the full theory is applied, which requires the use of a computer.

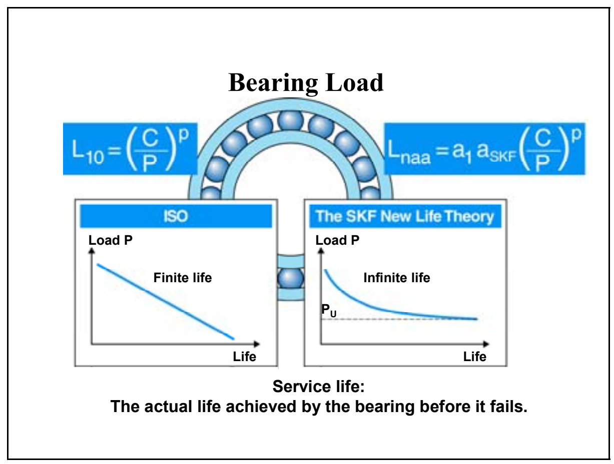

Figure 26. SKF New Life Theory.

Due to the complexity, a detailed description of the theory is beyond the scope of this article. However, to pass on the benefits inherent in the deeper understanding of bearing behavior on which the SKF Life Theory is based, a simplified catalog approach has been devised and presented in the IEC. This enables users to exploit the realistic life potential of bearings, to undertake controlled downsizing, and to recognize the influence of contamination on bearing life.

Most bearing manufacturers base their information on dynamic load ratings (except the comparative ratings), which are founded on the life that 90% of a sufficiently large group of identical bearings are expected to attain. This is called the *basic rating life* and agrees with the ISO definition. The *median life* is approximately five times the calculated basic rating life - referring to failure of 50% of the bearings.

7 Internal Clearances

Bearing internal clearance is defined as the total distance through which one bearing ring can be moved relative to the other in the radial direction (radial internal clearance) or in the axial direction (axial internal clearance).

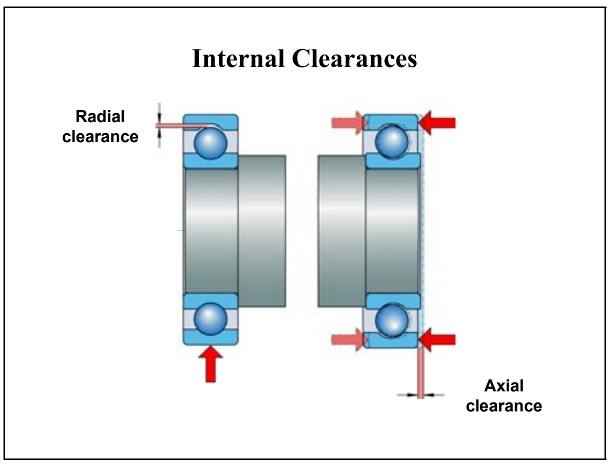

Figure 27. Internal Clearances.

It is necessary to distinguish between the internal clearance of a bearing before mounting and the internal clearance in a mounted bearing that has reached its operating temperature (operational clearance). The initial internal clearance (before mounting) is greater than the operational clearance because different degrees of interference in the fits and differences in bearing ring thermal expansion cause the rings to expand or compress.

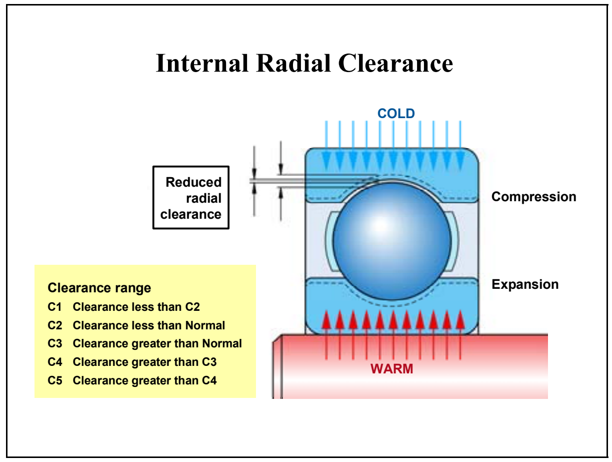

Figure 28. Internal Radial Clearances.

