MECHANICAL MAINTENANCE

BEARINGS

TRAINING MANUAL
COURSE EXP-MN-SM060
Revision 0

MECHANICAL MAINTENANCE

BEARINGS

CONTENTS

1. OBJECTIVES

By the end of this presentation, the mechanic (or future mechanic) will :

- Be able to adopt the appropriate approach to the different types of bearings
- Have acquired a basic understanding of the main problems encountered with bearings.

2. BASIC NOTIONS

2.1. DEFINITION OF BEARINGS

The origin of the word bearing in fact comes from the bearing components (ball, roller, needle bearings) that are placed between two parts in rotation and that allow rolling instead of friction.

A bearing is made up of four main parts:

- The outer bushing (2) placed in the housing (1)
- The inner bushing (6) placed on the rotating axle (7)
- The balls or rollers (3)
- The cage (4) used to hold the two rolling parts together

The pitch diameter (5) is the balls' rotation axis

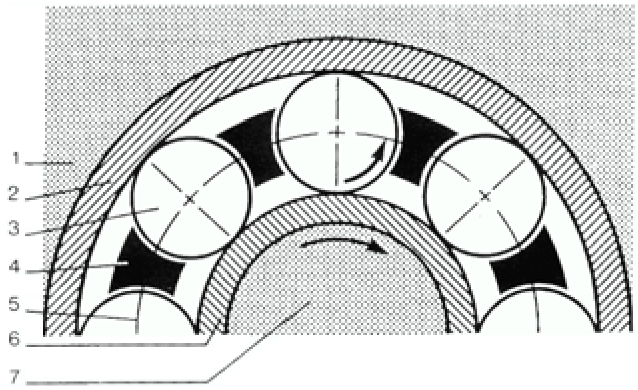


Figure 1: Composition of a bearing

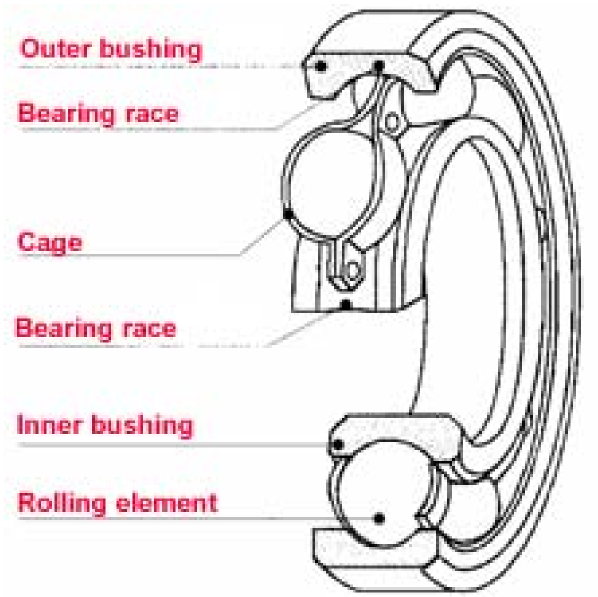


Figure 2: Detail of a bearing

2.2. WHAT PURPOSE DOES A BEARING SERVE? ITS ROLE

In an assembly, it is an element that ensures a moving link between two parts of a mechanism that rotate with respect to each other. It will enable the positioning, transmission of forces and rotation of those parts with a load applied, with precision and minimal friction.

The function of a bearing is to reduce the friction between two moving parts on the machine as much as possible and to support a load.

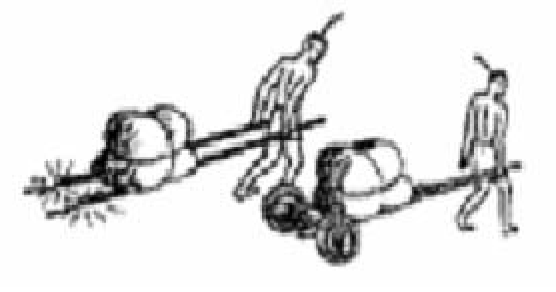


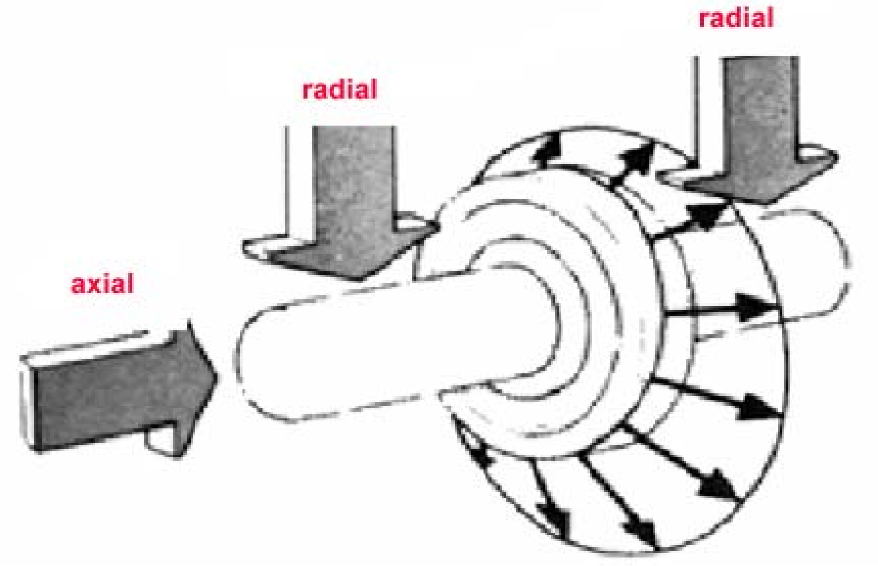
Figure 3: Sliding/rolling diagram

One of the key functions of a bearing is to support the loads imposed on it.

There are two types of load:

- Radial loads which are directed perpendicularly to the bearing axis
- Axial loads which are directed in the bearing's axis

Other loads also exist, such as compound loads which combine both types of load, axial and radial.



Radial (or carrier) bearings only bear the radial loads.

Axial or (thrust) bearings only bear axial loads.

Bearings supporting the two types of load are called angular bearings.

Figure 4: Distribution of loads

2.3. BEARING VOCABULARY

A French standard, the **ISO 5593**:1997 standard details a large number of definitions specific to bearings. It should be noted that the (I.S.O) TC 4 a Technical Committee is in charge of all bearings.

There is another standard, called **ABEC** (Annular Bearing Engineer Council), which is of American origin. It uses odd numbers (1 to 9) to note rolling quality in increasing order.

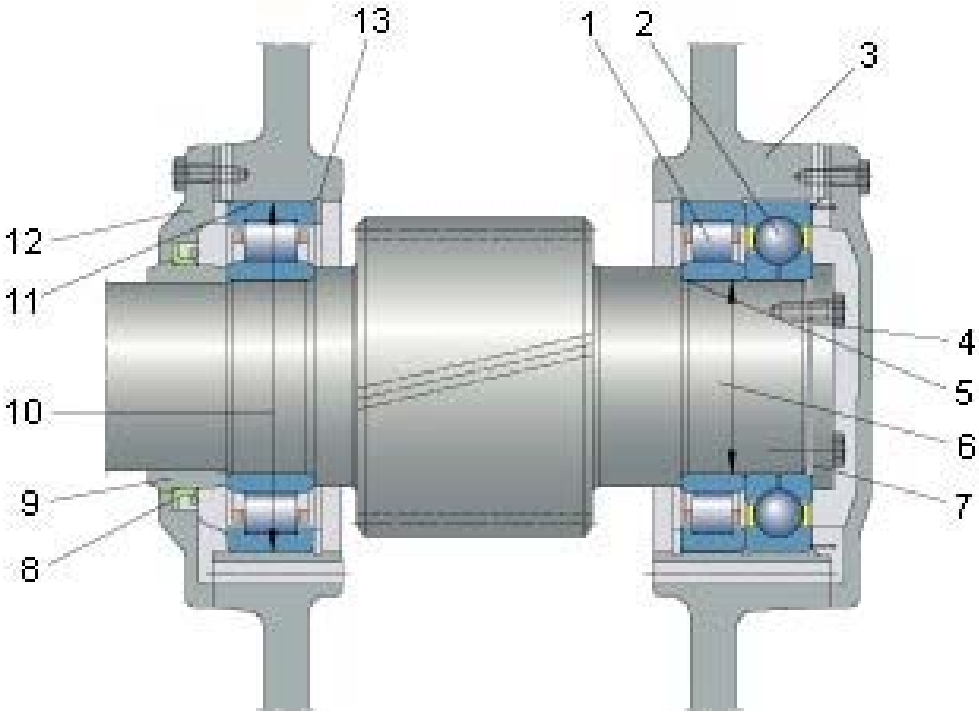
So, ABEC 1 bearings are of poorer quality than ABEC 3 bearings, and so on. The ABEC, standard defines the ball's finish and not the quality of the material.

As for the ISO standard, it designates the manufacturing quality of a bearing. (The ISO standard is a certification granted to brands by a specialist organisation that assesses the manufacturing processes and products).

ISO is a network of national standardisation institutes in 146 countries, with one member institute per country. The goal of this non-governmental organisation is to help, standardise and ensure the conformity of the products made by the industry.

Naturally, the ISO standard will take priority, but the ABEC standard is still used by the manufacturers, who find a more flexible comparison scale in this standard than with the ISO standard.

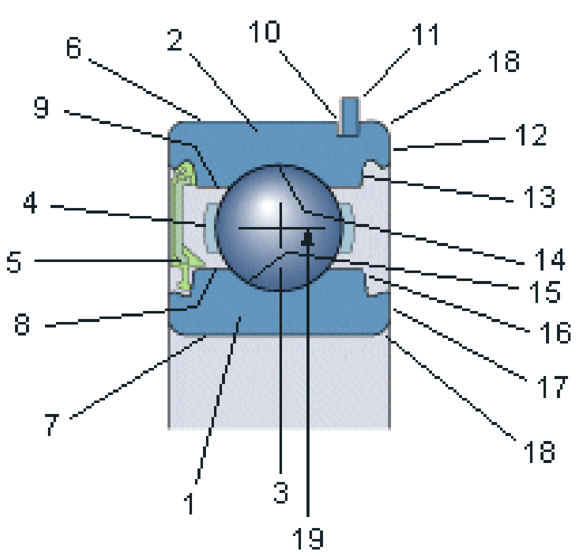
2.3.1. Vocabulary used in a bearing assembly



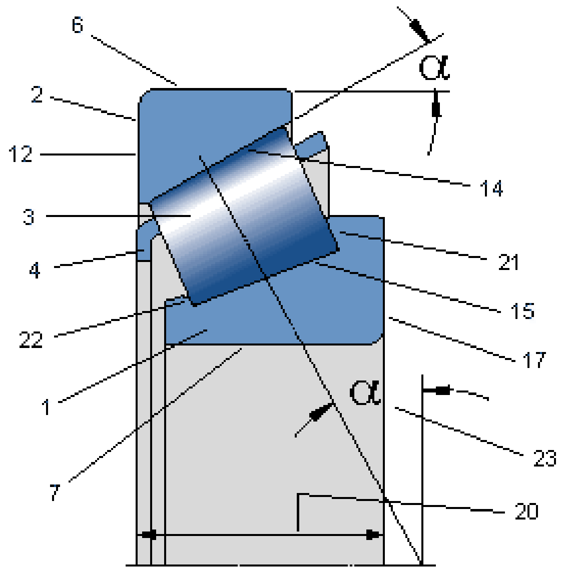
1 : cylindrical roller bearing	8 : radial shaft junction
2 : ball bearing	9 : spacer
3 : housing	10 : housing borehole Ø
4 : shaft	11 : housing borehole
5 : shaft thrust shoulder	12 : housing cover
6 : housing borehole Ø	13 : stop ring
7 : blocking plate	

Figure 5: Bearing assembly vocabulary

2.3.2. Ball and roller bearing vocabulary



Ball bearing

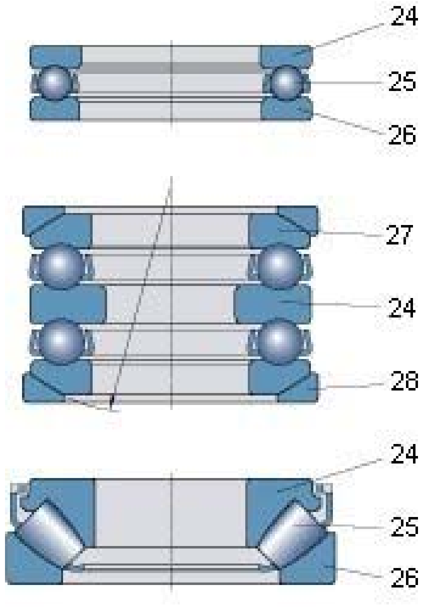


Roller bearing

1 : inner bushing	13 : seal housing groove
2 : outer bushing	14 : outer bushing bearing race
3 : rolling part (ball and tapered roller)	15 : inner bushing bearing race
4 : cage	16 : sealing groove
5 : sealing device (seal)	17 : inner bushing side face
6 : outer Ø of the outer bushing	18 : chamfer
7 : inner bushing borehole	19 : pitch Ø
8 : Ø of the inner bushing shoulder	20 : total width of the bearing
9 : Ø of the outer bushing shoulder	21 : guide shoulder
10 : groove for stop ring	22 : side shoulder
11 : stop ring	23 : contact angle
12 : outer bushing side face	

Figure 6: Ball bearing and roller bearing vocabulary

2.3.3. Thrust bearing vocabulary



24 : shaft washer	
25 : rolling part cage	
26 : housing washer	
27 : housing washer with spherical bearing surface	
28 : spherical counterplate	

Figure 7: Thrust bearing vocabulary

2.4. THE VARIOUS LOADS ACTING ON BEARINGS

The load is a force that weighs on the bearing. Depending on the application and therefore on the load to which the bearing is submitted, we will use such and such a type of bearing, which will have different qualities.

