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BEARING

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BEARING

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PREFACE

This book is designed mainly for mechanical engineering students and those who need a clear understanding of fundamentals of mechanical component. It is also suitable for those who are studying independently or through open-learning system. This book explains the fundamentals of mechanical component related to bearing

The entire book is written in a simple way to enable the students understand the concepts quickly and the subject in an easy manner. This book shall provide knowledge on the theory, concept and application of bearing and to acquire the problem solving skills related to the respective processes.

CONTENT

BEARING CONCEPTS

FRICTION, TEMPERATURE AND LUBRICATION

CONTENT

BEARING CONCEPTS

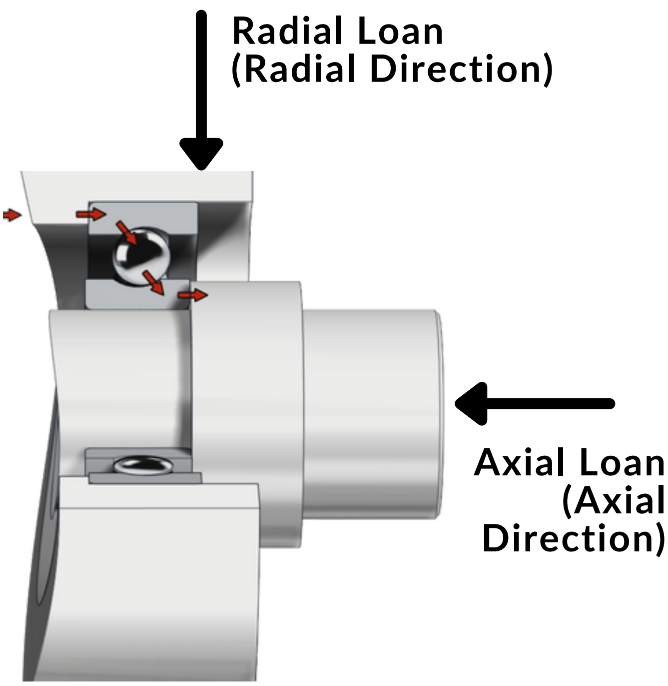
- Application of bearings
- Types of bearing and characteristic of bearings
- Nomenclature of Bearing
- Bearing Service Life
- Shield and Seal Bearings

Bearings' application

A bearing is a machine component that restricts the relative motion of moving elements to the intended motion.

• The bearing design may allow for free linear movement of the moving component or free rotation around a fixed axis; alternatively, it may inhibit motion by regulating the vectors of normal forces acting on the moving parts.
• Bearings are widely categorised according to the kind of operation, the permitted movements, or the directions of the loads (forces) applied to the components.
• Bearings are used to support spinning shafts and are categorised by the direction in which the principal load is applied.

Axial bearings are designed to handle axial thrust whereas radial bearings are constructed to sustain radial load.
Both combined



- A bearing is made up of two rings: an inner ring and an outer ring. Between them, a succession of rolling components is discovered. •
- Something (a cage) is there to hold the rolling elements in place.
- The rolling parts itself might be spherical (ball bearings) or cylinders (cylinder roller bearings).

Bearing types and characteristics

Bearings are typically grouped into two (2) groups according to the sort of contact they make between the rotating and stationary members.

Bearings With Rolling Elements

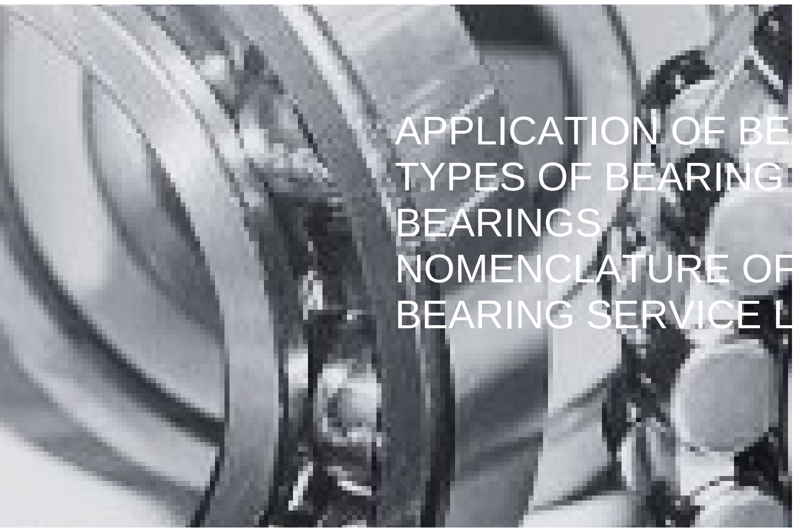
Rolling element bearings are often referred to as antifrictional bearings since they generate rolling friction rather than sliding friction like simple bearings do. A rolling element bearing is a cylinder with an interior ring of steel balls or rollers that moves.

For increased efficiency, therolling element bearings use balls or rollers. The friction created by rolling is always less than the friction created by sliding. The three fundamental kinds of rolling element bearings are as follows.

- Bearings, ball
- Ball and roller bearings.
- Needle Bearings

Different ball and roller bearing designs can accommodate radial, axial, and combined loads. Needle bearings are designed to accommodate only radial or axial loads.

- A bearing is made up of two rings: an inner ring and an outer ring. Between them, a succession of rolling components is discovered. •
- Something (a cage) is there to hold the rolling elements in place.
- The rolling parts itself might be spherical (ball bearings) or cylindrical (cylinder roller bearings).



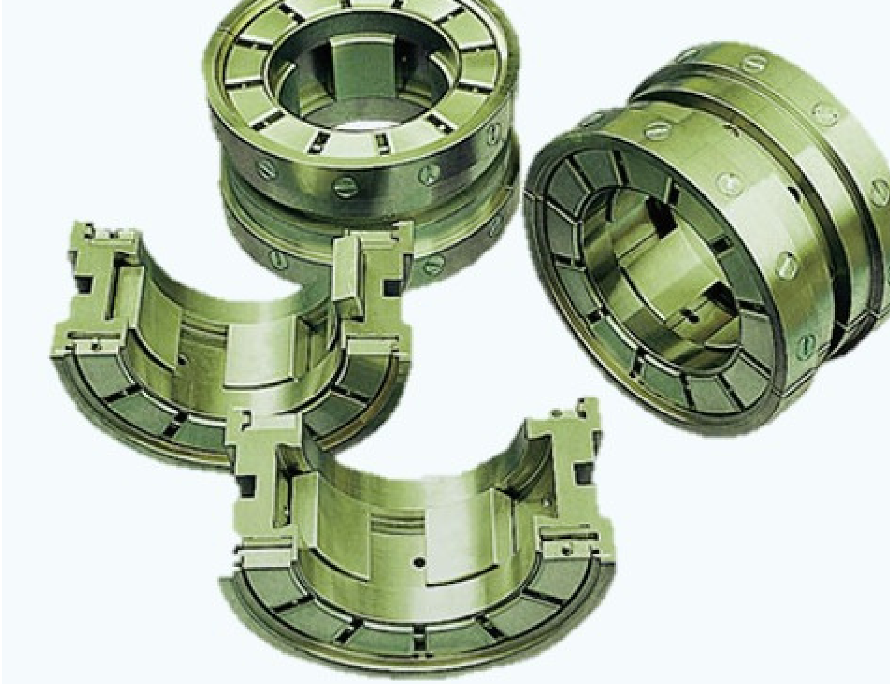
Sliding / Journal / Plain Bearings

A simple bearing is any bearing that operates by sliding rather than rolling. It might be lubricated or not. Plain bearings are sometimes known as journal bearings or sleeve bearings. Plain bearings are cylindrical in form and are intended to support radial loads. The phrases journal and sleeve are sometimes used synonymously: sleeve refers to the overall arrangement, while journal refers to the portion of the shaft in contact with the bearings. Plain bearings are also referred to as thrust bearings or thrust washers.
Plain bearings are classified into three types:

i. Class I Bearing systems are greased externally.

ii. Internal lubrication is used in Class II bearing systems.

iii. Class III Bearing systems use lubricant-free graphite, PTFE (Teflon), or plastic bearings.