The radial internal clearance of a bearing is of considerable importance to obtain satisfactory operation. As a general rule, ball bearings should always have an operational clearance of (virtually) zero, or there may be a slight preload. Cylindrical and spherical roller bearings, on the other hand, should always have some residual clearance, however small, in operation. The same is true of taper roller bearings except in bearing arrangements where stiffness is desired (e.g. pinion bearing arrangements) and the bearings are mounted with a certain amount of preload.

Normal bearing internal clearance is selected to obtain suitable operational clearance when bearings are mounted with the recommended fits and normal operating conditions. SKF single row deep groove ball bearings have normal radial internal clearance as standard. Some bearings, particularly the smaller sizes, are also available with greater or smaller clearance than normal.

8 Mounting/Dismounting

Bearing mounting and dismounting is only shortly discussed in this article. In January of 2002, SKF launched SKF.com/mount. Internet based, the system is an online rolling bearing mounting and dismounting instruction guide. It is important to mention that there are basically two different types of inner race bores to consider: cylindrical and tapered.

8.1 Cylindrical Bore

Bearings with cylindrical bore are easier to mount and dismount if the design is separable rather than non-separable, particularly if interference fits are required for both rings. They are also preferable if frequent mounting and dismounting are required. One ring of these separable bearings (i.e. cylindrical, needle, and taper roller bearings) can be fitted independently of the other ring.

8.2 Tapered Bore

Bearings with a tapered bore can easily be mounted on a tapered journal or cylindrical shaft seating using an adapter or withdrawal sleeve.

8.3 Interference Fit

The tolerances for the bore and outside diameters of rolling bearings are specified in ISO 5753:1991 and shown in Figure 29. To achieve an interference or a clearance fit, suitable shaft and housing seat tolerance ranges have to be selected.

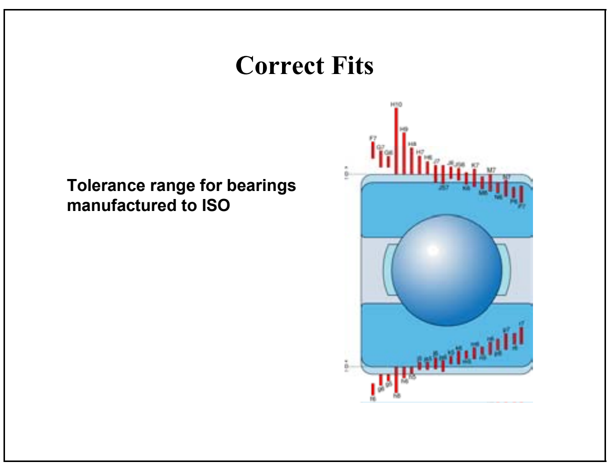

Figure 29. Correct Fits (ISO).

9 Bearing Selection Criteria

Each type of bearing displays characteristic properties that depend on design and designate the appropriate application. For example, deep groove ball bearings can accommodate moderate radial loads and axial loads. They have low friction and can be produced with high precision and quiet running variants. Therefore, they are preferred for small and medium-sized electric motors.

Spherical roller bearings can carry very heavy loads and are self-aligning. These properties make them popular for applications in heavy engineering, where loads are heavy and deformations and misalignments are common.

In many cases however, several factors must be considered when selecting bearing type. The information provided serves to indicate the most important points to consider when selecting bearing type.

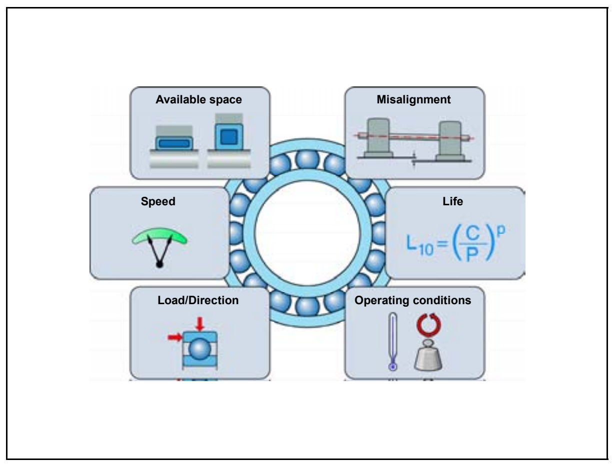

Figure 30. Bearing Selection Criteria.

9.1 Available Space

In many cases, one principal bearing dimension (generally the bore diameter) is predetermined by machine design. For small-diameter shafts all types of ball bearings can be used. For large-diameter shafts, cylindrical, spherical, taper roller bearings, and deep groove ball bearings are available.