Two types of load are of interest to us:

- The **radial load**, which is a load applied perpendicularly to the shaft's axis

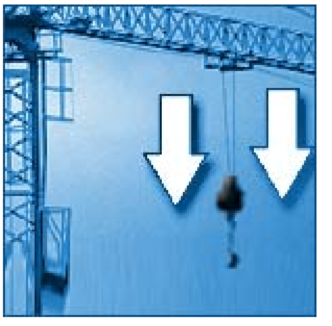


Figure 8: Example of a radial load: crane pulley block

- The **axial load**, which is a load parallel to the shaft's axis

Figure 9: Example of an axial load: power drill

- The two loads can also be combined: radial load + axial load

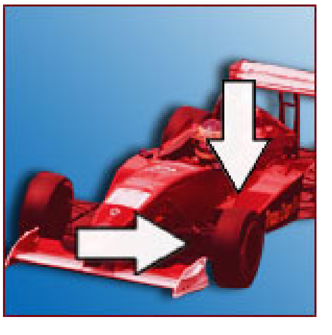


Figure 10: Example of combined loads: car wheel

Bearings can therefore be classified in two categories:

- Radial (or carrier) bearings, these bearings only support radial loads.
- Axial (or thrust) bearings, these bearings only support axial loads.
- The bearings that support both types of load are called angular bearings.

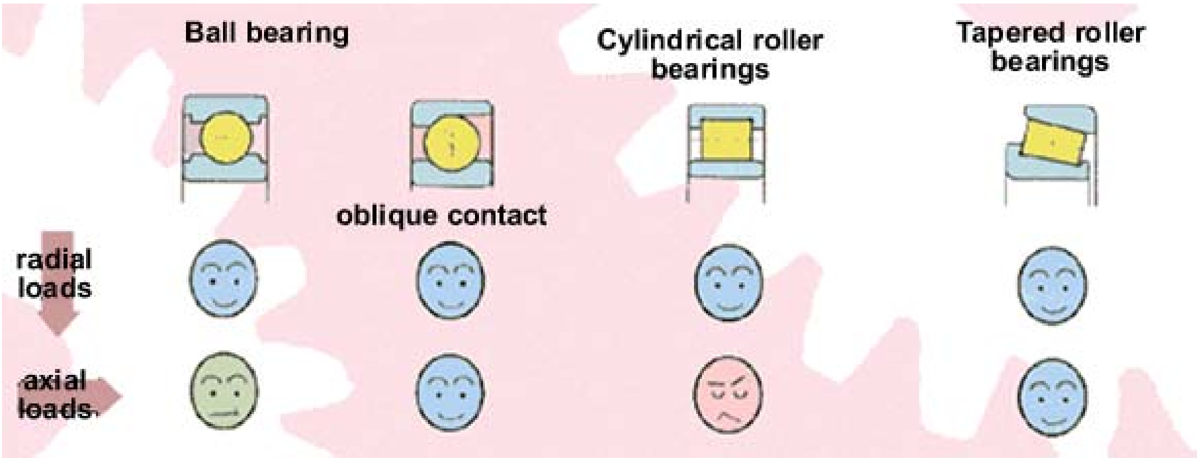


Figure 11: Types of bearings and their loads

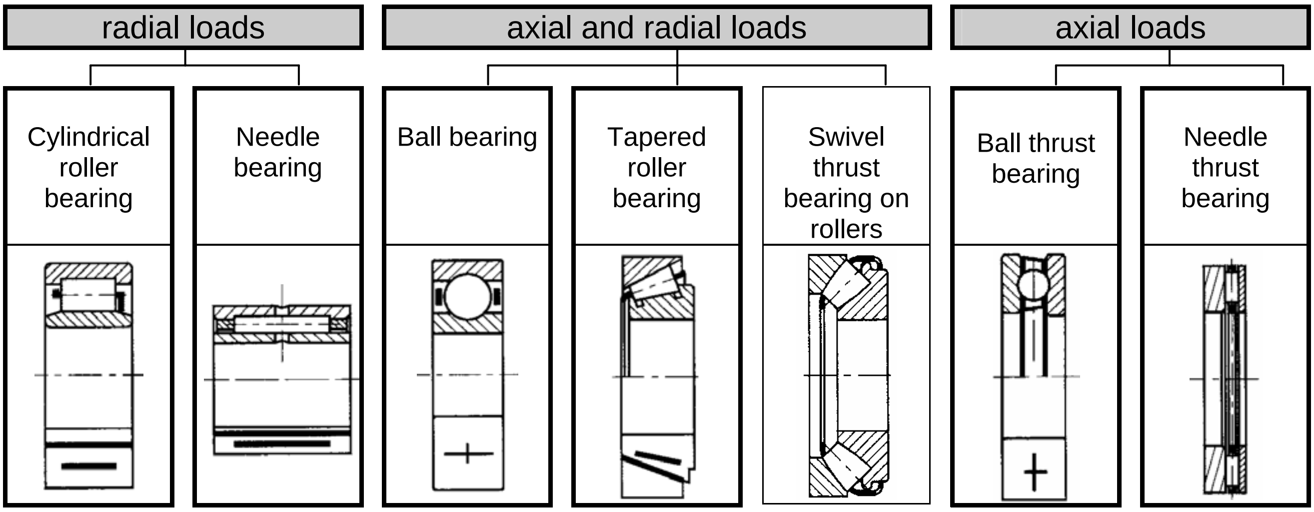


Figure 12: Bearing outline diagram

2.4.1. Loads on ball bearings

- They support high radial loads
- They are suitable for high speeds
- They do not withstand shocks well, or not at all.

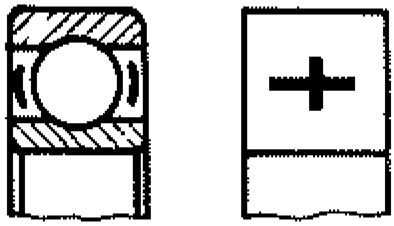
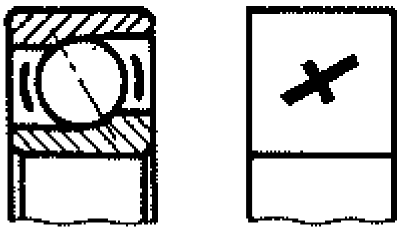
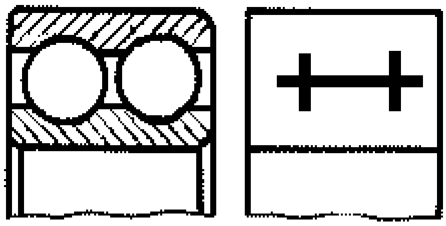
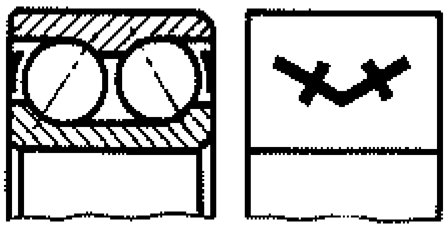
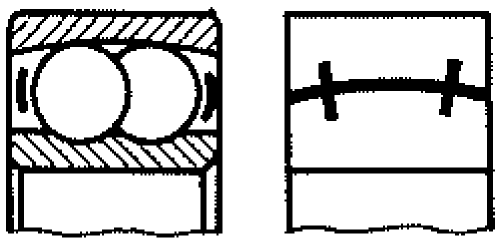
Designation	Diagram	Axial (C_a) and radial load (C_r)
Bearing with one row of balls		C_a : ++ C_r :++
Angular contact ball bearings		C_a : ++ C_r : +++
Bearing with two rows of balls		C_a : +++ C_r : +++
Bearing with two rows of angular contact balls.		C_a : +++ C_r : ++
Swivel bearings on two rows of balls		C_a : + C_r : 0

Table 1: Different loads on ball bearings and bearing diagrams

2.4.2. Loads on roller bearings

These can support very high radial loads, and may withstand shocks.

Tapered roller bearings support very high axial loads.

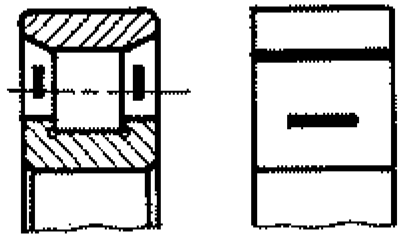
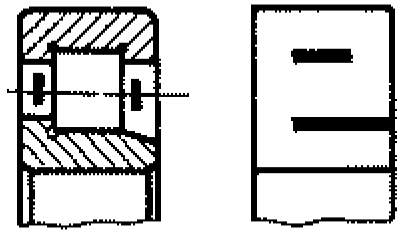
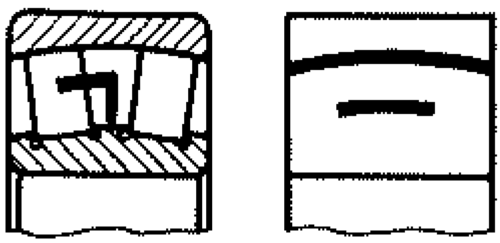
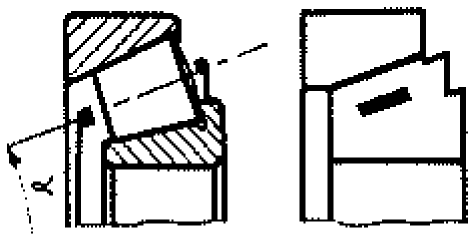
Designation	Diagram	Axial (C_a) and radial load (C_r)
Cylindrical roller bearings		C_a : +++ C_r : 0
Cylindrical roller bearings (shouldered bushing).		C_a : +++ C_r : +
Swivel bearings on rollers		C_a : +++ C_r : +
Tapered roller bearings.		C_a : +++ C_r : + à ++

Table 2: Different loads on roller bearings and bearing diagrams

3. MANUFACTURING A BALL BEARING

3.1. THE MATERIALS

The materials used to manufacture bearings must be very hard and highly resistant to compression.

This is why they are essentially made of steel or ceramics.

3.1.1. Steel

Basic material used to make the bushings and rolling parts.

Two families of steel are intended for the most widely used bearings

- Case hardened steels (*)
- Core hardened steel alloys

Figure 13: A steel bearing

(*) case hardening is a chemical-heat surface treatment with diffusion of carbon only, which makes it possible to increase the surface hardness of steel parts (T° comprised between 870° and 1100° C depending on the steel). This treatment is always followed by quenching. The hardness of the treatment depends on the depth desired (0.1 to 3 mm).

3.1.2. Ceramics

Industrial ceramics use materials based on oxides, carbides, etc.

A material made of a ceramic is very solid at room temperature and is neither metallic nor organic.

Ceramic objects are made by solidification of a paste at high temperature.

Figure 14: Ceramic bearing

3.1.3. Other materials

There are also bearings made of Teflon or nylon which will be used in certain special cases (model-making, household electrical appliances, medical equipment, etc.).

Figure 15: Bearings made of Teflon and nylon

3.2. THE MANUFACTURING METHODS

There are two possible manufacturing methods:

- By removal of material (turning/undercutting)
- By deformation (rolling, forging, stamping)

A well-defined process must be used to manufacture bearings. This requires a very high degree of precision in order to make a high-quality bearing.

The different materials that can be used to manufacture inner and outer bushings are generally steels containing chrome:

- Good load resistance
- Quenchability
- Heat treatment stability.

Three types of materials can be used to manufacture cages:

- Stamped sheet metal (or brass)
- Polyamide for synthetic cages (which do not support temperatures higher than 120° C)
- Machined brass (large dimension bearings)

3.2.1. Manufacture of inner and outer bushings

The different steps in ball manufacturing are as follows:

- Machining
- Heat treatment
- Grinding
- Superfinishing

3.2.1.1. Machining

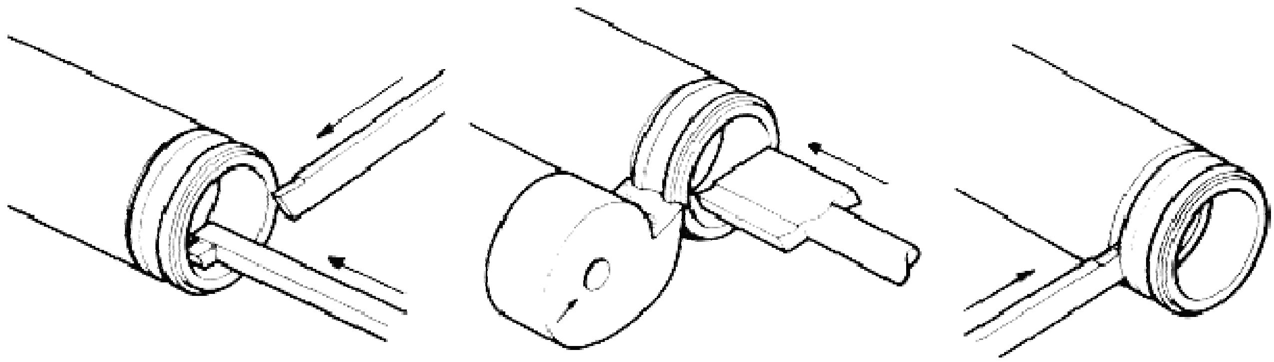


Figure 16: Inner bushing

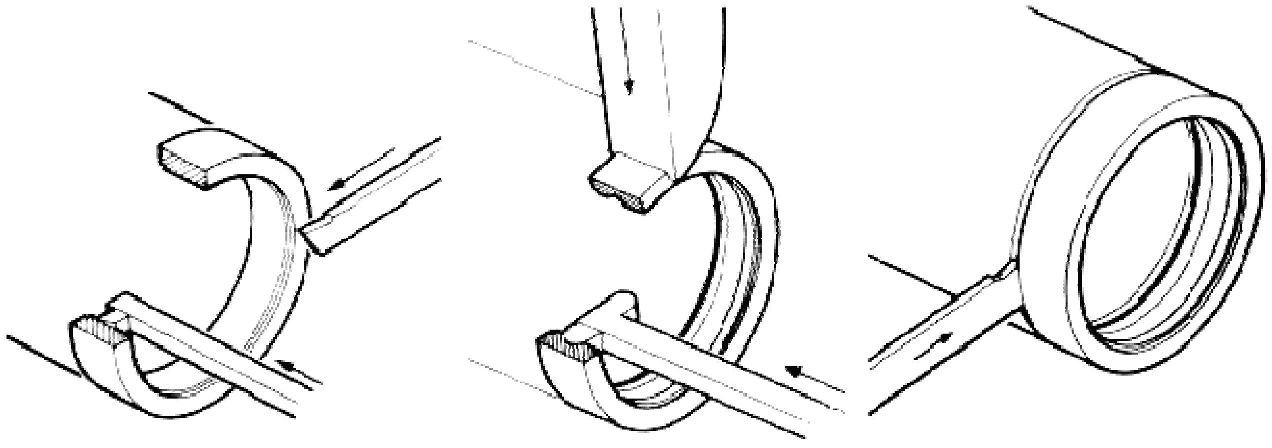


Figure 17: Outer bushing

3.2.1.2. Heat treatment

Heat treatment is carried out to increase the material's hardness.