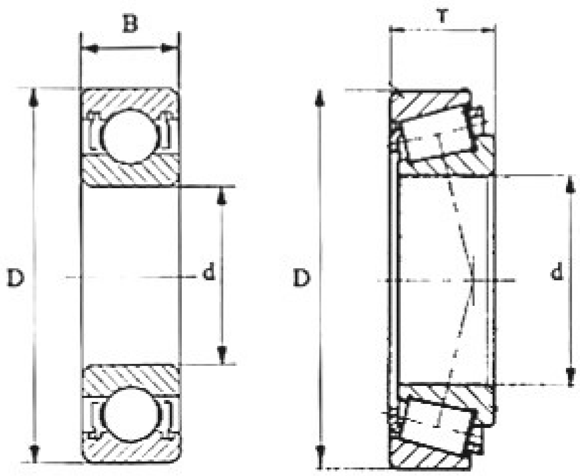
Journal Bearings

Bearing Nomenclature

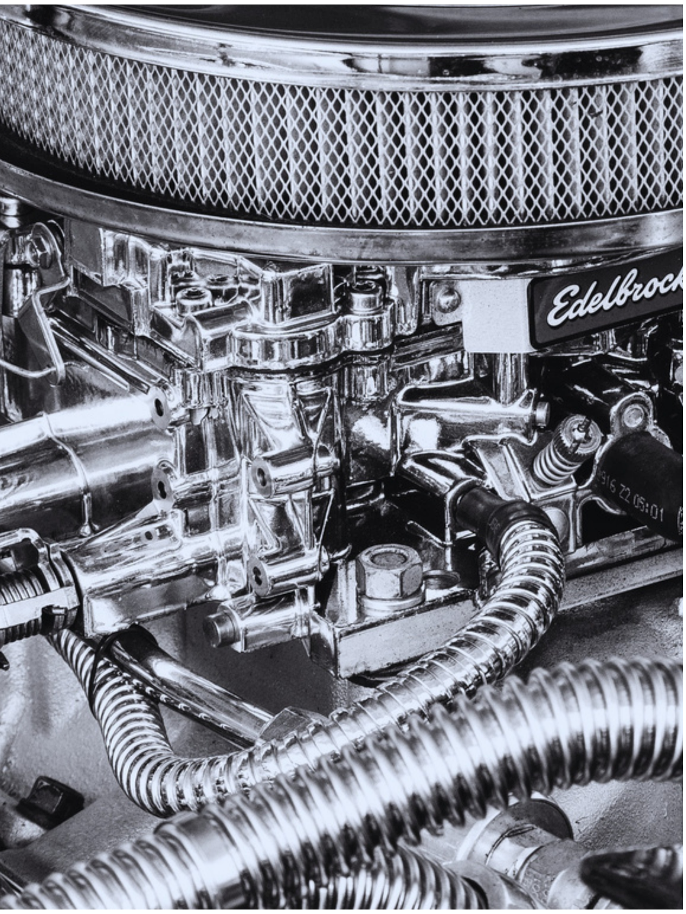
Rolling bearings are classified as radial and thrust bearings, which are designed to support radial and axial loads, respectively, and other bearing types that are designed to support both radial and axial loads. In general, ball bearings are used for mild to moderate loads, whereas roller bearings are preferred for large loads. There are nine fundamental bearings. Some of these fundamental kinds are available in a variety of configurations: for example, cylindrical roller bearings are available with one, two, or four rows of rollers.

Example : Code number of rolling bearing

Bearing Sizes



d = Inside diameter
D = Outside diameter
B/T = Width diameter

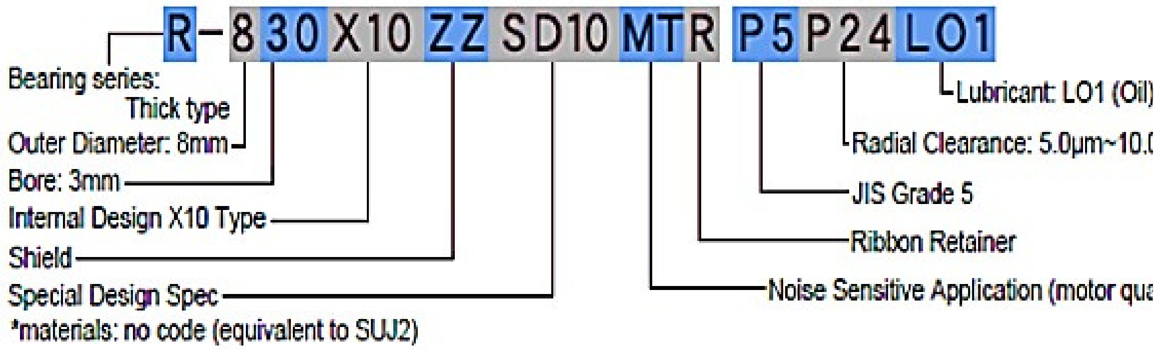


Ball bearings with a single row of deep grooves are normally available in nine distinct exterior configurations. Taper roller bearings are available in over 20 configurations. While the other basic type does not provide a wide variety of configurations, it should be noted that all kinds of rolling bearings are available in a variety of design variations and so may vary significantly in internal design depending on the manufacturer.

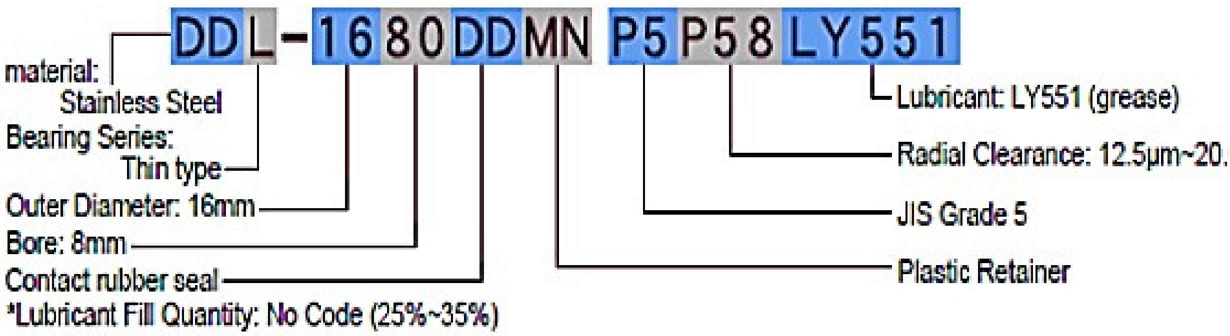
This guidebook is not intended to detail every kind of rolling bearing used in equipment; rather, it is intended to alert maintenance personnel to their presence. Details are available in the company's catalogue or by directly contacting the manufacturer.

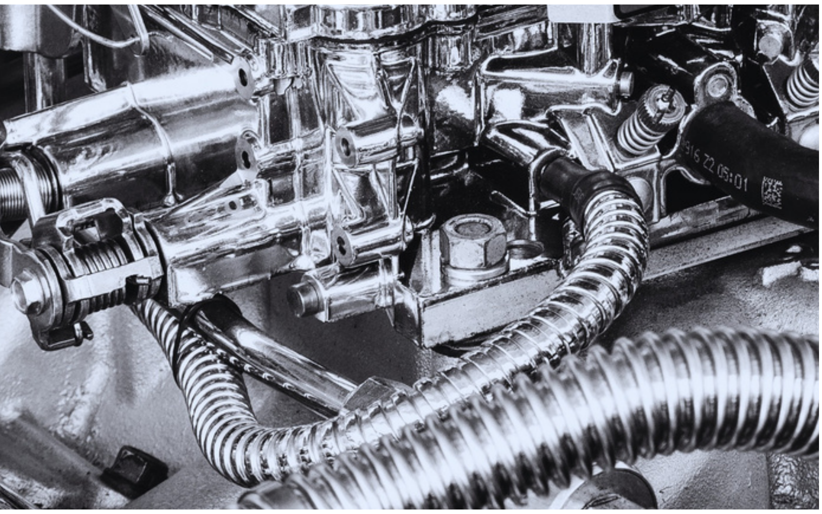
Each bearing has an inside diameter, an outer diameter, and a width diameter. The majority of bearings are metric in size, however some are imperial. Each bearing's primary dimensions are shown on our website.

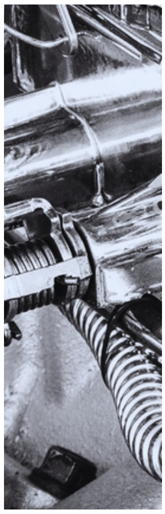
NMB part number (Example 1)

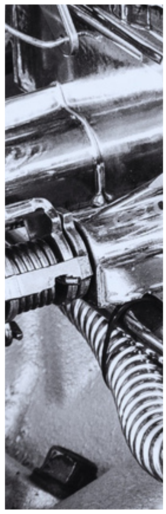


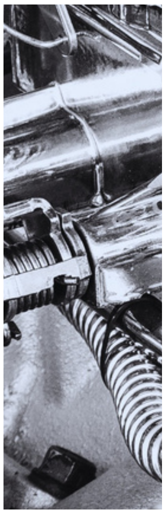
NMB part number (Example 2)











Bearing Service Life

As described in ISO and ABMA standards, basic life, or L10, is the life that 90% of a sufficiently large set of seemingly similar bearings may be anticipated to meet or surpass. The median or average life, which is commonly referred to as Mean Time Between Failure (MTBF), is about five times the computed basic rating life. The service life of a bearing is the time period during which it operates normally before failing or needing to be changed for any reason. The standard life is typically equal to the necessary L10 basic rating life and represents the manufacturer's demand based on prior experience with comparable applications.