When radial space is limited, bearings with a small cross section, particularly those with a low cross-sectional height, should be chosen. When space is limited in the axial direction, certain series of single row cylindrical roller bearings, deep groove ball bearings, and various types of combined needle roller bearings can be used for combined loads.

For purely axial loads, needle roller and cage thrust assemblies (with or without washers), and certain series of thrust ball bearings and cylindrical roller thrust bearings can be used.

9.2 Load / Direction

Please refer to section 6, Load Capabilities on page 11.

9.3 Misalignment

Angular misalignment between shaft and housing occur when the shaft bends (flexes) under operating load, when bearing seats in the housing are not machined at a single setting, or when shafts are supported by bearings in separate housings too far apart.

So-called rigid bearings cannot accommodate any misalignment, or can only tolerate very minor misalignments, unless by force. Self-aligning bearings, on the other hand, are suitable to accommodate misalignment produced under operating loads and can compensate for errors of alignment resulting from machining or mounting.

9.4 Precision

Bearings with higher precision than normal are required for arrangements that call for high running accuracy (machine tool spindle arrangements) and very high speed operation.

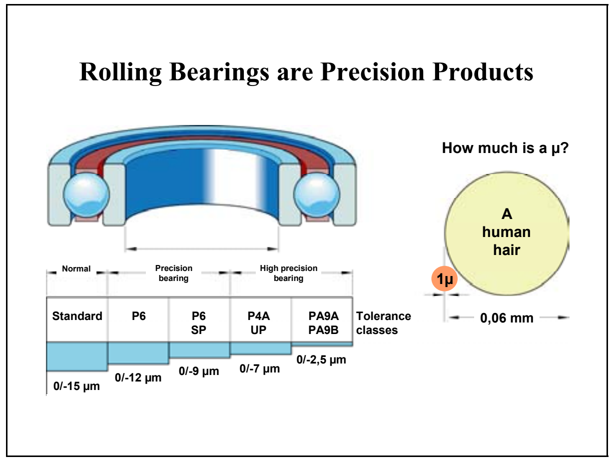

Figure 31. Precision.

Most bearing manufacturers produce a comprehensive range of high precision bearings, including single row angular contact ball bearings, single and double row cylindrical roller bearings, and single and double direction angular contact thrust ball bearings. See your bearing manufacturer's catalogue for specific precision products.

9.5 Speed

The permissible operating temperature limits the speed at which rolling bearings can be operated. Bearing types with low friction and correspondingly low heat generation are most suitable for high speed operation.

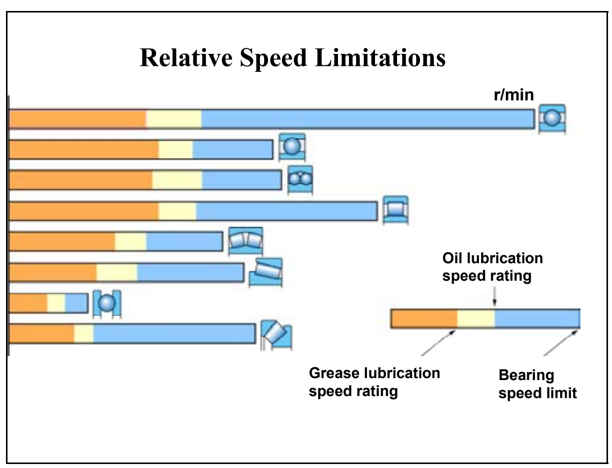

Figure 32. Relative Speed Limitations by Type.

The highest speeds can be achieved with deep groove ball bearings when loads are purely radial. This is particularly true of high precision bearings with special cages. Hybrid bearings (steel rings and ceramic balls) attain even higher speeds. Yet, because of their design, thrust bearings do not permit high speeds.

9.6 Quiet Running

In certain applications, such as small electric motors for household appliances or office machinery, the noise produced in operation is an important factor and can influence bearing choice. Deep groove ball bearings are especially produced for this application.

9.7 Stiffness

The stiffness of a rolling bearing is characterized by the magnitude of the bearing's elastic deformation (resilience) under load. Generally, this deformation is very small and can be neglected. In a very few cases however, stiffness is important (i.e. spindle bearing arrangements for machine tools or pinion bearing arrangements). Due to the contact conditions between rolling elements and raceways, roller bearings have higher stiffness than ball bearings.