- **Heating to 850°**: austenitizing (heating a steel part making it possible to transform its complete structure. This temperature varies according to the steel and is situated in the region of 800-900 °C) to change the material's structure
- **Quenching at 40°**: very fast cooling that freezes the material's structure to obtain greater hardness.
- **Tempering at 180°**: reheating of the part to decrease the effects of quenching (thermal shock) in the structure and stabilise the material.

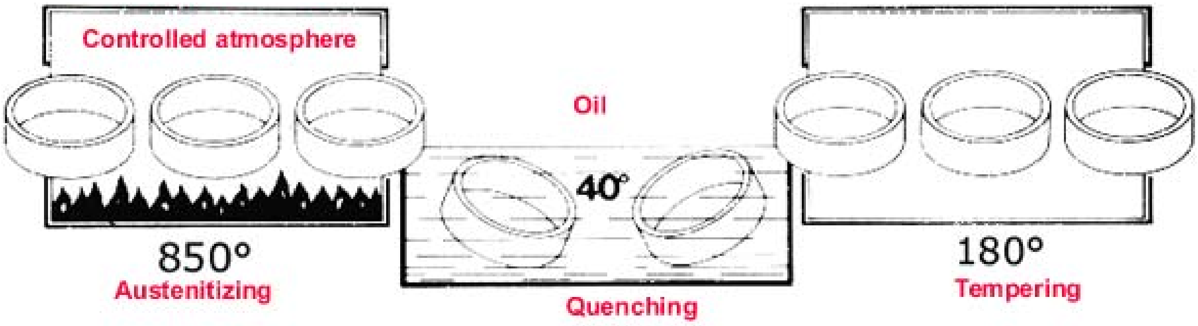


Figure 18: Heat treatment

3.2.1.3. Grinding

Grinding gives the bushings their final shape and improves their surface condition (elimination of roughness).

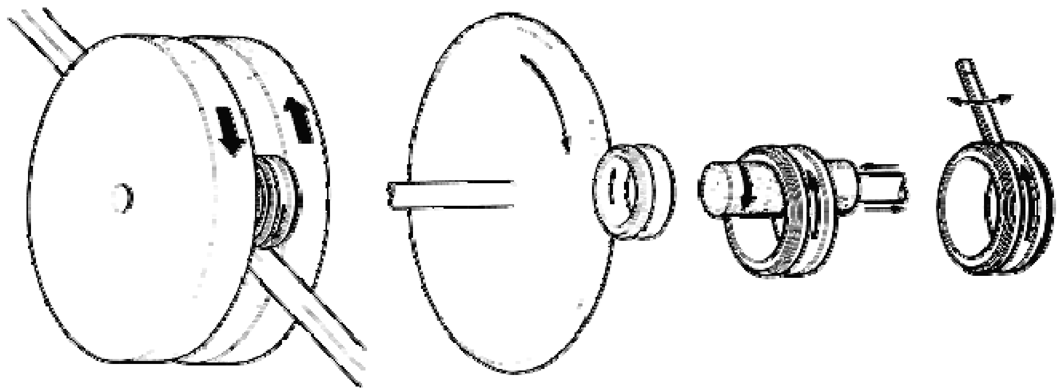


Figure 19: Grinding the inner bushing

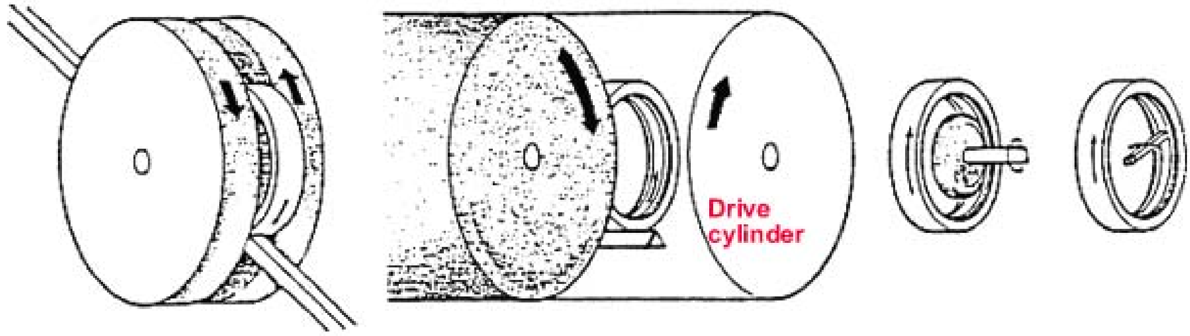


Figure 20: Grinding the outer bushing

3.2.1.4. Superfinishing

Superfinishing further improves the surface condition of the races by polishing with a honing stone.

3.2.2. Manufacturing the balls

The ball is an essential part of the bearing. Balls, as well as all the other rolling parts, are machined to within one hundredth of a micron.

Figure 21: Balls

They are made from a steel wire (Ø close to the final Ø)

The **various ball manufacturing stages** are as follows:

- Punching
- Rough machining of the ball
- Heat treatment
- Grinding on milling grinder
- Honing
- Washing
- Final inspection

3.2.2.1. Punching

Cutting and punching of the steel wire, which gives the rough shape of the future ball.

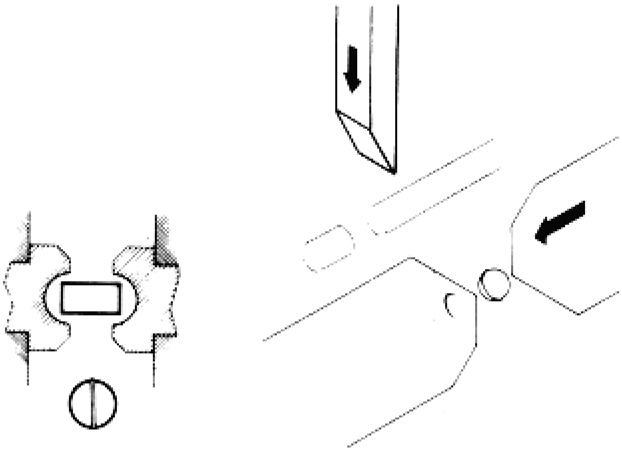


Figure 22: Ball cutting method

3.2.2.2. Rough machining of the balls

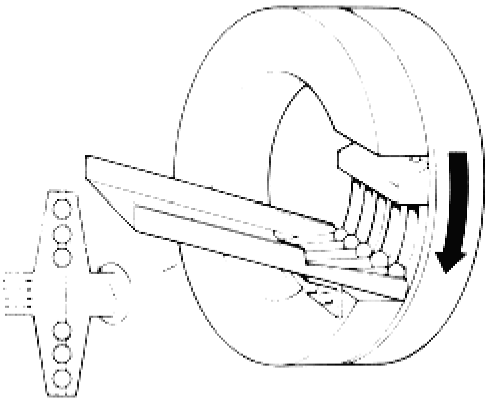


Figure 23: Rough machining of the balls

3.2.2.3. Heat treatment

Heat treatment follows the same process as for the heat treatment of bushings

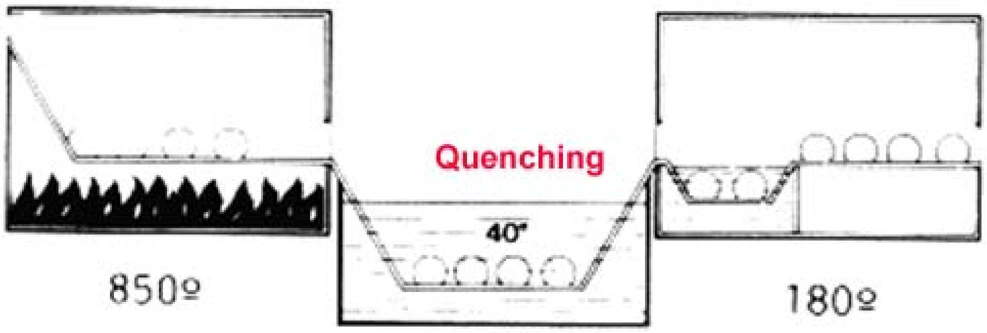
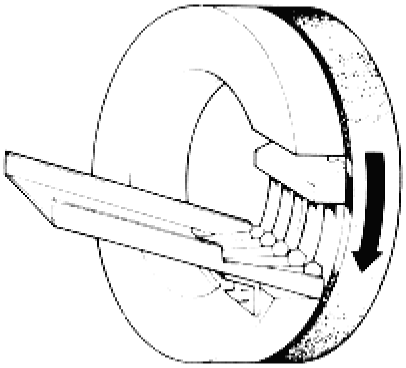


Figure 24: Ball quenching method

3.2.2.4. Grinding on milling grinder



Grinding on milling grinder improves the shape of the balls by placing them between a grinder and a cast iron plate.

Figure 25: Grinding

3.2.2.5. Honing

Honing makes it possible to bring the balls to their finished dimension by means of an abrasive. (This operation is carried out using an abrasive paste between two plates.)

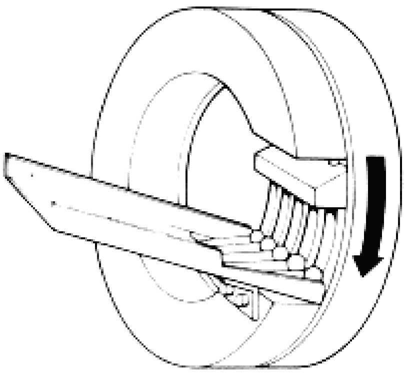


Figure 26: Honing the balls

3.2.2.6. Washing

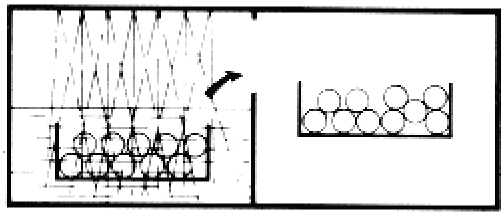


Figure 27: Washing and inspection process

3.2.2.7. Final inspection

The final inspection makes it possible to eliminate any balls with defects.

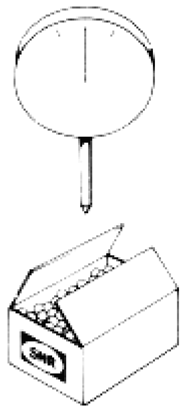


Figure 28: Final inspection

3.2.3. Manufacturing of tapered rollers

The various steps required for the manufacture of tapered rollers are more or less the same as for those required to manufacture balls:

- Die forging (punching)
- Deburring in a barrel
- Heat treatment
- Diameter grinding
- Face grinding
- Convex grinding
- Washing
- Final inspection

3.2.3.1. Die forging (punching)

Die forging (punching) follows the same process as for making balls.