Calculating Loads

Typically, engineers apply rolling-contact fatigue models to assess the influence of applied dynamic and static loads on bearing service life and dependability. The fundamental dynamic load rating applies to bearings that are dynamically strained and rotate under load. According to ISO 281, this rating is the bearing load that results in a basic rating life, or L10, of one million rotations. Dynamic loads should consist of a meaningful duty cycle or load spectrum, as well as any peak loads.
The basic static load rating is applicable to bearings that spin at less than 10 revolutions per minute, oscillate slowly, or stay stationary under load for extended periods of time. Include stresses of very brief duration (shock) since they might distort contact surfaces plastically and jeopardise bearing integrity.

Typically, basic catalogue or simplified calculations exclude elastic deformations in the bearing, housing, or machine frame, as well as moments generated in the bearing due to shaft deflection. These calculations may be made assuming constant magnitude and direction loads acting radially on a radial bearing or axially and centrically on a thrust bearing. Bearings in real service often encounter simultaneous radial and axial loads. When the sum of the radial and axial loads is constant in magnitude and direction, the equivalent dynamic bearing load is calculated as $P = XFr + YFa$, where P equals the equivalent dynamic bearing load in pounds; Fr equals the actual radial bearing load in pounds; Fa equals the actual axial bearing load in pounds; X equals the radial load factor for the bearing; and Y equals the axial load factor for the bearing.

Axial load has an effect on P only when the ratio Fa / Fr surpasses a particular limiting value for single-row radial bearings. For double-row radial bearings, even modest axial stresses are considerable. The above equation also holds true for spherical thrust bearings and other kinds of thrust bearings that can accommodate both axial and radial stresses. Consult manufacturer catalogues before purchasing axial-radial thrust bearings, since designs might vary significantly. The equation simplifies to $P = Fa$ for thrust ball bearings and other kinds that carry pure axial loads, assuming the load works centrically.

Rating Life Equations

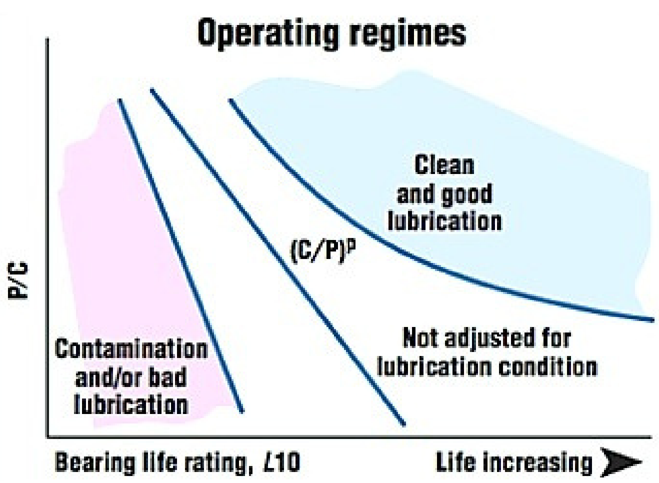
The ISO 281 or American Bearing Manufacturers Association (ABMA) Standards 9 and 11 equations calculate the basic, unadjusted rating life as follows:

L10 = (C / P)p in millions of rotations, where C is the basic dynamic load rating in pounds, P is the corresponding dynamic bearing load in pounds, and p is the life equation exponent (p = 3 for ball bearings and p = 10/3 for roller bearings).

For constant-speed bearings, it may be more practical to state the basic rating life in operation hours:

L10h = (1,000,000/60)nL10, where n is the rotating speed in revolutions per minute (rpm). Predicted bearing life is a statistical number in the sense that it is based on a bearing population and a certain degree of dependability.

The basic rating life is related with a 90% dependability of bearings manufactured using current production techniques and high-quality materials and operated under typical operating circumstances. In actuality, anticipated life may vary greatly from actual service life, up to roughly a factor of five in certain reported situations.



Service life is a realistic representation of bearing life under real-world situations, when field failures might be caused by factors other than bearing strain. Contamination, wear, misalignment, corrosion, mounting damage, insufficient lubrication, or improper sealing systems are all examples of underlying causes.

Bearing technology and manufacturing techniques continue to progress, extending bearing life and reducing susceptibility to extreme operating conditions. ISO 281 has evolved in lockstep with these advancements to improve the accuracy of service life predictions. The most recent version includes fatigue stress limitations for bearing materials and a factor for the influence of solid contamination on bearing life when utilising different lubrication methods such as grease, circulating oil, and oil bath.

The equation Lnm= a1aISOL10 calculates the modified rating life at n percent reliability in millions of revolutions at constant speed as follows: Lnm= a1aISOL10 where a1 is the life-adjustment factor for reliability (1.0 for 90 percent reliability); and an ISO is the manufacturer's life modification factor as defined in ISO 281.
ISO 4406 requires the use of a contamination factor that takes into account the lubrication system type, cleanliness class, bearing size, and lubrication working circumstances. Together with the ratio of the bearing fatigue load limit to the bearing equivalent load limit and the lubrication state, this contamination factor determines the ISO. By and large, improved lubrication conditions and reduced equivalent loads reduce the vulnerability of bearing life to contamination levels.

On the other hand, excessive loads and poor lubrication conditions increase the susceptibility of bearings to contamination.

FRICTION TEMPERATURE AND LUBRICATION

Friction in Bearing Systems
Relation between operating temperature with bearing friction
Principle of bearing lubrication

Friction

Low friction is one of the most important characteristics of a bearing. Rolling bearings, especially beginning friction, have a substantially lower friction coefficient than sliding bearings under typical working circumstances.

The dynamic friction coefficient for rolling bearings varies depending on the bearing type. Under typical operating circumstances, the estimated load, lubrication, speed, and other considerations

Temperature rise

Almost all friction loss in a bearing are converted to heat and causes the bearing's temperature to rise. The quantity of heat generated by the bearing and the amount of heat transmitted away from the bearing determines the bearing's operating temperature. In most circumstances, the temperature rises quickly during startup, then gradually climbs until it reaches a steady level, after which it remains constant. The quantity of heat produced, the heat capacity/diffusion of the shaft and bearing housing, the amount of lubricant used, and the type of lubrication all influence how long it takes to achieve this stable condition.

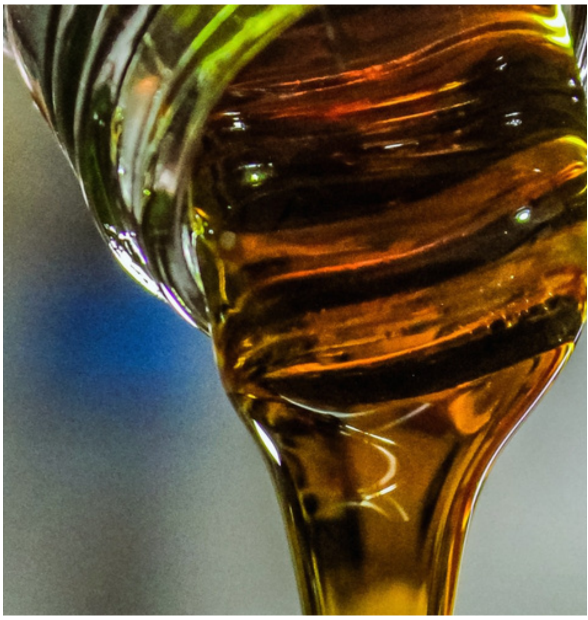
Bearing misalignment (due to moment load or faulty installation), inadequate internal clearance, excessive preload, too much or too little lubrication, or heat created by sealed components are all possible reasons of abnormal temperature. Examine the mechanical apparatus and, if required, remove and examine the bearing.

Introduction

Many bearings need to be serviced on a regular basis to avoid early failure, however certain bearings, such as fluid or magnetic bearings, may only need to be serviced once in a while.

Most bearings in high-cycle activities need to be lubricated and cleaned on a regular basis, and they may need to be adjusted to reduce wear.

When a bearing is maintained clean and adequately greased, it may last considerably longer. Many uses, however, make proper maintenance challenging. Bearings in a rock crusher's conveyor, for example, are constantly subjected to harsh abrasive particles. Cleaning is ineffective since it is costly, and the bearing becomes polluted again as soon as the conveyor is restarted.