9.8 Axial Displacement

In general, a shaft and other machine components are supported in locating and non-locating bearings. Locating bearings provide axial location for the machine component in both directions. The most suitable bearings for this task are those that can accommodate combined loads, or provide axial guidance in combination with a second bearing.

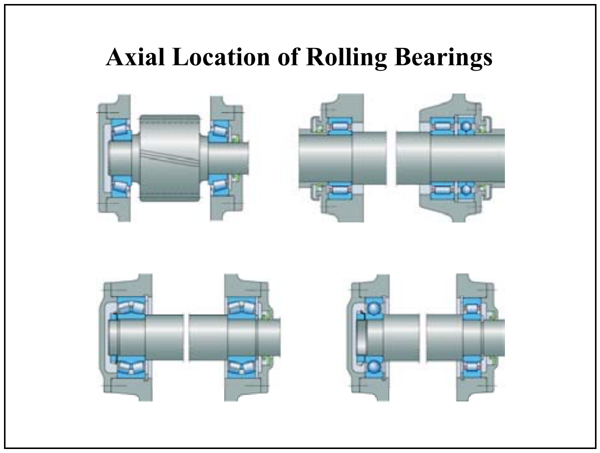

Figure 33. Axial Location of Rolling Bearings.

Non-locating bearings must permit movement in the axial direction so bearings are not additionally stressed when, for example, thermal expansion of the shaft takes place.

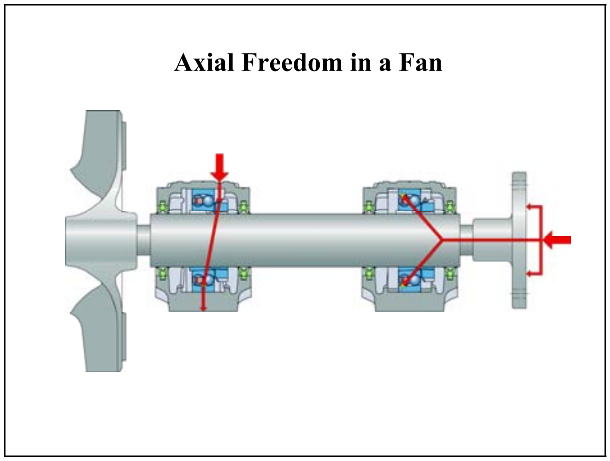

Figure 34. Axial Freedom in a Fan.

The most suitable bearings include needle roller bearings and cylindrical roller bearings, which have one ring without flanges of the NU and N designs. Cylindrical roller bearings of the NJ design and some full complement designs can also be used.

10 Dimensions

Manufacturers and users of rolling bearings are, for reasons of price, quality, and ease of replacement, only interested in a limited number of bearing sizes. The International Organization for Standardization (ISO) laid down *dimension plans* for the boundary dimensions of metric rolling bearings (ISO 15:1998 for radial bearings except taper roller bearings; ISO 355-1977 for radial metric taper roller bearings, and ISO 104:1994 for thrust bearings).

10.1 ISO Dimension Plan

The ISO dimension plan for radial bearings (except taper roller bearings) contains a progressive series of standardized outside diameters for every standard bore diameter arranged in diameter series 7, 8, 9, 0, 1, 2, 3, and 4 (in order of increasing outside diameter).

Within each diameter series, different width series have also been established (width series 8, 0, 1, 2, 3, 4, 5, 6, and 7 in order of increasing width). The width series for radial bearings correspond to the height series for thrust bearings (height series 7, 9, 1, and 2 in order of increasing height).

By combining a diameter series with a width or height series, dimension series, designated by two digits, are created. The first digit identifies the width or height series and the second, the diameter series.

In the ISO dimension plan for single row metric taper roller bearings, the boundary dimensions are grouped for certain ranges of the contact angle, known as the angle series (angle series 2, 3, 4, 5, 6, and 7 in order of increasing angle). Based on the relationship between outside and bore diameters, and between the total bearing width and the cross-sectional height, diameter and width series are laid down. Here, dimension series are obtained by combining the angle series with a diameter and a width series. These dimension series are designated by a combination of one figure (for angle series) and two letters (the first for the diameter series and the second for the width series).

Experience shows that the vast majority of bearing application requirements can be met using bearings with these standardized dimensions.