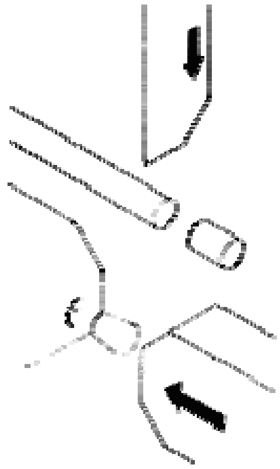


Figure 29: Cutting rollers

3.2.3.2. Deburring in barrels

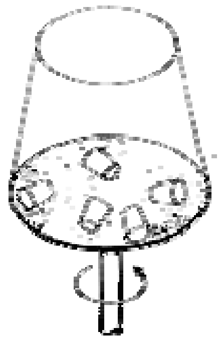


Figure 30: Deburring

3.2.3.3. Heat treatment

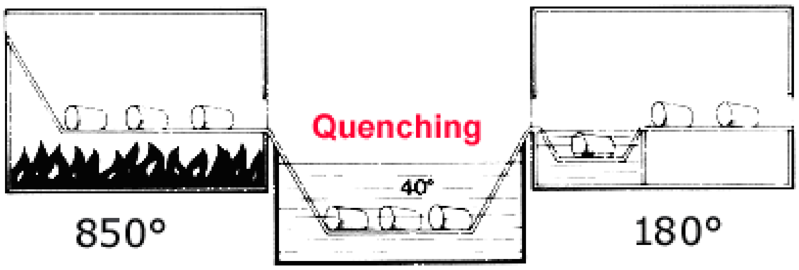


Figure 31: Quenching rollers

3.2.3.4. Diameter grinding

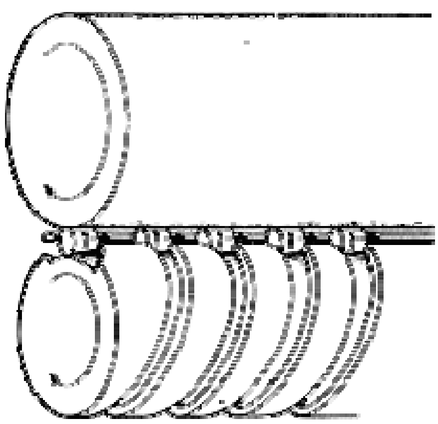


Figure 32: Grinding rollers

3.2.3.5. Face grinding

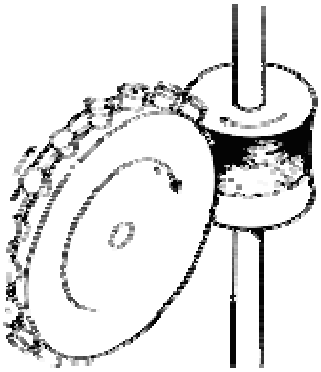


Figure 33: Grinding the face of rollers

3.2.3.6. Convex grinding

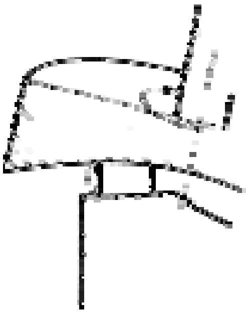


Figure 34: Grinding of the rollers' convex profile

3.2.3.7. Washing

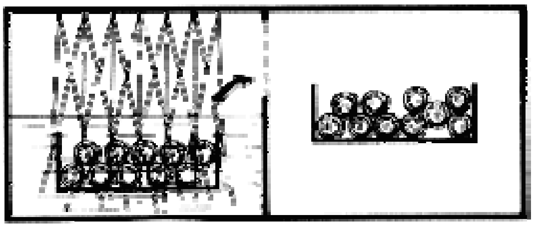


Figure 35: Roller washing

3.2.3.8. Final inspection

The final inspection makes it possible to eliminate any rollers with defects.

Same process as for balls

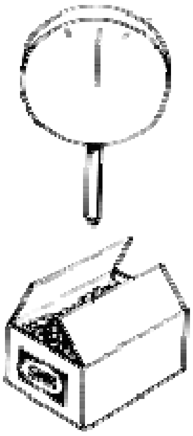


Figure 36: Inspection of the rollers

3.2.4. Manufacturing of cages

The cage manufacturing process depends on the material used:

- Sheet metal cages are made by stamping (manufacturing technique that makes it possible to obtain an object from a thin, flat sheet of metal).
- Synthetic cages are moulded.
- Cages for large bearings are machined.

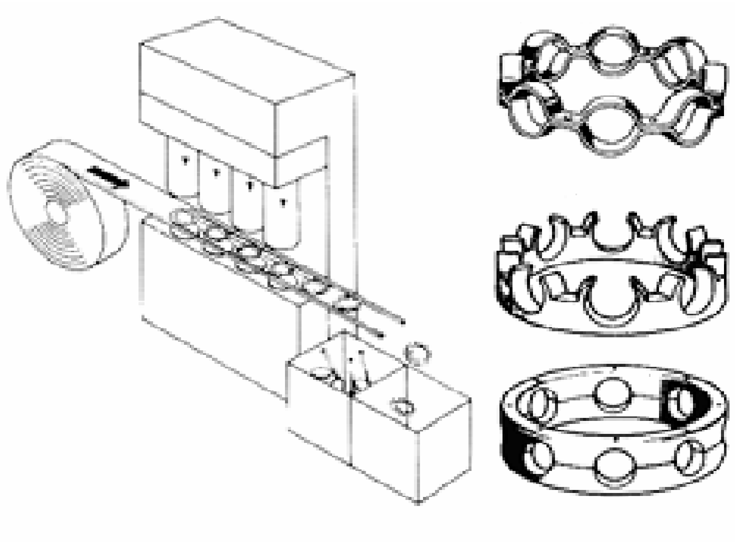


Figure 37: Cage manufacturing

3.2.5. Final assembly (ball bearings)

Final assembly is an operation that consists of assembling the various parts making up the bearing.

This operation requires compliance with the various play tolerances relative to the bearing's category.

Assembly is carried out by offsetting one bushing with respect to the other >> easier to introduce the balls into the bearing.

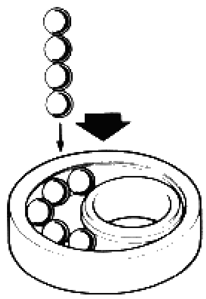
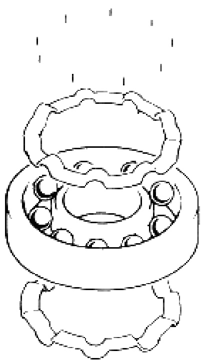


Figure 38: Installing the balls



The cage is then installed and riveted by means of a press.

Figure 39: Installing the cages

Figure 40: Detail of the 2 operations

Then, the protections are placed on the sides of the bearing (seal, protection deflectors depending on the models).

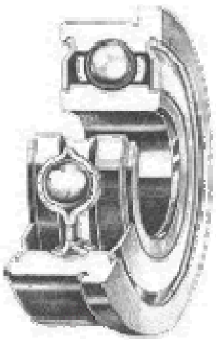
And finally the bearings will be washed and inspected (outer and inner Ø, noise, vibrations).

Figure 41: Different types of bearings

4. THE DIFFERENT TYPES OF BEARINGS (the most widely used)

There are two main families of bearings:

- **Ball bearings**



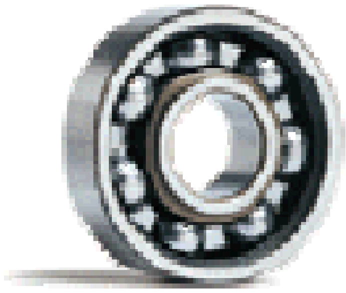


Figure 42: Ball bearings

- **Roller bearings**

Figure 43: Roller bearings

4.1. BALL BEARINGS

Ball bearings were invented by a Frenchman, **Jules Pierre SURIRAY** in 1869.

The ball bearing is a mechanical component that ensures the guidance of a shaft in rotation in a bearing block while reducing friction by means of inter-positioned parts.

This is the most widely used type of bearing.

It takes the form of 2 bushings (made of steel) that include bearing races between which the rolling bodies are placed.

- inner bushing
- outer bushing

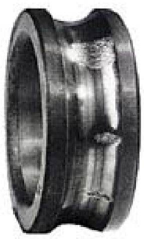


Figure 44: An inner bushing

The rolling parts (usually made of steel) ensure the movement of the two bushings with a minimum amount of friction.

The rolling parts are lightly lubricated, held in place and spaced by a cage.

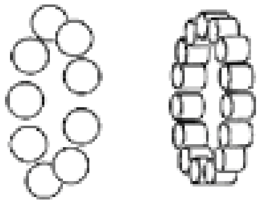


Figure 45: Rolling parts

The cage that separates and guides the rolling parts is made of brass, sheet steel, polyamide or resin.

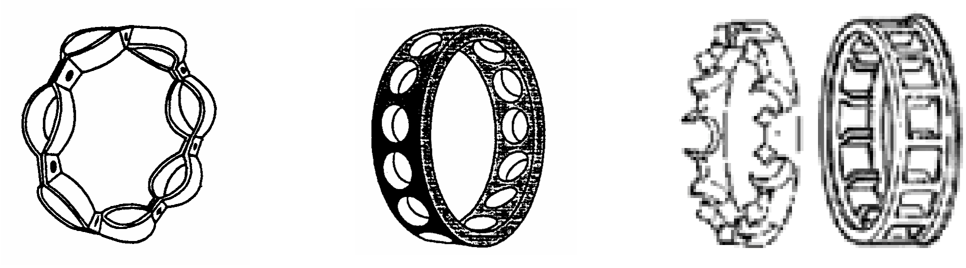
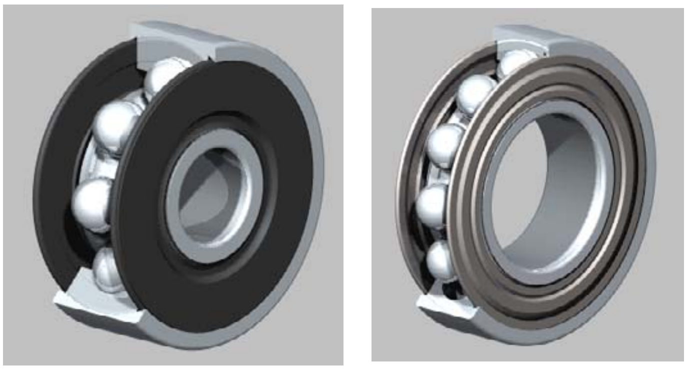


Figure 46: Different types of cages

The main purpose of lubrication (grease or oil) is not to reduce the friction between the balls and bushings.

In fact it above all serves to avoid seizing between the various parts and thus to ensure a maximum service life for the bearing.

Figure 47: Lubrication



A protection (seal or deflector) ensures sealing so that the bearing's parts (rolling bodies, races and cages) remain clean and lubricated at all times.

Figure 48: Seal and deflector

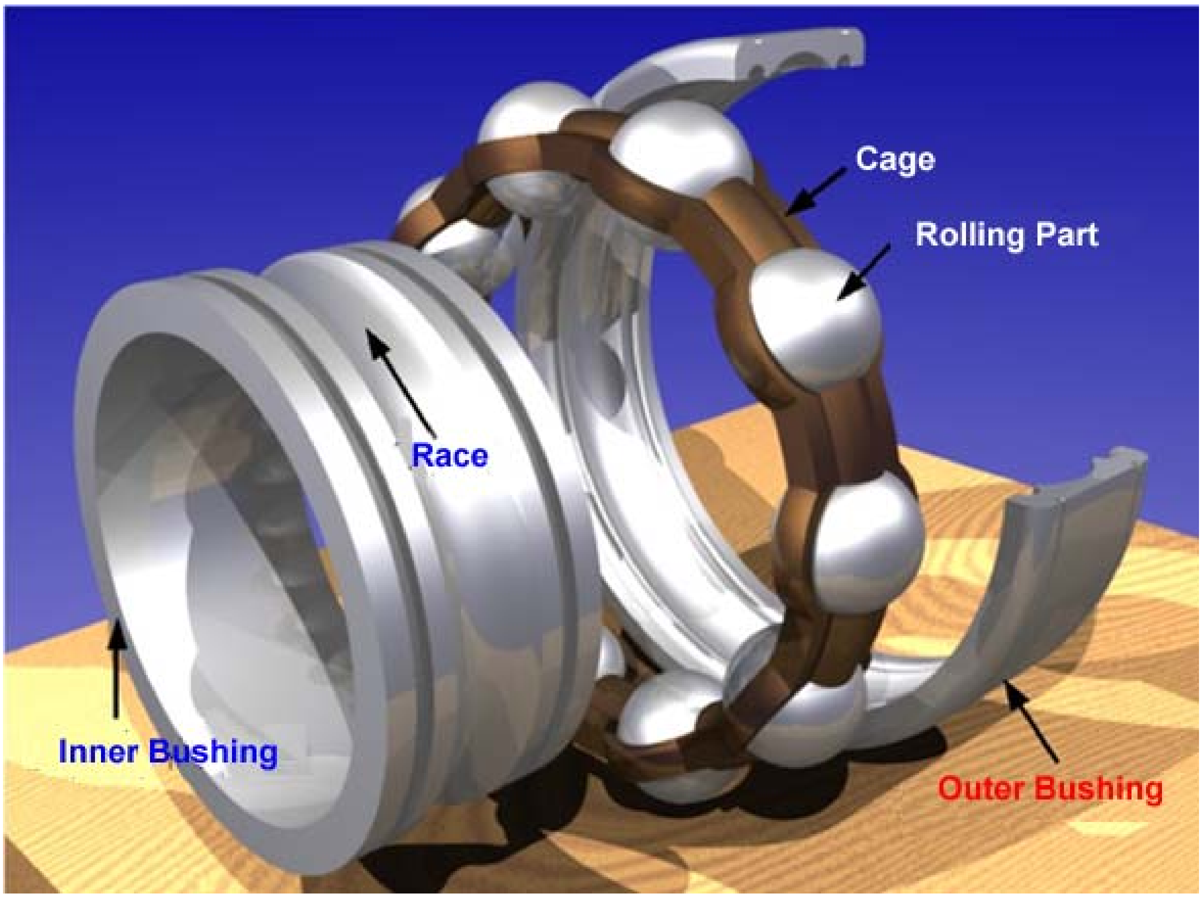


Figure 49: Exploded view of a ball bearing

There are many different types of bearings. They are all designed for a precise application so as to meet all sorts of constraints that exist in industrial mechanisms.

There are hundreds of different types for each category of bearing: either through their dimensions (inner Ø, outer Ø, pitch Ø, ball or roller Ø, etc.), or through their mechanical properties (load, temperature resistance, etc.).

For info: the largest bearing built to date (by the SKF company) weighs 55 tonnes and has a diameter of 11 meters.

4.1.1. Rigid radial contact bearings

This type of bearing has one or two rows of balls.

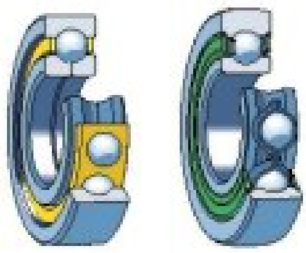


Figure 50: Bearings with one row of balls

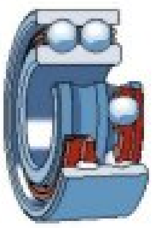


Figure 51: Bearings with two rows of balls

These are the most widely used bearings in the world.

They are designed essentially to withstand radial loads;

The depth of the races ensures a good stiffness and means that they can also withstand moderate axial loads.