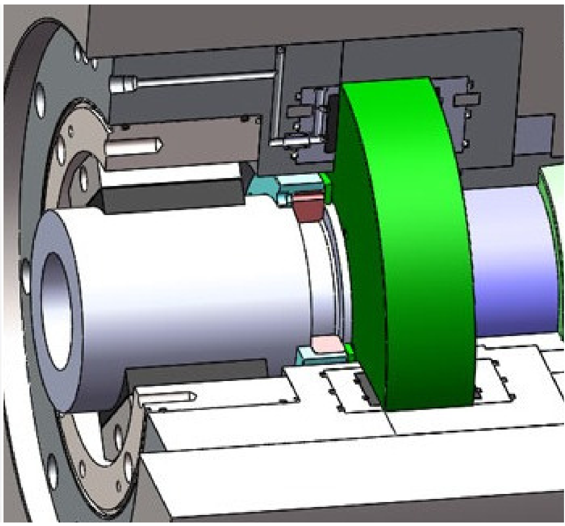
Packing

For lubrication, some bearings employ a thick grease that is forced into the spaces between the bearing surfaces, a process called as packing. A plastic, leather, or rubber gasket (also known as a gland) keeps the grease in place by covering the inner and outer edges of the bearing race to prevent it from escaping.

Other materials may be used to pack bearings. Historically, train carriages' wheels were equipped with sleeve bearings filled with waste or loose scraps of cotton or wool fibre saturated in oil, which were eventually replaced with solid cotton pads.

Ring oiler

A metal ring that sits loosely on the bearing's central spinning shaft might be used to grease it. The ring drops into a chamber filled with lubricating oil. Oil is drawn up the ring and onto the shaft by viscous adhesion as the bearing spins, and the oil migrates into the bearing to lubricate it. Excess oil is thrown away and gathered in the pool once again.

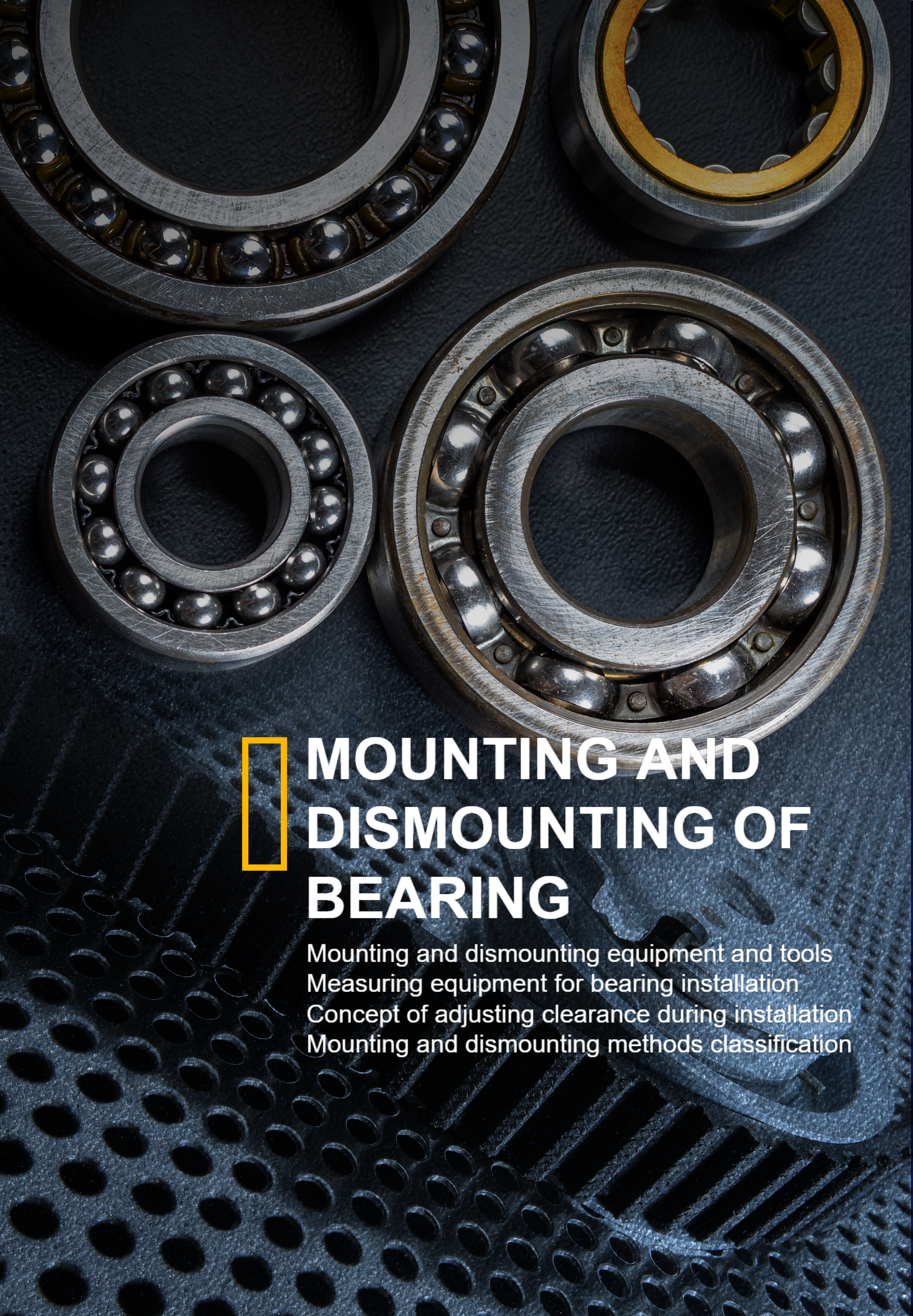


Splash lubrication

Some machines include a lubricant pool at the bottom, with gears partially submerged in the liquid or crank rods that may swing down into the pool while the machine is running. The spinning wheels blast oil into the air surrounding them, and the crank rods smack at the oil's surface, spraying it all over the engine's inner surfaces. Some tiny internal combustion engines include unique plastic flinger wheels that distribute oil about the inside of the mechanism at random.

Pressure lubrication

A lack of lubrication can cause fast bearing heating and breakage due to friction in high-speed and high-power machinery. In filthy surroundings, the oil can also become polluted with dust or particles, causing friction to rise. A constant supply of lubricant may be sent to the bearing and all other contact surfaces in these applications, and the surplus can be collected for filtering, cooling, and perhaps reuse. In big and complicated internal combustion engines, pressure oiling is widely employed in portions of the engine where direct splashing oil cannot reach, such as up into overhead valve assemblies. High-speed turbochargers often require a pressurised oil system to keep the bearings cold and prevent them from overheating owing to the turbine's heat.



MOUNTING AND DISMOUNTING OF BEARING

Mounting and dismounting equipment and tools
Measuring equipment for bearing installation
Concept of adjusting clearance during installation
Mounting and dismounting methods classification

Introduction

Mounting and installation of a bearing depends on the type and its fitting practice. The procedures covered are concerned with the proper methods and tools to accomplish installation of pressed fitted bearing rings. Even though some of the tools and procedures used for mounting a non-separable bearing are the same as those used for separable bearings, the methods covered here are specifically for non-separable bearings. If application requirements call for periodic inspections that require mounting and dismounting of the bearings, the ease and methods required for these bearing procedures should be a bearing selection consideration. Bearing mounting and removal is simplified by the use of bearings that have separable races. Bearings such as cylindrical roller bearings, needle roller bearings, and tapered roller bearings have separable races and should be considered for applications requiring frequent inspections and removal of the bearings.

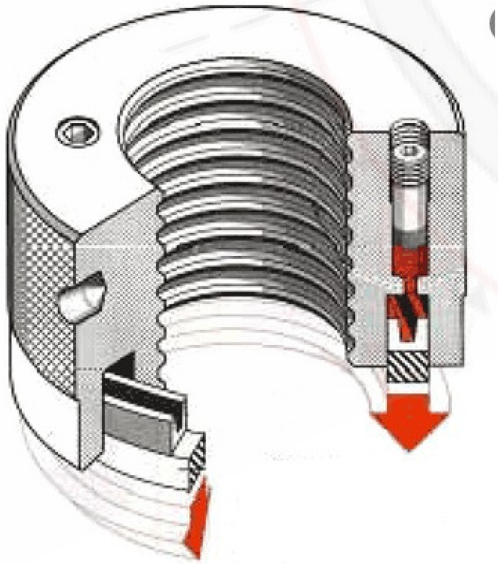
Since bearings with interference fits can be easily damaged during removal, precautions to prevent damage during removal should be taken. Of course, if a bearing is to be discarded, methods such as torch cutting can be used for bearing removal. If the bearing is to be reused or checked for causes of damage, care needs to be taken during removal. To ease removal and avoid damage to the bearing, the proper tools and methods need to be employed.

MOUNTING AND DISMOUNTING EQUIPMENTS AND TOOLS.

Premature bearing failures are caused by poor fitting, usually using brute force, and being unaware of the availability of the correct mounting tools and methods. Individual installations may require mechanical, heat or hydraulic application methods for correct and efficient mounting. Professional fitting, using specialized tools and techniques, is another positive step towards achieving maximum machine uptime. Reliability variety of bearing installation and removal tools, hydraulic and manual jaw pullers, bearing heaters, etc.