In addition to metric bearings, some inch-size ball bearings and cylindrical roller bearings are available.

10.2 Manufacturer Designations

Most bearing manufacturers' standard bearings have a characteristic basic designation, which generally consists of 3, 4, or 5 figures, or a combination of letters and figures. The figures and combinations of letters and figures have the following meaning:

The first figure or first letter, or combination of letters, identifies the type of bearing; the actual bearing type is identified from the presentation and listed under the heading. The following two figures identify the ISO dimension series; the first figure indicates the width (B or T) or height (H or T) series and the second the diameter series (D). The last two figures of the basic designation give the size of the bearing. When the size is multiplied by five, the bore diameter in millimeters is obtained.

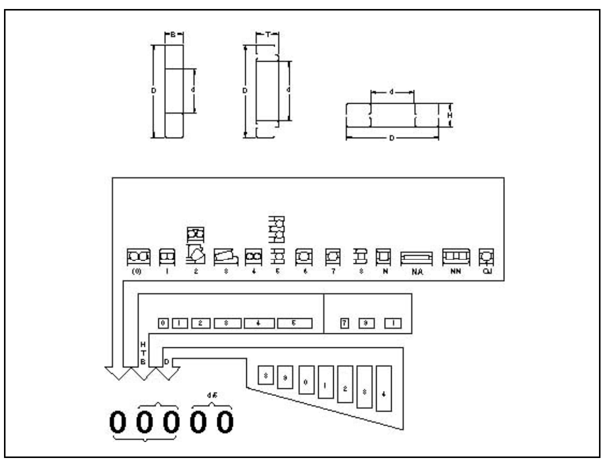

Figure 35. Manufacturer Designations.

In some cases, the figure for the bearing type and/or the first figure of the dimension series identification is omitted. These figures are given in brackets.

For bearings with a bore diameter smaller than 10 mm and equal to, or greater than 500 mm, the bore diameter is generally given in millimeters direct, which means the size identification is separated from the rest of the bearing designation by an oblique stroke, e.g. 618/8 (d = 8 mm) or 511/530 (d = 530 mm). This is also true of standard bearings to ISO 15, which have bore diameters of 22, 28 and 32 mm, for example 322/28 (d = 28 mm). Bearings with bore diameters of 10, 12, 15, and 17 mm have the following size identifications:

00 = 10 mm

01 = 12 mm

02 = 15 mm

03 = 17 mm

For some deep groove, self-aligning, and angular contact ball bearings with a bore diameter smaller than 10 mm, the bore diameter is also given in millimeters (un-coded) but is not separated from the basic designation by an oblique stroke; for example, 629 or 129 (d = 9 mm).

Bore diameters that deviate from the standard bore diameter of a bearing have always been specified un-coded in millimeters with up to three decimal places. This bore diameter identification is part of the basic designation and is separated from the basic designation proper by an oblique stroke; for example, 6202/15.875 (d = 15,875 mm). However, such bearings will, in the future, be identified by a drawing number.

10.3 Series Designations

Each standard bearing belongs to a given bearing series, which is identified by the basic designation without size identification. Series designations often include a suffix A, B, C, D, or E, or a combination of these letters. The series designations are used to identify differences in internal design, such as the contact angle.

The most common series designations are shown above bearing drawings. The figures in brackets are not included in either the basic designation or the series designation.

11 Lubrication and Maintenance

If rolling bearings are to operate reliably they have to be adequately lubricated to prevent direct metallic contact between the rolling elements, raceways, and cages. Keeping metallic components from contacting each other prevents wear, but the lubricant also protects the bearing surface from corrosion.

Thus, the choice of a suitable lubricant, method of lubrication, and lubricant maintenance for each bearing application is important. The various references in this paper provide insight into methods of lubrication, changing of oil, proper bearing handling, and servicing. For damaged bearing analysis, SKF can offer an online bearing diagnostic advisory system (see the @ptitudeXchange site) where the user inputs bearing and condition information and the program provides an analysis of probable causes.

The following information relates to bearings without integral seals or shields. Bearings and bearing units with integral seals or shields are supplied greased. The standard greases used for these products have operating temperature ranges and other properties to suit the intended application areas and filling grades appropriate to the bearing size. The service life of the grease often exceeds bearing life so that, with some exceptions, no provision is made for re-lubrication.