They accept slight misalignments: 1/10°

They may be useful in applications where the rotation speed is high and for limiting energy losses.

Bearings with two rows of balls can withstand greater radial loads and axial loads in both directions.



Figure 52: Examples of radial contact ball bearings

4.1.2. Angular contact ball bearings

The design of angular contact ball bearings is similar to that of radial ball bearings.

The only difference is that the bearing races are offset with respect to each other.

This type of bearing also exists with one or two rows of balls.

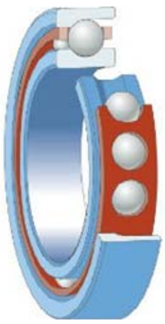


Figure 53: Angular contact bearing with one row of balls

Figure 54: Angular contact bearing with one row of small balls

They can withstand greater axial loads.

They accept slight misalignments: 1/10°

Figure 55: Examples of angular contact ball bearings

These bearings are assembled on a single axis opposite another bearing of the same type.

This design is suitable for applications combining radial and axial loads.

The angular contact bearing with two rows of balls can withstand high axial loads and moderate radial loads.

4.1.3. Swivel bearing son balls

These are made up of two rows of balls and one shared concave ball race in the outer bushing.

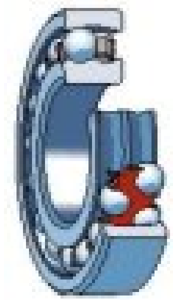


Figure 56: Swivel bearing on balls without a seal

Figure 57: Swivel bearing on balls with a seal

They are not particularly sensitive to slight misalignments, these are self-aligning bearings.

Figure 58: Swivel bearing on balls with wide inner bushing

They have less friction than the other types of bearings, which gives them the advantage of heating up less, even at high speed.

They are highly recommended when the shaft is likely to be subject to a great deflection or has a serious alignment defect.



Figure 59: Swivel bearings on balls

4.2. ROLLER BEARINGS

Roller bearings are also a very widely used category of bearing.

Roller bearings withstand a higher radial force than that supported by ball bearings, because the contact of these rolling elements with the bushings is linear (this term is used for all magnitudes that are measured using a unit of length).

4.2.1. Cylindrical roller bearings

Cylindrical roller bearings are designed to withstand heavy radial loads. They have a larger contact surface than ball bearings.

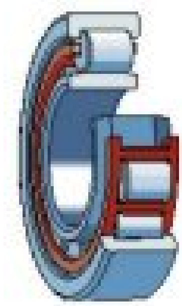


Figure 60: One-row cylindrical roller bearing

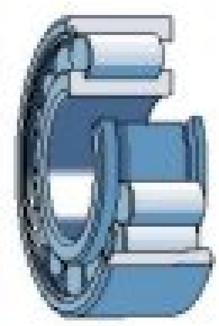


Figure 61: Joined-roller bearing

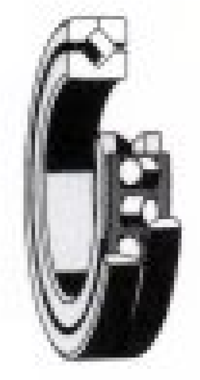


Figure 62: Crossed-roller bearing

They enable high rotation speeds.

They can withstand slight axial loads.

Figure 63: Examples of cylindrical roller bearings

Particularity: this type of bearing may exist without an inner bushing or without an outer bushing, in which case the ball race will be machined directly on the shaft or in the mechanism's housing.

4.2.2. Tapered roller bearings

This is an angular contact bearing made up of separate parts (taper and cup) and it is easy to mount.

Figure 64: One-row tapered roller bearing

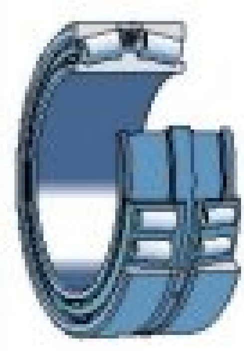


Figure 65: Two-row tapered roller bearing

These bearings can withstand very great loads.

The greater the angle, the greater the axial loads that the bearing can withstand.

They tolerate slight self-alignment defects.

Because of the axial load in a single direction, it is imperative to mount a bearing of the same type in opposition on the same shaft.

Figure 66: Examples of tapered roller bearings

4.2.3. Bearings on spherical roller swivel

Bearings on spherical roller swivels are similar to swivel bearings with two rows of balls.

External bushing made up of a spherical ball race >> this authorises a large alignment defect.

They can withstand very high radial loads

They also accept axial loads.

They are designed for harsh applications.

Figure 67: Examples of bearings on spherical roller swivels

4.3. NEEDLE BEARINGS

Needle bearings represent a quite particular type of bearing. They have a lengthwise shape, and they can therefore withstand great radial loads in a small space.

They do not accept any axial load. Only bearings made up of a needle thrust bearing and a needle cage can withstand both loads.

Figure 68: Examples of needle bearings

4.3.1. Cages with one or two rows of needles

This type of bearing guarantees precise individual guidance.

This bearing also makes it possible to obtain a great degree of stiffness, and a large load capacity in a small space.


Figure 69: Examples of bearings with one or two rows of needles

4.3.2. Needle socket

Several types of needle socket exist, with or without sealing, with or without a bottom.

Needle sockets are very small-sized bearings that are force fitted in the housing.

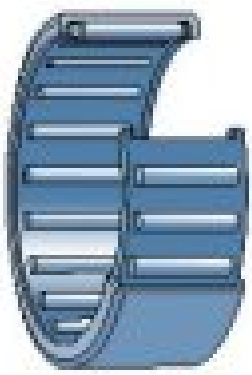



Figure 70: Needle sockets

4.3.3. Needle bearings

They can withstand high radial loads despite their small size, and they exist with or without an inner bushing.

Figure 71: Needle bearings

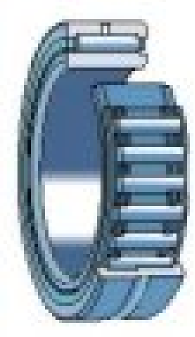


Figure 72: Needle bearing with inner bushing

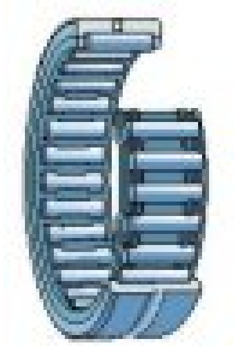


Figure 73: Needle bearing without inner bushing

4.4. RECAP OF THE TYPES OF BEARINGS

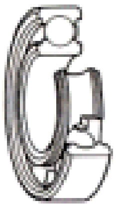
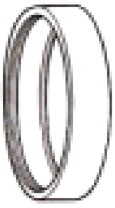
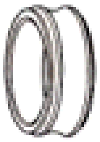
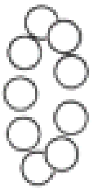
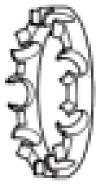
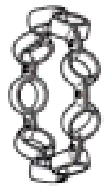
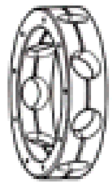
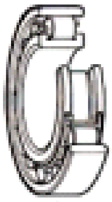
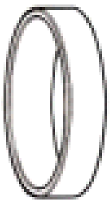
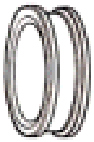
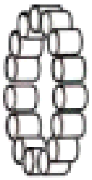
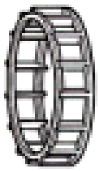
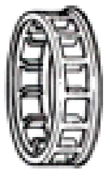
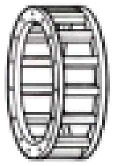
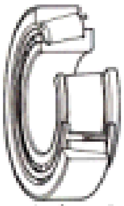
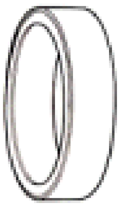
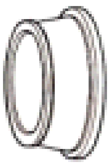
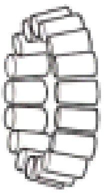
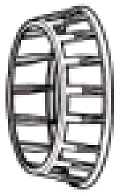
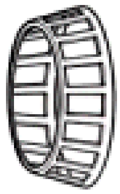
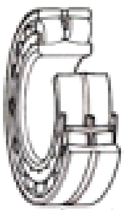
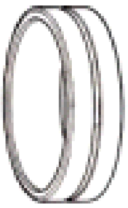
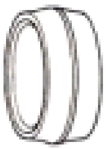
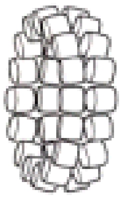
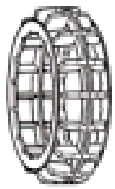
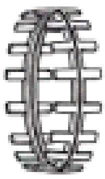
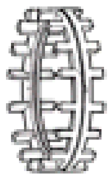
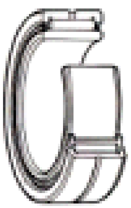
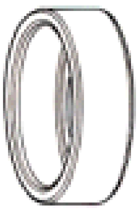
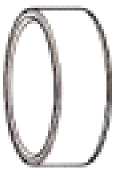
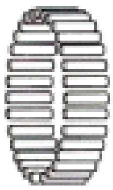
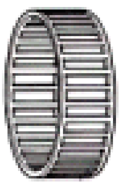
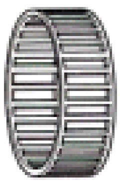
Type	Outer bushing	Inner bushing	Rolling parts	Cage		
				Synthetic material	Stamped sheet metal	Machined solid
 With balls						
 With cylindrical rollers						
 With tapered rollers						
 With spherical rollers						
 With needles						

Table 3: Recap of common types of bearings

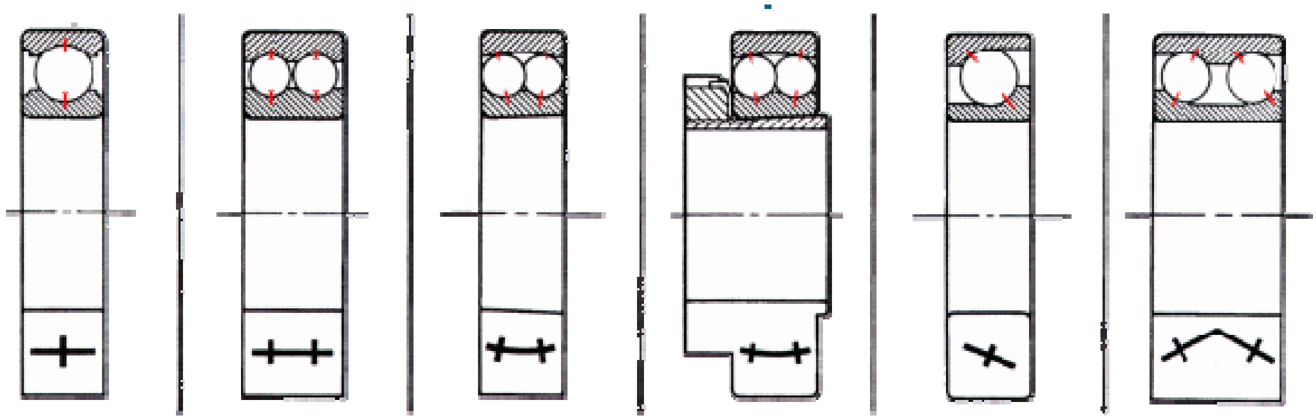


Figure 74: Contact of bearings with intermittent contacts

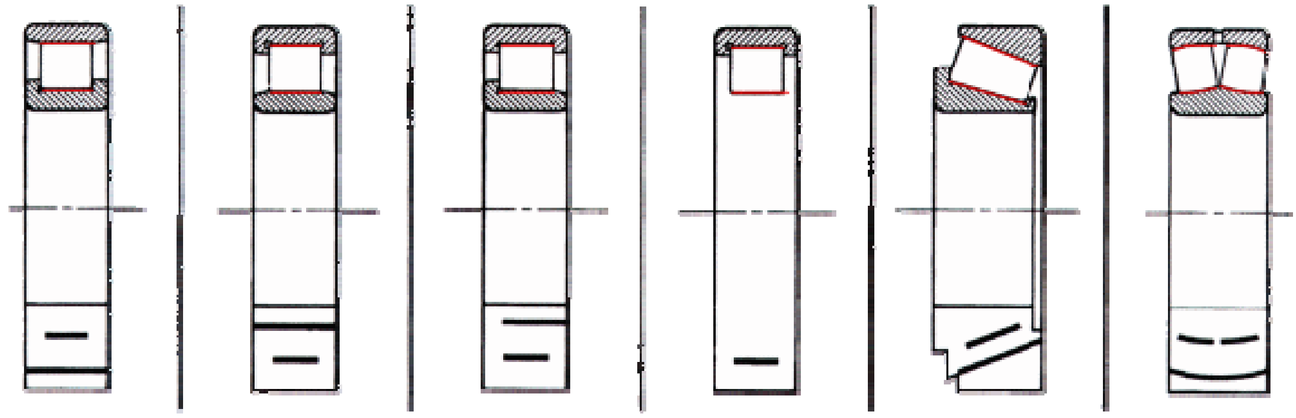


Figure 75: Contact of bearings with linear contacts

5. THRUST BEARINGS

A thrust bearing is a part designed to limit the travel of a moving part

5.1. BALL THRUST BEARINGS

Ball thrust bearings have all the advantages of ball bearings:

- not much friction
- simplicity.

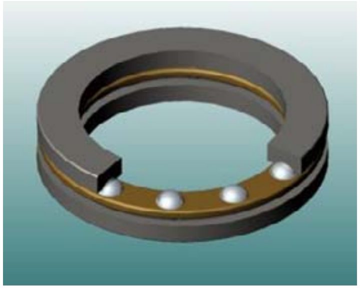


Figure 76: Single-acting ball thrust bearing (1)

Figure 77: Single-acting ball thrust bearing (2)

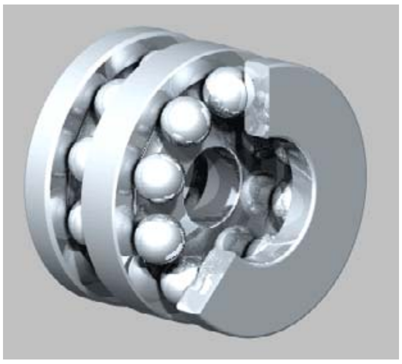


Figure 78: Double-acting ball thrust bearing

This type of bearing can only withstand axial forces.