Mounting and Dismounting

Air Driven Hydraulic Pump



Thread Hydraulic Nut

Dismounting

standard jaw puller

Induction Heater

Measuring equipment for bearing installation

Waviness, roundness and form analyzer

Waviness on the bearing components can cause high vibration levels in most applications. As the amplitude of these waves is as small as some nanometers, you can understand the importance of measuring accuracy and resolution. Waviness testers allow analysis of the waviness on the components and thus give the production engineer a powerful tool to improve the production process. Because low noise and vibration of bearings is becoming more important, there is a high demand on the measuring accuracy and resolution.

i. Rotational measuring system with top concentricity precision, with electronics and mechanics combined to perfection
ii. Air-bearing spindle with run out better than 0,02 μm and velocity-proportional evaluation gives you direct indication of the waviness level of the component
iii. The calibration of this equipment is also very important and is performed to an excellent standard.

Measuring equipment for bearing installation

Noise and vibration tester

A noisy application might be caused by wavy bearing components, local defects in the rings and balls or by dirt particles in the bearing. While basic requirements on a bearing like stiffness, load capacity, speed limit and service life play a critical role in applications, low noise and vibration are becoming even more important. High tech analysis and measurement such as frequency analysis (FFT) and further advanced analysis pinpoints faults. Spectral masks help to optimize the bearing performance in the particular application.

Measuring equipment for bearing installation

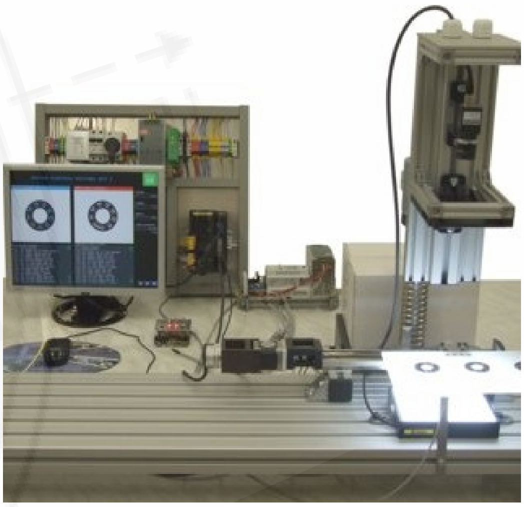
Dimension measuring machines

Stricter process requirements cause tighter tolerances and higher output, resulting in high demands on the measuring machine capability and time pressure when resetting measuring equipment. In many cases, the resetting time of the measuring machines already bottlenecks the process where there is still a need for thousands of master parts. As documented on high precision automation technology, full in-line production control, with minimized resetting times and closed loop post process features, reduce costs and give you flexibility.

Measuring equipment for bearing installation

Optical inspection

SKF provides products and solutions for a wide variety of optical measurement and optical inspection applications related to bearing manufacture. Primarily for rotation symmetric components, such as balls, rollers, rings and bearings, industrial optical inspection equipment from SKF keeps costs to a minimum while maximizing your application. In optical systems, the following basic physical principle is involved: "The appearance of the product is different to what we have decided to be acceptable." That appearance is dependent on three factors: i. condition of the object - colour, roughness, etc. ii. nature of the illumination - white light, coloured light, laser light, etc. iii. properties of the sensors - matrix camera, line camera, single photo-detector, etc.



Measuring equipment for bearing installation

Non destructive testing

The thorough inspection of components is a way to check that each component is defect free, or complies with certain quality requirements to retain their usability. The various NDT techniques include:

i. ultrasonic inspection
ii. Eddy current testing
iii. magnetic particle inspection
iv. resonant inspection

Measuring equipment for bearing installation

Gauges for bearing mounting

When checking features such as tapered seatings, roller set bores or outside diameters of cylindrical roller bearings, conventional measuring methods and instruments are not always suitable. This gauge is specially designed to meet the measuring needs of cylindrical roller bearings with a tapered bore. These gauges are also useful for other applications. Ring gauges can be used to check the most common tapered seatings. Measurements can be made quickly and accurately. While a ring gauge can be used only to check a tapered seating for a particular bearing size, the taper gauges can be used for a range of diameters. To precisely adjust the radial internal clearance or preload when mounting cylindrical roller bearings with tapered bores, it is necessary to accurately measure the roller set bore or outside diameter.

Concept of adjusting clearance during installation.

Selecting the correct bearing internal clearance and determining whether preload is needed for a particular application is critical to obtaining the desired bearing performance.

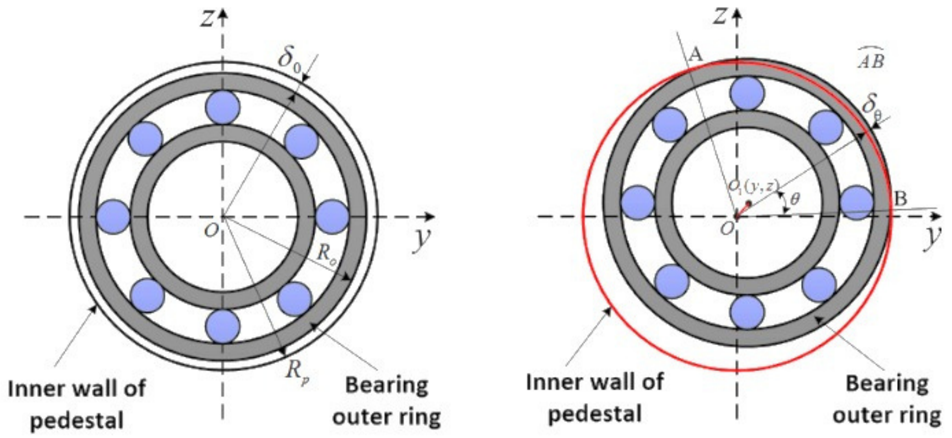
Description of Internal Clearances

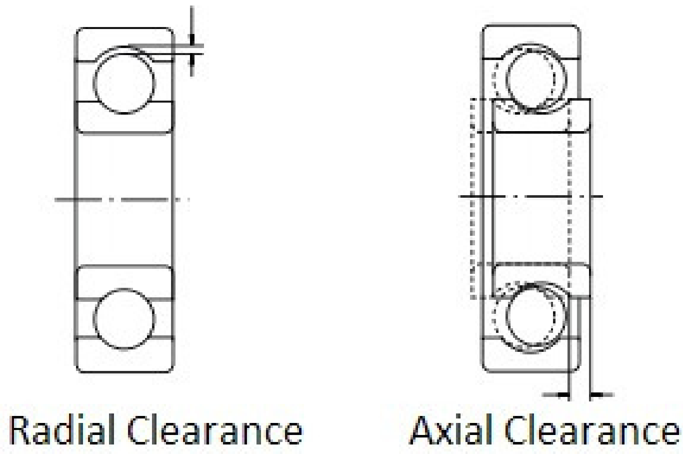
Bearing internal clearance is described as being either radial or axial and is the total distance that either the inner or outer ring can be moved in the radial or axial direction while the other ring is held stationary. With only a few exceptions, bearing internal clearance is normally discussed in terms of radial clearance. Matched pairs of angular contact ball bearings are specified in terms of axial internal clearance. Also, when two single row tapered roller bearings are setup opposing each other, the clearance value between the rows is an axial measurement.

Clearance prior to mounting is generally referred to as the original clearance. This initial clearance value is what is provided in the bearing at the time of shipment. After the bearing is fitted on a shaft and into housing, the original clearance is reduced due to contraction or expansion of the rings and is called the residual clearance or mounted clearance. Effective clearance is the residual clearance after taking into account changes from temperature differentials within the bearing.

Operating clearance is defined as the effective clearance with the additional effect of elastic deformations from application loading. Successful bearing performance depends on having the appropriate “operating clearance” to avoid premature bearing damage and reduced fatigue life.

Concept of adjusting clearance during installation.





internal clearance gauges for cylindrical roller bearings

Concept of adjusting clearance during installation.

Fit Selection Considerations

As previously pointed out, there are other operating conditions to consider in addition for knowing which ring will be rotating when trying to determine the proper fits to use. The operating conditions that should be considered when determining bearing ring fits are the following:

i. Load characteristics
ii. Load magnitude
iii. Temperature effects
iv. Effect on bearing internal clearances
v. Finish of mating surface
vi. Shaft and housing material & section thickness
vii. Mounting design and fixed and float considerations
viii. Bearing type and size

Mounting methods classification.

Introduction

Proper installations of bearing such as a substantial impact shorten its lifecycle. With proper installation of bearing it can significantly extends its life of which is a positive impact on maintenance costs. Incorrect installation can cause damages to the bearing and an early failure. Incorrect adaption for the assembly can cause excessive wear and early damage.

To avoid the above mentioned problems it is very important to select appropriate method and proper manner bearing assembly.

Mechanical Installation

Mechanical or cold mounting is suitable for small to medium-sized bearings. Use appropriate tools to prevent damage to bearings, other components and not the least injury to people.