While there are a wide selection of greases and oils available for the general duty lubrication of rolling bearings, solid lubricants, designed for extreme temperature conditions, are also available. The actual choice of lubricant depends primarily on operating conditions. Temperature range and speeds, and the influence of the surroundings can also be dictated by the lubrication of adjacent machine components.

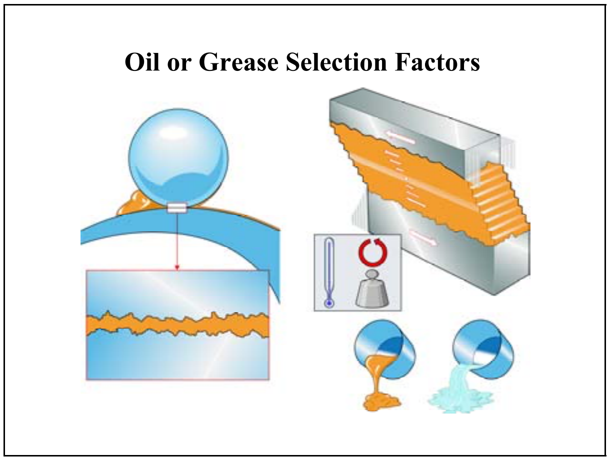

Figure 36. Oil or Grease Selection Factors.

Other environmental factors such as the presence of dust, water spray, condensation, or other aggressive media, the arrangement of the shaft (horizontal, inclined or vertical), the sealing arrangements, and the ability to relubricate all have an influence on lubrication choice. The compatibility of the lubricant with the bearing materials, particularly the cage and seals, must also be taken into account.

The most favorable operating temperatures are obtained when the bearing is supplied with the minimum quantity of lubricant needed to provide reliable lubrication. However, when the lubricant has additional tasks, such as sealing or reducing heat, larger quantities are required.

11.1 Lubrication Selection

To address these complex lubrication issues, SKF offers an online selection guide called LubeSelect (see the @ptitudeXchange site). This system gives grease or oil selection suggestions based on bearing dimensions, operating conditions, and special circumstances. Because LubeSelect only requires you to fill in the blanks, it is easy to use. In addition, all required parameters must be entered before LubeSelect will make its calculations, which ensures accurate feedback.

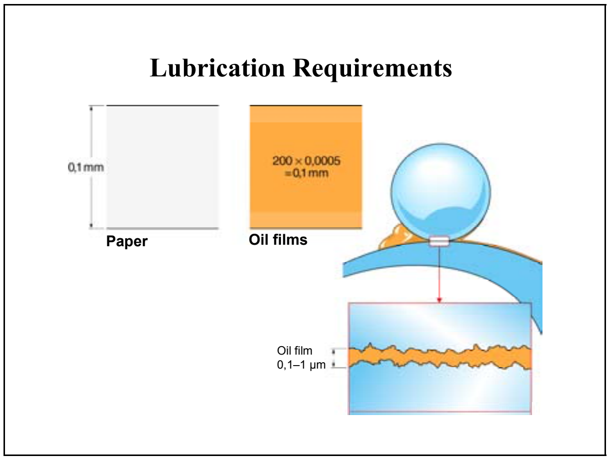

Figure 37. Lubrication Requirements.

The lubricant fill in a bearing arrangement will gradually lose its lubricating properties during operation as a result of mechanical working, aging, and contaminant build-up. It is necessary for grease to be replenished or renewed, or oil to be filtered and changed at certain intervals. Due to the large number of different lubricants available, there may be differences in lubricating properties of seemingly identical greases produced at different locations. Bearing manufacturers do not accept liability for the lubricant or its performance, except for some pre-greased bearings with integrated seals. The user is therefore advised to specify the required lubricant properties in detail and to obtain a guarantee from the lubricant supplier that the particular lubricant will satisfy.

11.2 Storage and Handling

Bearings can be stored in their original packages for years, provided relative humidity in the storeroom does not exceed 60% and there are no great fluctuations in temperature.

With sealed or shielded bearings, the lubricating properties of the grease with which they are filled may deteriorate over time. Great care should be taken to protect bearings that are not stored in their original packages from moisture and contamination.

Large rolling bearings should only be stored lying down, preferably with support for the whole extent of the side faces of the rings. If kept in a standing position, the weight of the rings and rolling elements can give rise to permanent deformation because the rings are relatively thin-walled. For the same reason, if large and heavy bearings are moved or held in position using lifting tackle, they should not be suspended at a single point; rather, a sling or other suitable aid should be used. A spring between the hook of the lifting tackle and the sling facilitates positioning the bearing when it is pushed onto a shaft.