The single-acting thrust bearing can only withstand axial loads in one direction whereas the double-acting thrust bearing can withstand axial loads in both directions.

With these thrust bearings, a minimal axial load is required to make the balls roll and thus obtain correct operation of the thrust bearing.

5.2. ROLLER THRUST BEARINGS

This type of thrust bearing is often replaced by a tapered roller bearing.

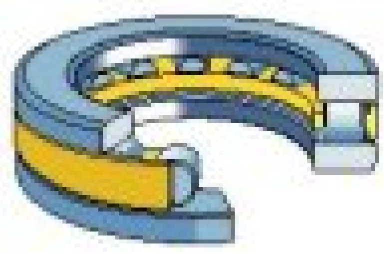


Figure 79: Tapered roller thrust bearing

Furthermore, it has a high axial load capacity and can withstand relatively high radial loads (half the amount of the axial loads).

It tolerates a slight misalignment (0.5°) of the rotation shaft with respect to the rest of the mechanism.

Figure 80: Needle thrust bearing

Figure 81: Tapered roller thrust bearing

Figure 82: Swivel on roller thrust bearing

6. BEARING BLOCKS

A bearing block is an assembly that includes an integrated bearing (called insert bearing) inserted in a support that serves as its housing.

This support can very easily be attached to an installation by means of screws or bolts. This type of setup makes it possible to avoid having to machine a housing for the bearing and for the shaft.

6.1. TWO-PART BEARING BLOCK

This is made up of a body and a cap, this type of bearing block is easy to dismount. It will therefore be very easy to disengage the shaft.

The outer bushing's housing is designed to allow an axial movement of the bearing which must be of the swivel type (balls or spherical rollers).

The acceptable alignment defects are lower than those that the bearing can withstand because of the body of the bearing block and the sealing system.

This sealing system consists of a strip of felt, and it may be reinforced because the body of the bearing block is machined so it can receive an additional seal, or be completely replaced to allow greater misalignments or greater rotation speeds.

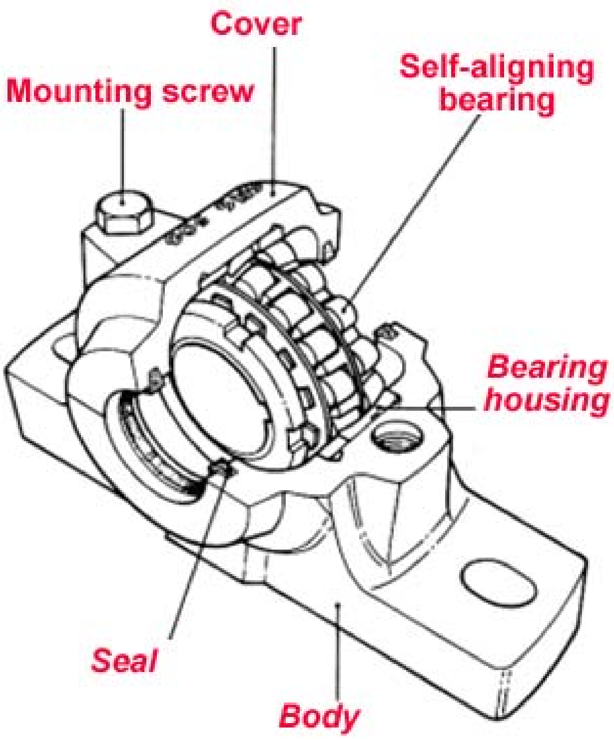


Figure 83: Two-part bearing block

Figure 84: Different types of two-part bearing blocks

6.2. SELF-ALIGNING BEARING BLOCKS

This type of bearing block consists of a spherical-shaped housing and of a bearing with one row of sealed and lubricated radial contact balls and an outer bushing with a spherical surface that serves as swivel bearing.

The outer bushing is a wide bushing and has a quick-disconnect fastener attaching it to the shaft.

A maximum misalignment of 10° is tolerated.

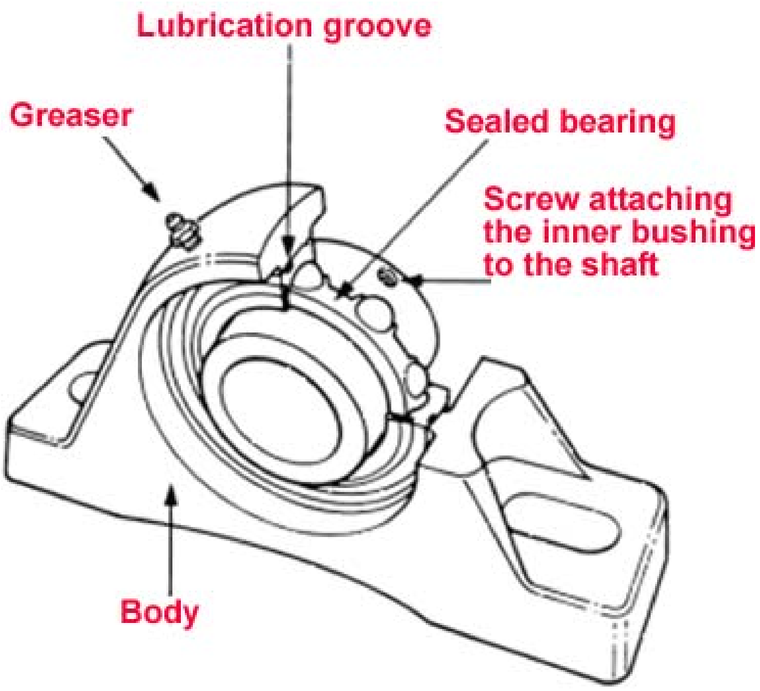


Figure 85: Self-aligning bearing block

Figure 86: Self-aligning bearing block with greaser

Figure 87: Polymer bearing block with greaser

Figure 88: Different types of bearing blocks

Figure 89: Bearing blocks with and without greasing

6.3. INTEGRATED BEARINGS

Different types of insert bearings:

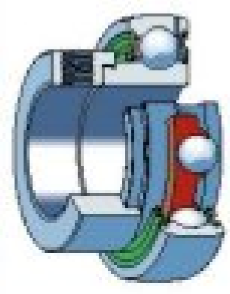


Figure 90: Insert bearing with eccentric blocking bushing

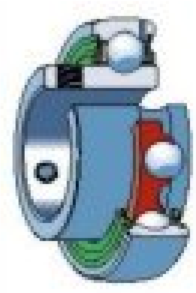


Figure 91: Insert bearing with blocking screw

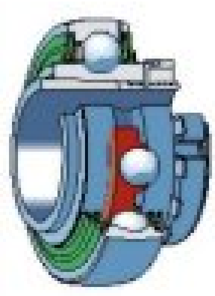


Figure 92: Insert bearing with tightening sleeve

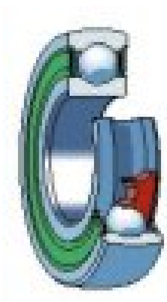


Figure 93: Insert bearing with normal inner bushing

7. BEARING INSTALLATION

7.1. PRINCIPLE OF BEARING ASSEMBLY

The adjustments required when installing a bearing are made by varying the tolerances of the shafts and boreholes.

The bushing of a bearing rotating with respect to the loading direction must be tight-fitted to avoid the "rolling" phenomenon (bushing rotating on the shaft or in its housing. This phenomenon occurs when there is a difference of rotation speed between the shaft and the inner bushing or between the housing and the outer bushing).

A bearing's fixed bushing with respect to the loading direction is mounted so it can slide.

7.1.1. "Rotating shaft" installation

- Inner bushing driven in rotation
- Fixed outer bushing

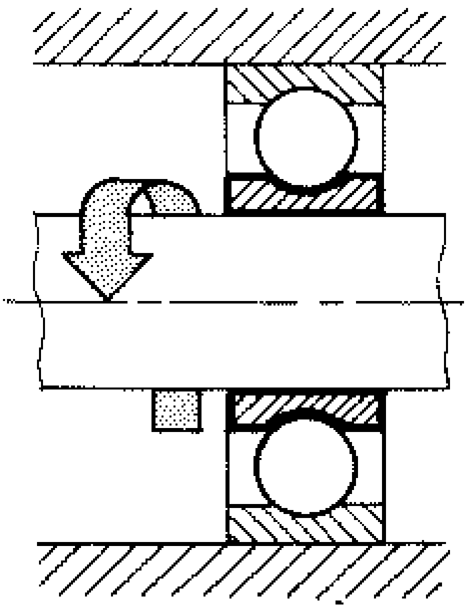


Figure 94: Example of a rotating shaft installation

7.1.2. Rotating housing installation (fixed shaft)

- Outer bushing driven in rotation
- Fixed inner bushing

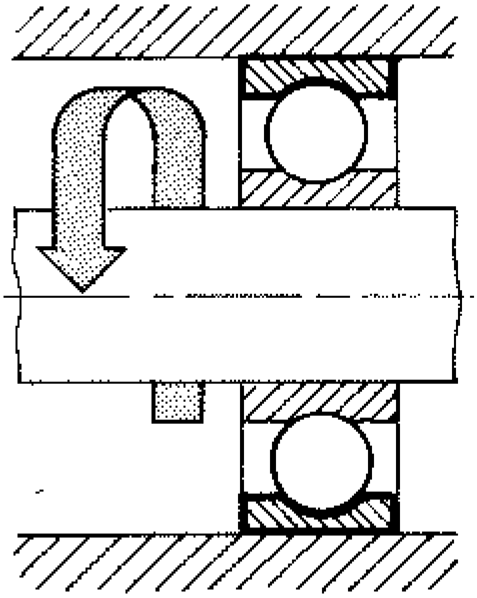


Figure 95: rotating housing installation

7.1.3. Angular contact bearings

Due to their particular structure, these bearings must be mounted in opposing pairs.

Two types of installation are possible:

- "X" installation
- "O" installation

7.1.3.1. "X" installation

<u>(Or direct installation)</u>

This is a solution that is very easy to implement and make.

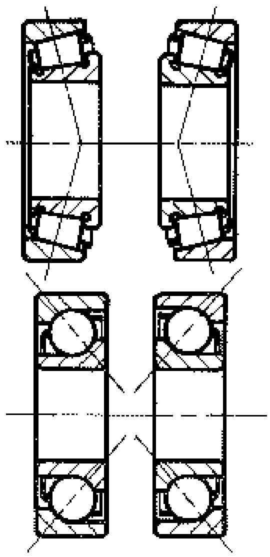
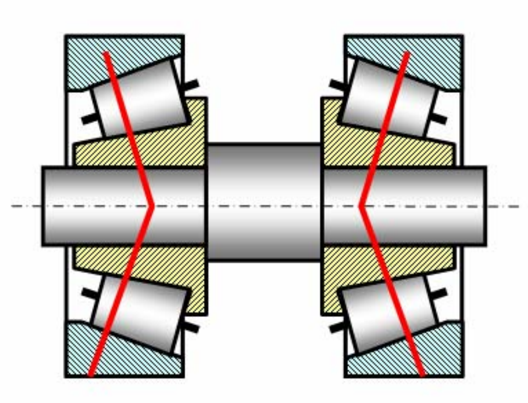


Figure 96:"X" installation (1)

This type of installation is used:

- In the case of rotating shafts with transmission systems (gears, etc.) situated between the bearings;
- Setting of the internal play carried out on the outer bushings.



The bearings must be separated as much as possible because this type of installation brings the bearings' thrust centres closer and reduces the stability of shaft guidance with respect to the housing.

Figure 97: "X" installation (2)

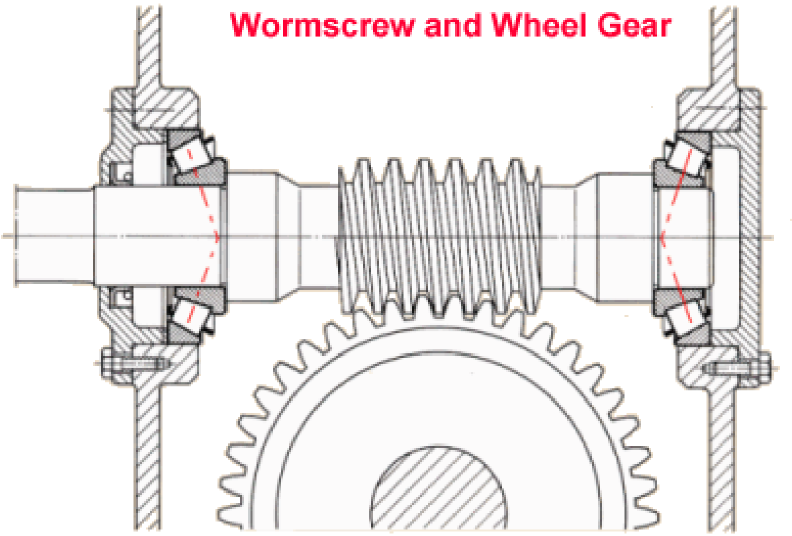


Figure 98: Example of an "X" installation

7.1.3.2. "O" installation

(Or indirect installation)

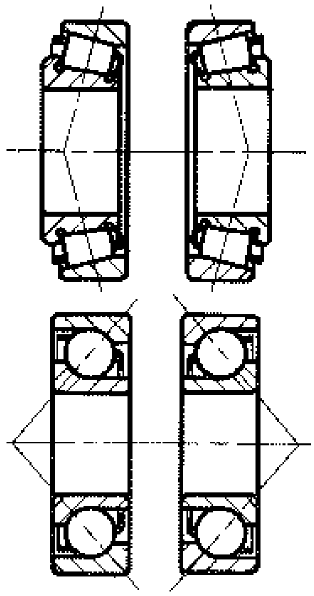
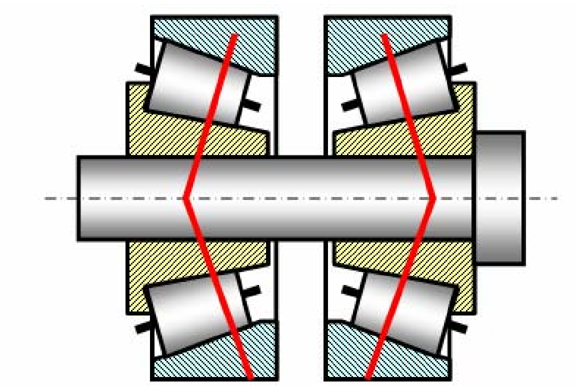


Figure 99: "O" installation (1)

This type of installation should be preferred when:

- the housings are rotary (tight-fit outer bushings)
- a great overall linkage stiffness is requireed
- there is a very large gap between the two bearings

The setting of the internal play is carried out on the inner bushings.