Installation using heating

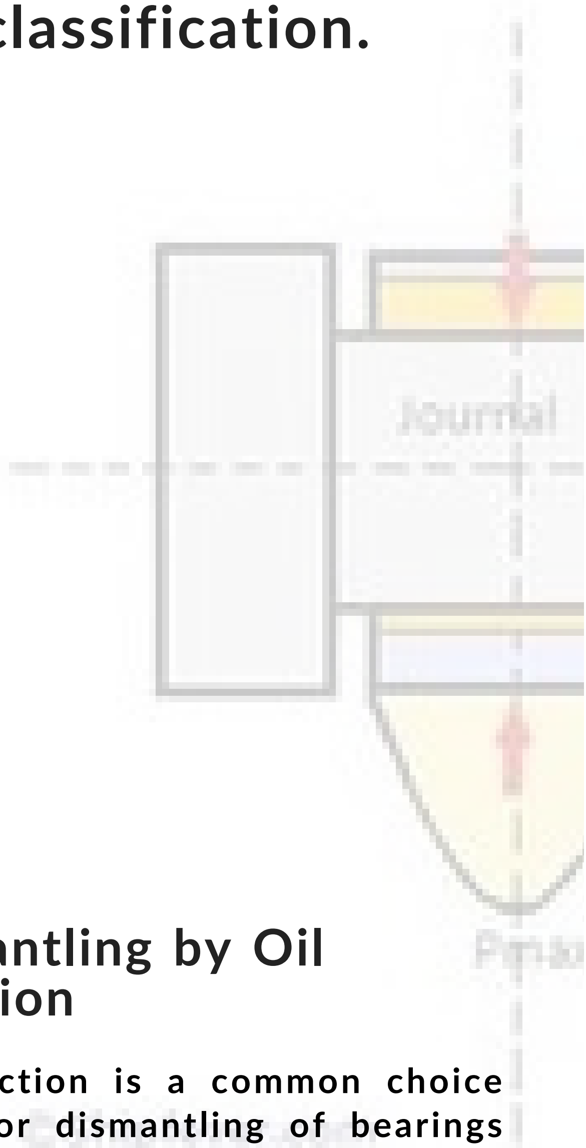
Installation by using heating means based on the induction and it is used in medium and large bearings. By increasing the size of bearings also increase the force required for assembly of the bearing. Due to the size of force are larger the bearings will be very difficult to push the shaft or casing. Pre- heating of the bearing or casing before installation will extremely simplify the job. In assembly with heated bearing to a temperature that is 80 to 90 ° C above the temperature of the shaft, from which the bearing can be mounted easily

Installation using hydraulic

In this method, there is minimal risk of damage to be bearing, shaft and other components. Despite the size and weight of the bearing requires very little effort which is required for installation, while providing a safe working environment without significant risk injury to employees. Principle of the hydraulic assembly technique consists of injecting the thin layer of oil between the bearings and shaft, which greatly reduces friction and allows the bearing assembly with the minimum necessary force. The method is not only useful for bearings, but also in other mechanical components, which the classic method of assembly would have been rather problematic.

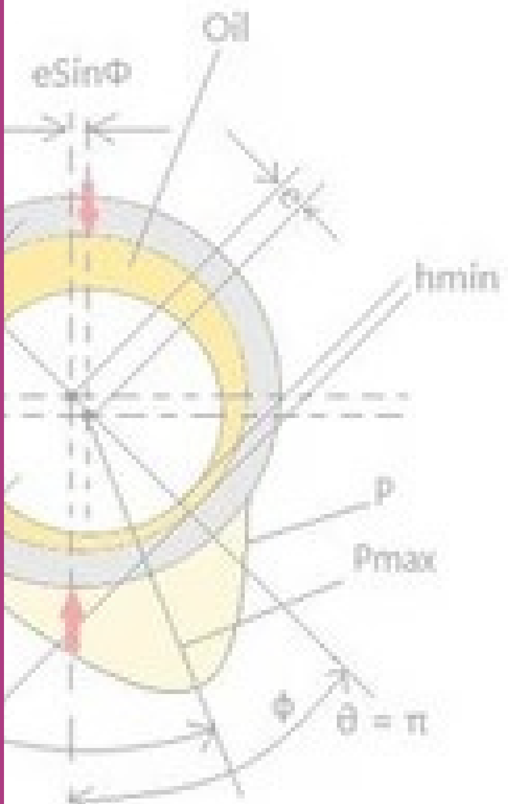
Dismounting methods classification.

Dismounting with Heat



Dismantling with heat is mainly suitable for bearings with close fitting. The use of mechanical downloads could damage the shaft or bearing rings in this case, it requires more power. By using special heaters it will significantly are significantly easier to dismantle and reduce the chance of damage to components and body injury. The heaters for dismantling are basically divided into:

i. heated rings
ii. induction heaters.



Dismantling by Oil Injection

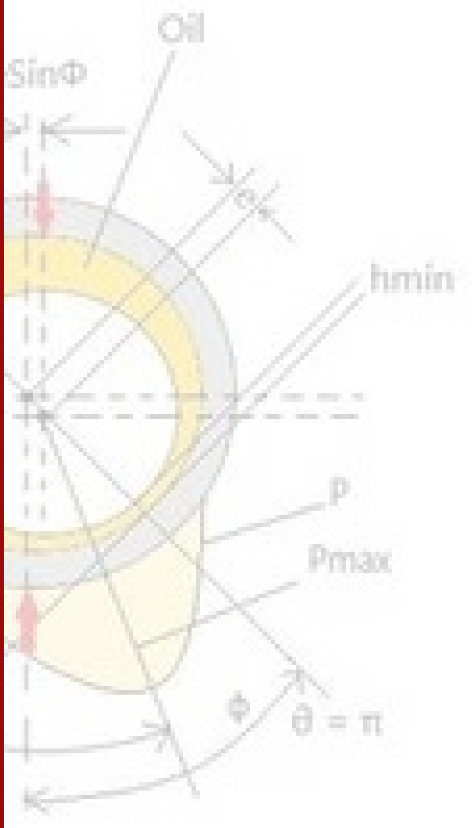
Oil injection is a common choice for major dismantling of bearings and other components. Allows disassembly with a substantially lower power and significantly reduce of possibility of damaging bearing, shaft and grounding. The basic principle of the method is injecting oil down with a certain viscosity between two surfaces, while between them the pressure generated by the oil film will separate them. This method can reduce the necessary force to dismantle the casing up to 90%.

ANALYZE BEARING DAMAGE

Bearing damage and failure symptoms
Observations for preventive maintenance
Bearing maintenance procedure

Introduction

When a bearing is used under ideal conditions, it should meet or exceed its predicted service life and will eventually be damaged by rolling fatigue. Damage from rolling fatigue can occur prematurely if operating conditions are severe or the wrong bearing was selected for the application. However, as indicated by the following statements, the majority of premature bearing failures are caused by improper lubrication, bearing mounting and handling issues. If damage is found on a bearing during inspection, it is important to document the bearing's operation history properly to identify the causes, even if the damage is very small. Also, it is essential to examine not only the bearing but also the shaft, housing and lubricant.



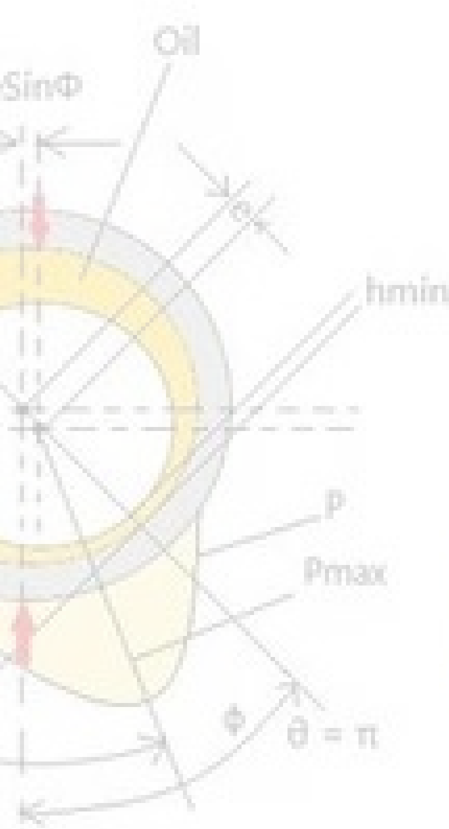
Bearing damage and failure symptoms.

Since there are many different failure modes and damage bearings will exhibit, the following pages will review these and cover possible causes and preventive measures that can be taken.

Bearing damage and failure symptoms.

Flaking

Flaking is damage where material is removed in flakes from a surface layer of the bearing raceways or rolling elements due to rolling fatigue. This failure mode is generally attributed to the approaching end of bearing service life. However, if flaking occurs at early stages of bearing service life, it is necessary to determine causes and adopt preventive measures.