For ease of lifting, large bearings often have threaded holes in the ring faces into which eye bolts can be screwed. As the hole size is limited by the ring thickness it is only permissible to lift the bearing itself or the individual ring by the bolts. When mounting a large housing over a bearing that is already in position on a shaft, it is advisable to provide three-point suspension for the housing, and for the length of one sling to be adjustable. This enables the housing bore to be exactly aligned with the bearing.

12 Some Special Terms

A few special terms are adapted from the SKF dictionary, available at http://www.skf.com

- **Ceramic Bearings**; Bearings with rings and rolling elements of ceramic material. Available as ball and roller bearings including sealed versions. Main application areas are pumps and compressors where the bearings are lubricated by the process liquid.

- **Hybrid Bearings**; Rolling bearings with rings of steel and rolling elements of ceramic material. Hybrid bearings have longer service life than all-steel bearings and are electrically insulating. They can operate at high speeds and tolerate poor lubrication. Available also as high precision angular contact ball bearings intended for machine tool spindles etc.

- **Slewing Bearings**; Large rolling bearings for slewing movements used in cranes and excavators. The rings are bolted to the structure and one of the rings is often equipped with gears, to take an active part in the slewing movement drive system. Available in different designs such as single row four point ball bearings and single row crossed roller or triple row roller bearings.

- **Insocoat;** Many bearing failures in electric motors and generators are caused by passage of current through the bearings. See bearing damage due to electric current. INSOCOAT® bearings are insulated by a layer of aluminium oxide on the outer ring that will break a circulating current and prevent bearing damage due to passage of current. INSOCAOT is a registered trademark of the SKF Group.

- **Split Bearing Units**; The units consist of a split housing, a split bearing and two split seals. The bearing may be either a spherical or cylindrical roller bearing. Due to the split design of all components, this greatly facilitates bearing replacements. The units are used in continuous casting, long propeller shafts etc.

- **Magnetic Bearing**; Magnetic bearings basically consist of a shaft and housing. The oil film, which in rolling bearings separates the moving parts, has been replaced by a magnetic field that supports the shaft in the housing bore and prevents metallic contact. These bearings are suitable for low loads and high speeds. See also www.revolve.com

- **Sensor Bearing Units**; Mechatronic machine components covering the fields of both sensor and bearing engineering. Sensor body, impulse ring and bearing are mechanically attached to each other, forming an integral ready-to-mount unit. When the inner ring rotates, the impulse ring moves past the stationary sensor ring, generating a magnetic field of changing polarity. SKF sensor bearing units are used for recording number of revolutions, speed, direction of rotation, relative position, acceleration and deceleration.

- **NoWear**; A coating method for rolling elements and raceways in bearings. NoWear coating is 40-80% harder than the steel used in bearings. It has low friction and is thermally stable up to 200 oC (392 oF). NoWear increases the bearing service life and provides good properties under conditions of poor lubrication and contaminated environments. NoWear is a registered trademark of the SKF Group.

13 Conclusion

There are many bearing styles to select from for any given bearing application. Engineering catalogs and guides are an excellent information source for choosing the correct bearing. Bearing manufacturers and distributors can also offer assistance and advice in proper bearing selection and bearing technology. Thus, contact your bearing manufacturer or distributor with questions or concerns regarding bearing selection and maintenance.

14 Further Reading

SKF General Catalogue, Publication 5000 E. 2003. See also http://www.skf.com

SKF Sperical Plain Bearings And Rod Ends, Publication 4407 E, 2000, http://www.aptitudexchange.com

SKF Rolling Bearing in Paper Machines, Publication 4690 E, 2002. http://www.aptitudexchange.com

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SKF, Tips for Bearing Mounting, RB02017, http://www.aptitudexchange.com

SKF, Proper Bearing Handling and Storage, RMI03003, http://www.aptitudexchange.com

International Standards Organization, http://www.iso.org

American Bearing Manufacturers Association (ABMA), http://www.abma-dc.org

Society of Tribologists and Lubrication Engineers (STLE), http://www.stle.org

American Society of Mechanical Engineers (ASME), http://www.asme.org

National Lubricating Grease Institute (NLGI), http://www.nlgi.com