As the shaft dilations tend to reduce the load on the bearings, this tends to increase the internal play.

The O installation is also used with rotary shafts when the transmission systems are situated outside the link.

Figure 100: "O" installation (2)

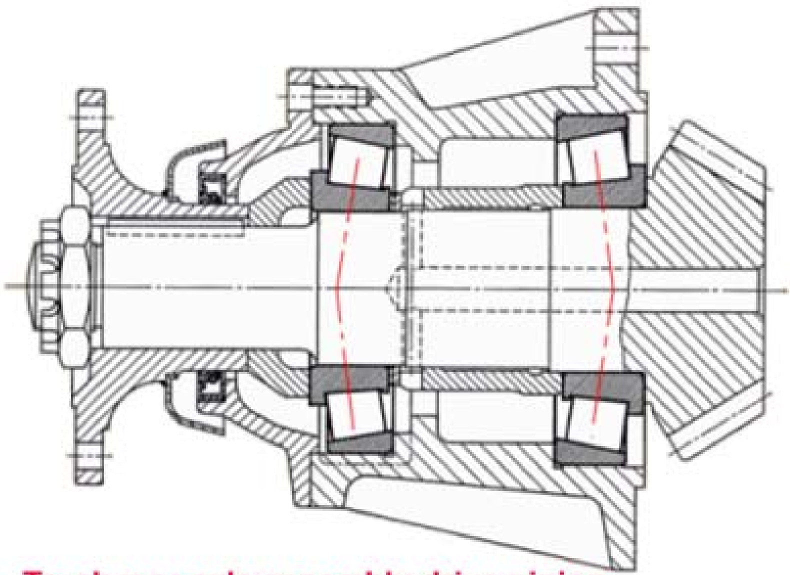


Figure 101: Example of O installation

7.1.4. Bearing fitting

The tolerances on the diameter of the inner bushing borehole and on the outer diameter of the outer bushing of bearings are defined by international standards.

The conditions for installing bearings on the shaft and in the housing are very important for the correct operation of the bearing and of the equipment.

There are two different types of fitting for each of the two bushings:

- Free fit
- Tight fit

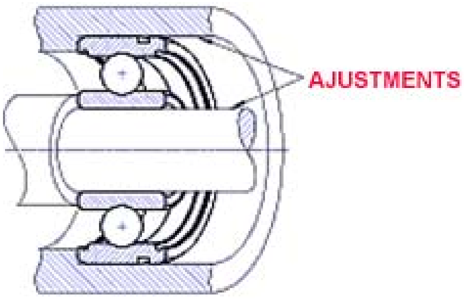


Figure 102: Fitting

Free fitting is the most practical (ease of implementation).

At least one of the bushings must be tight-fit, in order to avoid rolling which would damage the bush(es) and require replacement of the bearing.

Several criteria will be required to define the choice of fitting:

- Surface condition and shape of the shafts and housings: parameters affecting tightening and noise (at high speed).
- Temperature and temperature variations: a modification of the internal play (free or blocked fitting), and possibly variations in the length may occur when there are great temperature variations.
- Magnitude, direction and type of load: an increase in the load requires tighter fittings.
- Operating conditions: rotary bushings are fitted tighter than fixed bushings (rolling phenomenon).
- Rotation precision: severe requirements must be met concerning the surface condition and geometrical shapes.
- Impact of radial play: inappropriate tolerances may result in dilation of the bearing's inner bushing, and tightening of the outer bushing respectively. The consequences will be a decrease in the radial play or even elimination of that play.

The dimensions of the shaft's and housing's thrust faces must be sufficiently great to obtain a precise fit, exact alignment and axial resistance in the case of an axial load. The thrust faces must not touch the protections.

The fits are only valid for a normal operating temperature.

For operation at limit temperatures, you must check that the radial play does not become too great (otherwise, look for the best trade-off).

Use				Shaft	Borehole				
					H6	H7	H8	H9	H11
Parts moving with respect to each other	Part whose operation requires great play (dilation, poor alignment, very long bearing surfaces, etc.)			**c**				9	11
				d				9	**11**
	Ordinary case of parts rotating or sliding in a bushing or bearing block (good greasing ensured)			**e**		7	**8**	**9**	
				f	6	6 7	**7**		
	Part with precise guidance for low-amplitude movement			**g**	5	**6**			
Parts that do not move with respect to each other	Disassembly and re-assembly possible without deteriorating the parts	The fit cannot transmit forces	Manual installation possible	**h**	**5**	**6**	**7**	**8**	
				js	**5**	6			
			Installation using a mallet	**k**	**5**				
				m		**6**			
	Disassembly impossible without deteriorating the parts	The fit can transmit forces	Installation using a press	**p**		**6**			
			Installation using a press or by dilation (check that the constraints imposed on the metal do not exceed the elastic limit)	**s**			7		
				u			7		
				x			7		
				z			7		

Table 4: Main types of fit used

7.2. HANDLING BEARINGS

Bearing handling is a delicate operation that requires special know-how. The bearing must be correctly placed in order to guarantee its optimum operation.

You must never suspend a heavy or large bearing from a single point when moving it with hoisting apparatus; you should install a belt or steel cable hoop around it.

Figure 103: Slinging method

In order to facilitate the transport of large bearings, they often have holes tapped in the face of the bushings allowing hoisting eyelets to be installed.

As the Ø of the tappings is limited by the thickness of the bushing, the use of eyelets will be limited to lifting the bushing or the bearing on its own.

The force must only be applied to the eyelets in the direction of their threaded rod axis.

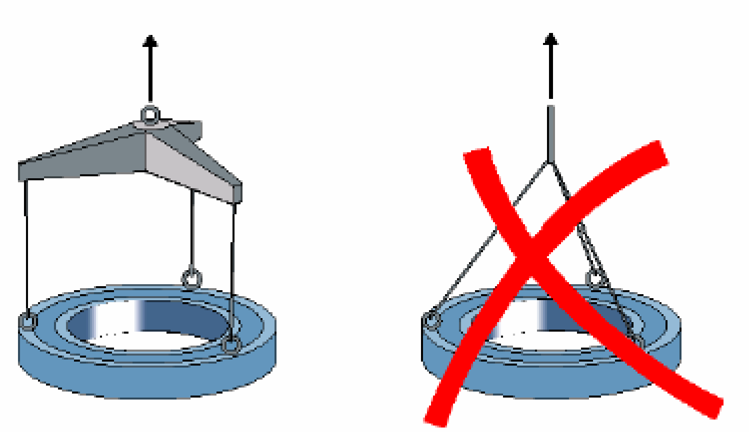


Figure 104: Method with force spreader

7.3. INSTALLING BEARINGS

Cleanliness is essential when performing a bearing replacement operation. The bearing will be damaged very quickly if foreign matter enters into it.

The method (mechanical, hydraulic, heating tool) used to install a bearing will depend on the bearing's type and size.

Before doing anything else, you must check several points on the shafts and/or housings:

- Visual check: surface conditions, defects, cleanliness, etc.
- Measurements and inspections: out-of-round, dimensions

Check the diameters of the shafts and cylindrical housings in 4 radial directions and at 2 levels of depth using an interior gauge and a micrometer.

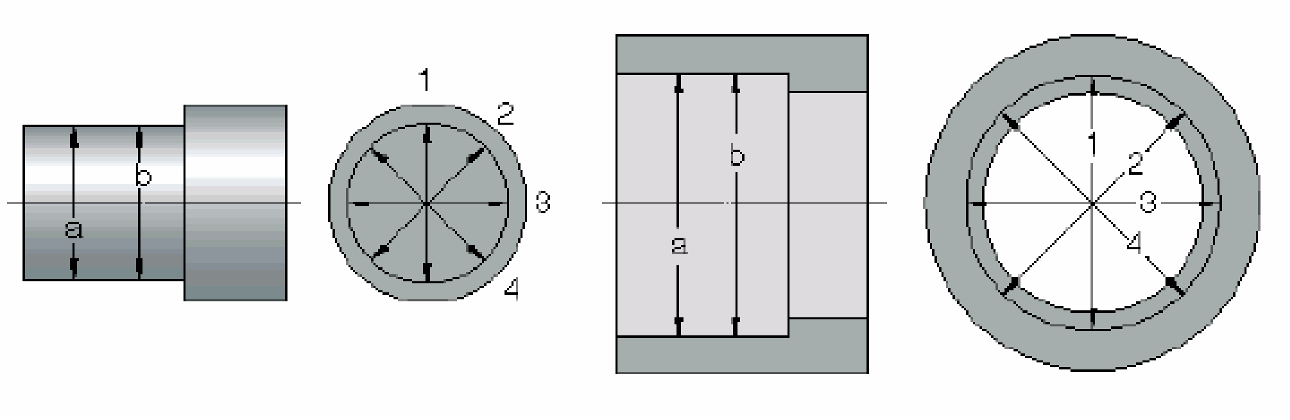


Figure 105: Measurement points

For large bearings, it is important that the parts and measuring apparatuses should be at the same temperature.

The setup methods vary according to the type and size of the bearing.

When the bearing bushing is installed on a shaft requiring a free fit, bearing installation is usually carried out by hand.

When the bushing requires a tight fit, there are several different installation methods:

- Cold fit (bushing on shaft)
- Hot fit

The bearings must not be heated to a temperature higher than 130° C, otherwise there will be a risk of the characteristics of the steel or of the bearing's internal components being modified.

Bearings equipped with flanges or seals, filled with grease, should not be hot-fit or, if it is essential, you must never heat them to more than 80° C.

You must absolutely avoid overheating the bearings locally (blowtorch). Consistent heating can be achieved without any risk using an electrical heater tool, an oven or an oil bath.

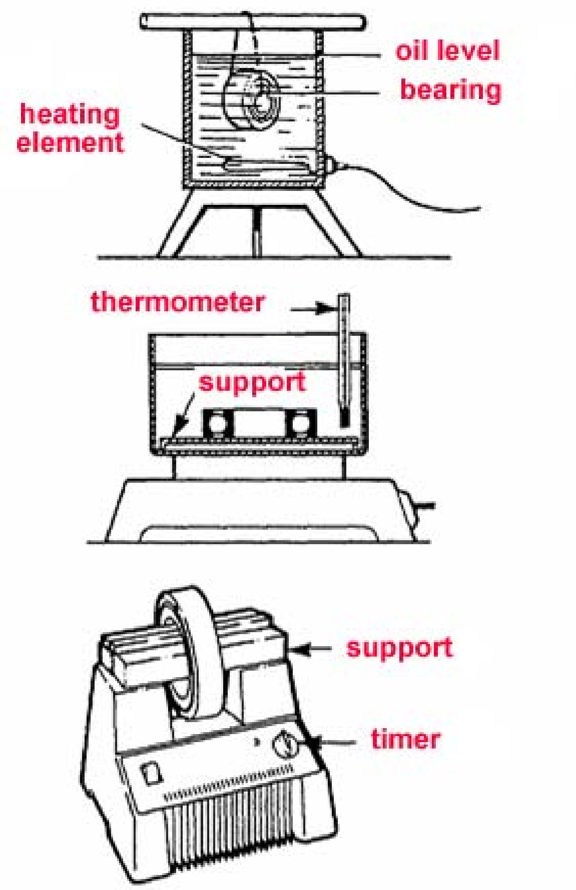


Figure 106: Example of bearing heating

In the case of an outer bearing requiring a tight fit (in its housing), tight fitting is usually carried out cold, because it is difficult to heat the housings.

In this case, we use a mounting bush (or, where applicable, a metal tube).

Bearings mounted on a tapered support or on a tightening collar are easier to install. A tightening nut (pre-stressed) tightened with a wrench will block the bearing.

When a bearing is blocked with this type of nut, we usually use a lock washer which locks the nut and thus prevents any untimely loosening.

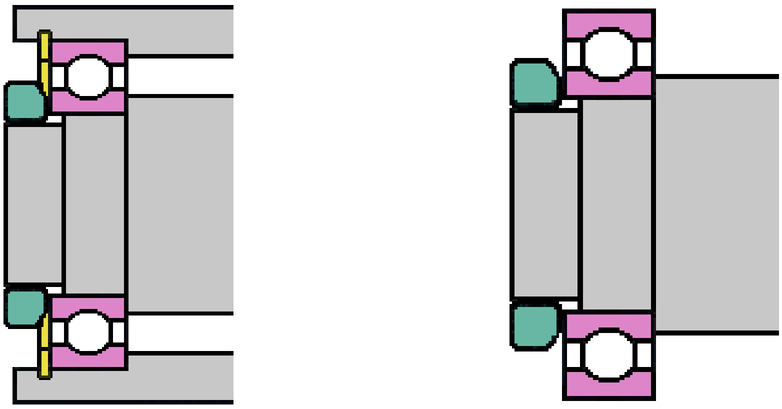


Figure 107: Mounting with and without a washer

The installation force must not in any event be transmitted via the rolling element.