Cracking, Chipping

Usually referred to as spalling is a fracture of the running surfaces and subsequent removal of small discrete particles of material

Chipping

Cracking

Bearing damage and failure symptoms.

Brinelling, Nicks

Brinelling is a small surface indentation generated either on the raceway through plastic deformation at the contact point between the raceway and rolling elements, or on the rolling surfaces from insertion of foreign matter, when heavy load is applied while the bearing is stationary or rotating at a low rotation speed. Nicks are those indentations produced directly by rough handling as hammering.

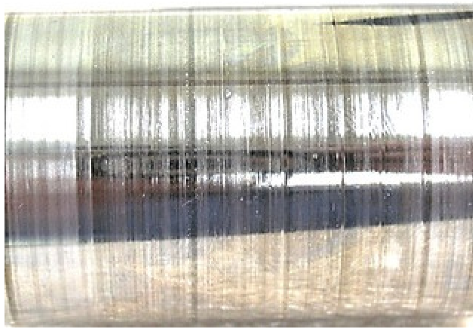
Pear Skin, Discoloration

Pear skin is damage in which minute Brinell marks cover the entire rolling surface, caused by contamination. This is characterized by loss of lustre and a rolling surface that is rough in appearance. In extreme cases, it is accompanied by discoloration due to heat generation. This phenomenon is also commonly called frosting. Discoloration is damage in which the surface colour changes because of staining or heat generation during rotation. Colour change caused by rust and corrosion is generally separated from this phenomenon.

Bearing damage and failure symptoms.

Scratch & Scuffing

Scratches are relatively shallow marks generated by sliding contact, in the same direction as the sliding. This is not accompanied by apparent melting of material. Scuffing refers to surface marks, which are partially melted due to higher contact pressure and therefore a greater heat effect. Generally, scuffing may be regarded as an advanced case of scratches.



Smearing

Smearing is damage in which clusters of minute seizures cover the rolling contact surface. Since smearing is caused by high temperature due to friction, the surface of the material usually melts partially; and the smeared surfaces appear very rough in many cases.

Bearing damage and failure symptoms.

Rust, Corrosion

Rust is a film of oxides, or hydroxides, or carbonates formed on a metal surface due to chemical reaction. Corrosion is damage in which a metal surface is eroded by acid or alkali solutions through a chemical reaction (electrochemical reaction such as chemical combination and battery formation); resulting in oxidation. It often occurs when sulfur or chloride contained in the lubricant additives is dissolved at high temperature. It can also occur when water becomes entrapped in the lubricant.

Wear

Normally, wear on bearings is observed on sliding contact surfaces such as roller end faces and rib faces, cage pockets, and cage riding lands. However, wear caused by foreign material and corrosion can affect not only sliding surfaces but also rolling surfaces.

Bearing damage and failure symptoms.

Fretting

Fretting occurs to bearings that are subjected to vibration while in a stationary condition or which are exposed to slight axial movements. It is characterized by rustcolored wear particles. Fretting damage on the rotating ring is usually a clear indication of an improper fit. Since fretting on the raceways often appears similar to brinelling, it is sometimes called “false brinelling”.

Cage Damage

Since cages are made of low hardness materials, external pressure and contact with other parts can easily produce dents and distortion. In some cases, these are aggravated and become chipped and cracked. Large chipping and cracks are often accompanied by deformation, which may reduce the accuracy of the cage itself and may prevent the smooth movement of rolling elements. Also, if cage damage is observed, the bearing raceways should be examined for misalignment, as even minor misalignment can cause cage breakage.

Bearing damage and failure symptoms.

Creeping

Creeping is a phenomenon in which bearing rings move relative to the shaft or housing during operation.

Seizure

Seizure is damage caused by excessive heating in bearings.

Observations for preventive maintenance

Flaking

DAMAGE	Possible Causes	Preventive Measures
Flaking occurring at an initial stage	• Too small internal clearance • Improper or insufficient lubricant • Excessive loading • Rust	• Provide proper internal clearance. • Select proper lubricating method or lubricant.
Flaking on one side of radial bearing raceway	• An excessively large axial load	• Fitting between outer ring on the free side and housing should be changed to clearance fit.
Symmetrical flaking along circumference of raceway	• Inaccurate housing roundness	• Correct machining accuracy of housing bore. (Especially for split housings, care should be taken to ensure machining accuracy.)
Slanted flaking on the radial ball bearing raceway Flaking occurring near the edge of the raceway or rolling contact surface of roller bearings	• Improper mounting • Shaft deflection • Misalignment of the shaft and housing	• Correct centering. • Widen bearing internal clearance. • Correct squareness of shaft or housing shoulder.
Flaking on the raceway surface at the same interval as rolling element spacing	• Heavy impact load during mounting • Damage on a cylindrical roller bearing or tapered roller bearing caused when they are mounted. • Rust gathered while out of operation.	• Improve mounting procedure. • Provide rust prevention treatment before long cessation of operation.

Observations for preventive maintenance

Cracking, Chipping

DAMAGE	Possible Causes	Preventive Measures
Cracking in outer ring or inner ring	• Excessive interference. • Excessive fillet on shaft or housing. • Heavy impact load. • Advanced flaking or seizure	• Select proper fit. • Adjust fillet on the shaft or in the housing to smaller than that of the bearing chamfer dimension. • Re-examine load conditions.
Cracking on rolling elements	• Heavy impact load. • Advanced flaking.	• Improve mounting and handling procedure. • Re-examine load conditions.
Cracking on the rib	• Impact on rib during mounting. • Excessive axial impact load.	Improve mounting procedure. Re-examine load conditions.

Brinelling, Nicks

DAMAGE	Possible Causes	Preventive Measures
Brinelling on the raceway or rolling contact surface	• Entry of foreign matter	• Clean bearing and it's peripheral parts. • Improve sealing devices.
Brinelling on the raceway surface at the same interval as the rolling element spacing	• Impact load during mounting. • Excessive load applied while bearing is stationary.	• Change mounting procedure. • Improve machine handling.
Nicks on the raceway or rolling contact surface	• Careless handling.	• Improve mounting and handling procedure.

Observations for preventive maintenance

Pear Skin, Discoloration

DAMAGE	Possible Causes	Preventive Measures
Indentation similar to pear skin on the raceway and rolling contact surface.	• Entry of minute foreign matter	• Clean the bearing and its surrounding parts. • Improve sealing device.
Discoloration of the raceway, surface rolling contact surface, rib face, and cage riding land.	• Too small bearing internal clearance. • Improper or insufficient lubricant. • Deterioration of lubricant due to aging, etc.	• Provide proper internal clearance. • Select proper lubricating method , • amount and lubricant type.

Scratch & Scuffing

DAMAGE	Possible Causes	Preventive Measures
Scratches on raceway or rolling contact surface	• Insufficient lubricant during start-up. • Careless handling.	• Apply lubricant to the raceway and rolling contact surface when mounting. • Improve mounting procedure.
Scuffing on rib face and roller end face	• Improper or insufficient lubricant. • Improper mounting. • Excessive axial load.	• Select proper lubricating method or lubricant. • Correct centering of axial direction.

Observations for preventive maintenance

Smearing

DAMAGE	Possible Causes	Preventive Measures
Smearing on raceway or rolling contact surface	• Improper or insufficient lubricant. • Slipping of the rolling elements This occurs due to the break down of lubricant film when an abnormal self-rotation causes slip of the rolling elements on the raceway.	• Select proper lubricating method or lubricant. • Provide proper preload.

Rust, Corrosion

DAMAGE	Possible Causes	Preventive Measures
Rust partially or completely covering the bearing surface.	• Improper storage condition. • Condensation in atmosphere.	• Bearing should be stored in dry area. • Improve sealing devices. • Provide a preservative oil treatment before long cessation of operation.
Rust and corrosion at the same interval as rolling element spacing.	• Contamination by water or corrosive matter	• Improve sealing devices.

Observations for preventive maintenance

Wear

DAMAGE	Possible Causes	Preventive Measures
Wear on the contact surfaces (roller end faces, rib faces, cage pockets)	• Improper or insufficient lubricant	• Select proper lubricating method or lubricant. • Improve sealing device. • Clean the bearing and surrounding application component parts and housing.
Wear on raceways and rolling contact surfaces	• Entry of contaminants. • Improper or insufficient lubricant.	

Fretting

DAMAGE	Possible Causes	Preventive Measures
Rust-colored wear particles generated on the fitting surface (fretting corrosion)	• Insufficient interference fit	• Provide greater interference fit. • Apply lubricant to the fitting surfaces.
Brinelling on the raceway surface at the same interval as rolling element spacing (false brinelling)	• Vibration and oscillation when bearings are stationary.	• Improve fixing method of the shaft and housing. • Provide means to insulate machine from vibrations and movement. • Provide preload to bearing.

Observations for preventive maintenance

Creeping

DAMAGE	Possible Causes	Preventive Measures
Wear, discoloration and scuffing, caused by slipping on the fitting surfaces	• Insufficient interference fit. • Insufficient tightening of sleeve.	• Provide greater interference fit. • Proper tightening of sleeve.

Cage Damage

DAMAGE	Possible Causes	Preventive Measures
Flaws, distortion, chipping, cracking and excessive wear in cages. Loose or damaged rivets.	• Considerable vibration, impact loading. • Improper or insufficient lubricant. • Improper mounting (misalignment). • Dents made during mounting. • Rapid acceleration and very high speeds .	• Re-examine load conditions. • Select proper lubricating method or lubricant. • Minimize mounting deviations and clearances. • Re-examine cage types. • Improve mounting.

Seizure

DAMAGE	Possible Causes	Preventive Measures
Discoloration, distortion and melting together of bearing components	• Too small internal clearance. • Improper or insufficient lubricant. • Excessive load.	• Provide proper internal clearance. • Select proper lubricating method or lubricant. • Re-examine bearing type. • review maintenance & re-lubrication schedule.

Bearing maintenance procedure

For properly identifying the cause of bearing damage in an application, the following procedure and investigation are recommended:

- Review service and maintenance records and any other previous data from bearing monitoring equipment.
- Prior to bearing removal and inspection, a final noise and temperature check should be performed and recorded.
- Create a sheet for documenting bearing and application inspection observations that should include pertinent photos.
- Lubricant samples should be taken from bearings and surrounding areas including housing and seals.
- A sample of new unused bearing lubricant should also be collected.
- When the bearing is removed from the equipment, step 5 shown in the 'bearing removal methods' section of this book should be followed.
- If the bearing must be removed from the shaft by pulling on the outer ring, mark position of the balls on the inner ring so that the damage that is caused during disassembly can be identified and not mistakenly attributed to an assembly problem.
- The machine components surrounding the bearings such as backing shoulders, locknuts, and any sealing devices need to be inspected for damage and wear and then documented on the inspection sheet.
- The shaft and housing should be measured for bore and OD sizes, roundness and taper.
- After the bearing has been removed and cleaned, all markings and part numbers should be recorded.
- If a bearing is to be returned to the manufacturer for analysis, do not clean the lubricant from the bearing.
- The general condition of the bearing should be noted and recorded, with specific attention to the condition of the rolling elements and raceways.
- If further analysis of the bearing damage is required or a metallurgical check may be needed, a preservative oil should be applied to the bearing prior to repackaging and shipment.

QUESTIONS TO DISCUSS

Which of the recommended responses (there may be more than one, or none) is correct? Are you able to provide additional and/or better responses?

1. Preloading is the procedure of loading a bearing to seat it and then unloading it before putting it into service:

True or false

2. Preload is commonly achieved by imparting a percentage of the bearing's maximum load when it is placed, with a mechanism that maintains the preload over the bearing's lifetime:

True or false

3. Preload is frequently achieved by rubbing one set of bearings against the other:

True or false

4. By utilising a soft spring to load one set of bearings against another, preload can be maintained more consistently, even when temperature changes:

True or false

5. In order to achieve the best performance, bearings must always be preloaded in some way:

True or false

6. Bearings preloaded with a soft spring have a low stiffness in the spring's direction:

True or false

7. Simple stiffness and friction torque models can assist a designer in making an informed decision about the bearing to use:

True or false

8. To avoid binding, sliding contact bearings should always be constructed with clearance:

True or false

9. To save money, sliding contact bearings should be used for linear and rotary motion whenever possible:

True or false

10. Sliding contact bearings can often provide appropriate load capacity and motion precision, thus ball bearings are not always the ideal option:

True or false

11. If the preload implies the spring constant is much lower than the major load support path, sliding contact bearings can be preloaded:

True or false

12. Jewel bearings are mostly found in watches and jewellery, with a few exceptions in machinery and instruments:

True or false

13. Preloaded rolling element rotary motion bearings can handle impact loads better:

True or false

14. Thermocentric designs balance the thermal expansion of several parts in order to maintain a near-constant preload:

True or false

15. The lines of action through the bearing contact areas connect at positions far distant from the centre of stiffness in a back-to-back configuration of bearings:

True or false

16. A bearing configuration with back-to-back bearings offers a high degree of angular stiffness:

True or false

17. A face-to-face arrangement of bearings has the lines of action through the bearing contact regions intersecting at points close to the center of stiffness:

True or false

18. A face-to-face arrangement of bearings has a high degree of angular compliance:

True or false

19. Rolling element rotary motion bearings arranged in a face-to-face configuration are generally insensitive to thermal expansion:

True or false

20. Rolling element rotary motion bearings arranged in a back-to-back configuration are generally sensitive to thermal expansion:

True or false

21. To allow for thermal expansion of a high speed rotating shaft supported by bearings, you can:

Constrain one set of bearings, at the end of the shaft nearest the load, to the bore and the shaft, and constrain the other set of bearings to the shaft and use adhesive to fix the outer ring to the bore
Constrain one set of bearings, at the end of the shaft nearest the load, to the bore and the shaft, and constrain the other set of bearings to either the shaft or the bore, but let either the inner or outer ring slide
Use springs to maintain preload while allowing for thermal expansion
Exactly constrain the system, including providing for compliance or motion to accommodate thermal growth of the shaft

22. The preload on rolling element rotary motion bearings arranged in a back to-back configuration generally does not change with temperature:

True or false

23. Preload reduces the sensitivity of rolling element bearing systems to shock and impact loads:

True or false

24. Extreme care should be taken when pressing or shrink-fitting a bearing onto a shaft because the strains could cause too much preload in the bearing:

True or false

25. Maintaining proper bearing preload is a significant challenge in designing bearing systems for high speed spindles:

True or false

26. High speed rolling element rotary motion bearings should be mounted with all bearings fully constrained to maximize elastic averaging:

True or false

27. High speed rolling element rotary motion bearings must always be mounted so the system is exactly constrained to maximize thermal stability:

True or false

28. Rolling element bearing supported spindles are generally used for modest precision high speed, applications, and there are a number of reputable suppliers, so buy before build if possible:

True or false

29. Roller-type (e.g., cylindrical, tapered, spherical) bearings are generally used for high load, moderate speed applications that also require more damping:

True or false

30. Roller-type (e.g., cylindrical, tapered, spherical) bearings are generally stiffer and have higher load capacity than ball bearings:

True or false

31. Cylindrical roller bearings only support radial loads and thus are typically used in conjunction with ball or tapered roller bearings:

True or false

32. Cylindrical roller bearings are in sensitive to misalignment when mounted in a back-to-back configuration:

True or false

33. Spherical roller bearings are generally used for high load, moderate speed applications that also require misalignment capability:

True or false

34. Tapered roller bearings can provide axial and radial load support:

True or false

35. Flexural bearings use elastic deformation of elements to allow for relative motion between elements:

True or false

36. Flexural bearings can use plastic deformation of elements to allow for relative motion between elements, but this is a rare application:

True or false

37. Cylindrical roller bearings only support radial loads and thus are typically used in conjunction with ball or tapered roller bearings:

True or false

38. The relative proportion between the size of a monolithic flexural bearing and its allowable range of motion is typically on the order of 20:1 :

True or false

39. Clamped-flat-spring flexural bearings are assembled from components because:

To obtain the range of motion required in the space allotted, high aspect ratio hardened spring steel flexural elements (blades) are required, and the cost to EDM the system from a hardened steel block can be prohibitive If the flexure is damaged, only the blade typically needs to be replaced

40. Flexural bearings are inherently preloaded:

True or false

41. Flexural bearings are often chosen for use because they are inherently preloaded and can have essentially infinite life:

True or false

42. Flexural bearings require specially formulated lubricants to avoid damaging the grain structure of high strength steels:

True or false

43. The relative proportion between the size of a clamped- flat-spring steel flexural bearing and its allowable range of motion is typically on the order of 10:1 :

True or false

44. The dominant factors that affect the relative size of flexural bearings and their allowable range of motion are: Material modulus of elasticity Material strength Thickness of the material Surface finish

45. The dominant factors that affect the life of flexural bearings are:

Material strength Transition zone between the blade and the structure Applied loads Applied off-axis loads

46. Flexural bearings have poor inherent damping:

True or false

47. Flexural bearings can be damped by adhering a sheet of visco-elastic material to the side of the flexure or placing viscoelastic foam between the blades:

True or false

48. Parasitic error motions in flexural bearings are those errors in the desired motion which are caused by:

Errors in dimensions Off-axis loads deforming the flexural elements
Loads not being applied through the center of stiffness of the bearing
Dust mites in the lab which feed on hair that falls off researcher's heads as they try to get their device to work

49. Thermal expansion errors can be problematic in flexural bearings because the large surface area to volume ratio of the flexural blade elements makes them more susceptible to temperature changes:

True or false

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