Never hit the bearing directly with a hammer.

Keep the bearing in its packing until the time of installation to avoid dirtying it.

7.3.1. Cold tight-fit (bushing on shaft)

This method requires the use of a mounting tool (mounting bush also called punch bush, see illustration, hydraulic press).

If you do not have this type of tool, you can use a metal tube instead with the same Ø as the bearing bushing on which it is to bear (alternative solution)

You must also check that the bearing is perfectly installed on the shaft (risk of damage to the shaft).

7.3.2. Hot tight-fit

This method causes dilation making it possible to install the bearing easily by temporarily cancelling out the tight-fit.

Hot mounting makes it possible to dilate the bearing and install it on its shaft without any effort.

When the required T° has been reached, fit the bearing on to the shaft (dilation of the bearing makes it easier to fit). You just have to push the bearing to make it slide to its final position.

With this method, hold the bearing blocked against the shoulder during the cooling phase.

The bearing heating temperature depends on the dimensions and the tightness of the fit.

For your information, the following temperatures can be applied:

- Up to Ø 100 mm >> + 90° C
- Ø 100 to 150 mm >> + 120° C
- Ø 150 and above >> + 130° C

7.3.2.1. Induction heating

An induction apparatus makes it possible to heat the bearing using an induced electric current.

Figure 108: Examples of induction heaters

Figure 109: Induction heater apparatus

Figure 110: Induction heating (1)

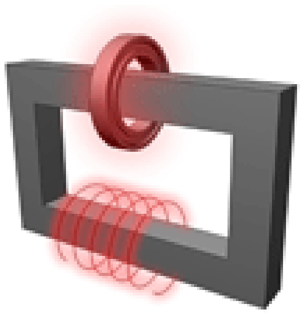


Figure 111: Induction heating (2)

7.3.2.2. Oil bath heating

Heat a bearing in an oil bath, (the oil temperature is given, in principle, in the apparatus's maintenance book. If this is not the case, you should use a T° of 100°), an oven or use a hotplate. (Or an induction apparatus; they are now found quite widely in workshops.)

If you opt for an oil bath, use the same oil as is used in the installation. (The oil must be clean and fluid.)

With this heating principle, locally higher temperatures could damage the bearing. To avoid this, you just have to place an insulating support between the bearing and the bottom of the container (see figure).

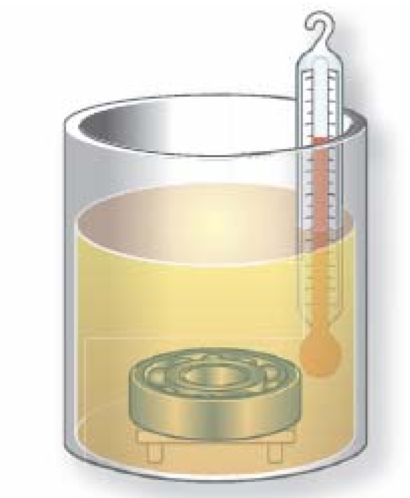


Figure 112: Oil bath method

7.3.2.3. Heating on a hotplate

Place a shim between the hotplate and the bearing if the hotplate does not have an automatic temperature regulation system.

For sealed bearings, you must absolutely position a shim.

If you use a hotplate, you will have to turn the bearing over several times.

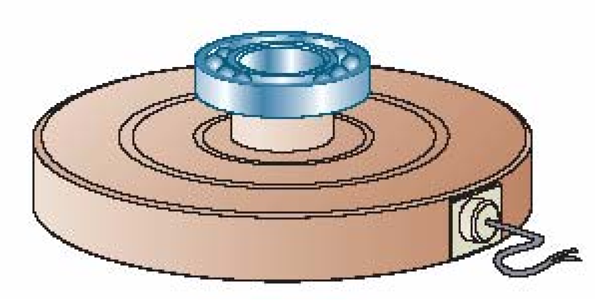


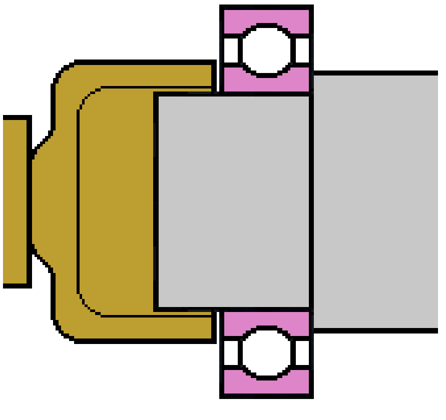
Figure 113: Electric hotplate

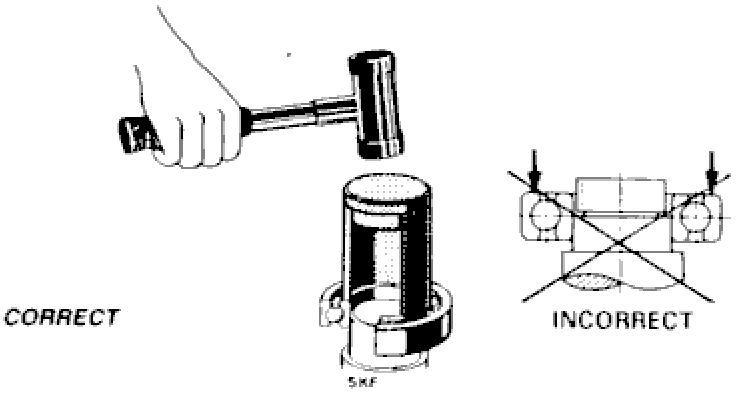
7.3.3. Combined hot / cold method

There also exists a method where you can use hot and cold fitting at the same time. To do this, you just have to put the shaft in a liquid nitrogen bath (-170° C) which will cause it to contract, and when the bearing has been heated to the required temperature, you will be able to fit it on to the shaft very easily (slide it on to the shaft).

7.3.3.1. Inner bushing with tight fit

Always apply the force to the bushing to be installed. Here, it will be the inner bushing.





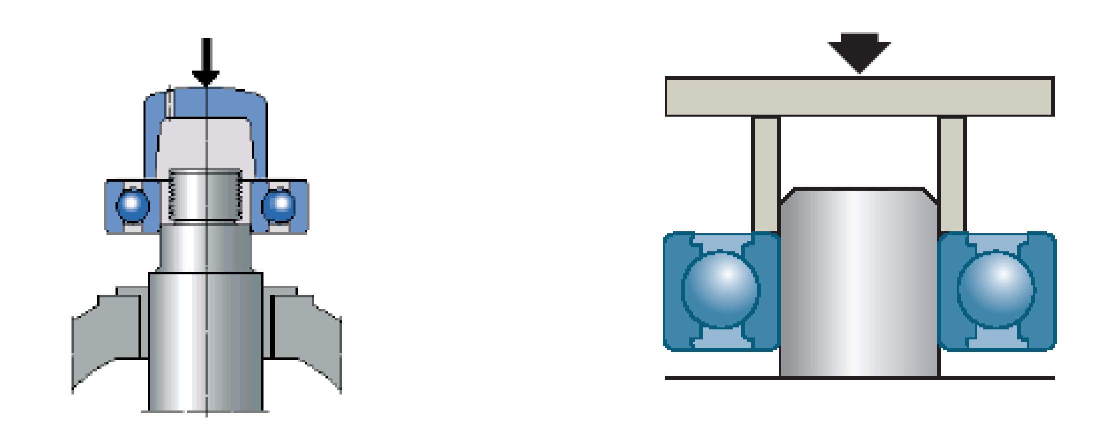


Figure 114: Tight-fitted inner bushing

7.3.3.2. Outer bushing with tight fit

Here the force must be applied to the outer bushing.

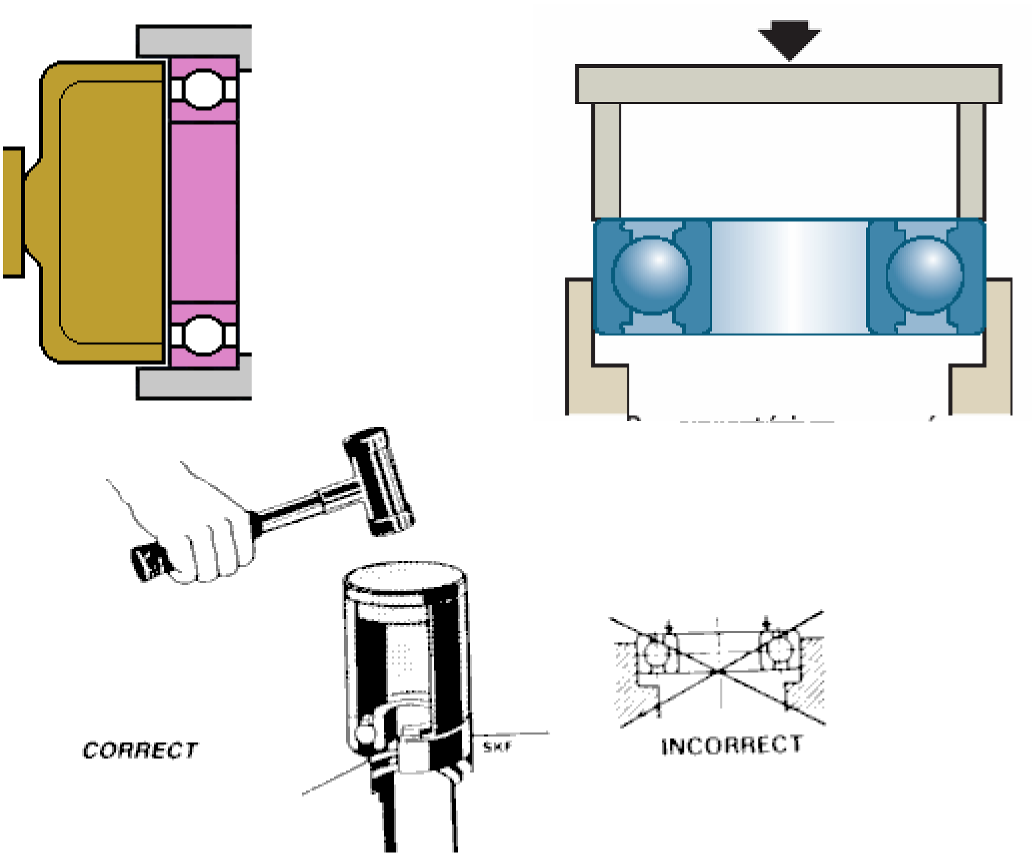


Figure 115: Tight-fitted outer bushing

7.3.3.3. Two bushings with tight fit

In this case, the tool must bear on the 2 bushings at the same time.

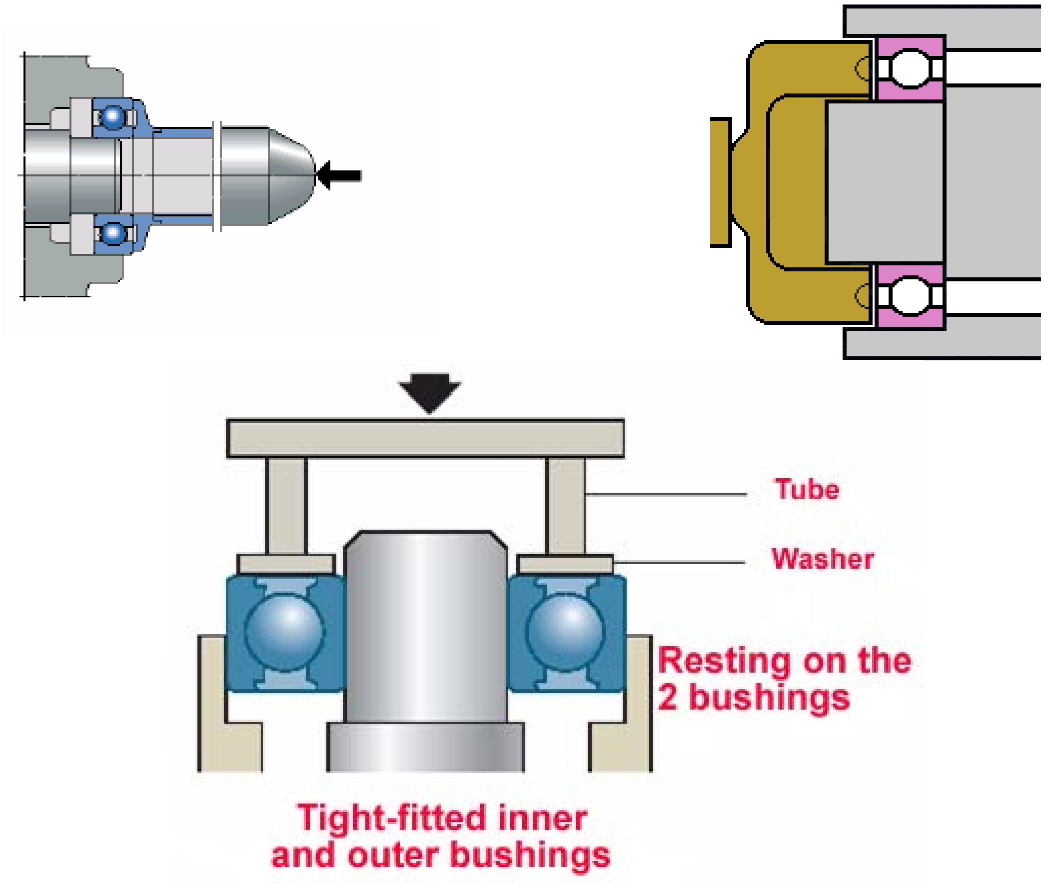


Figure 116: Two tight-fitted bushings

7.3.4. Some installation applications

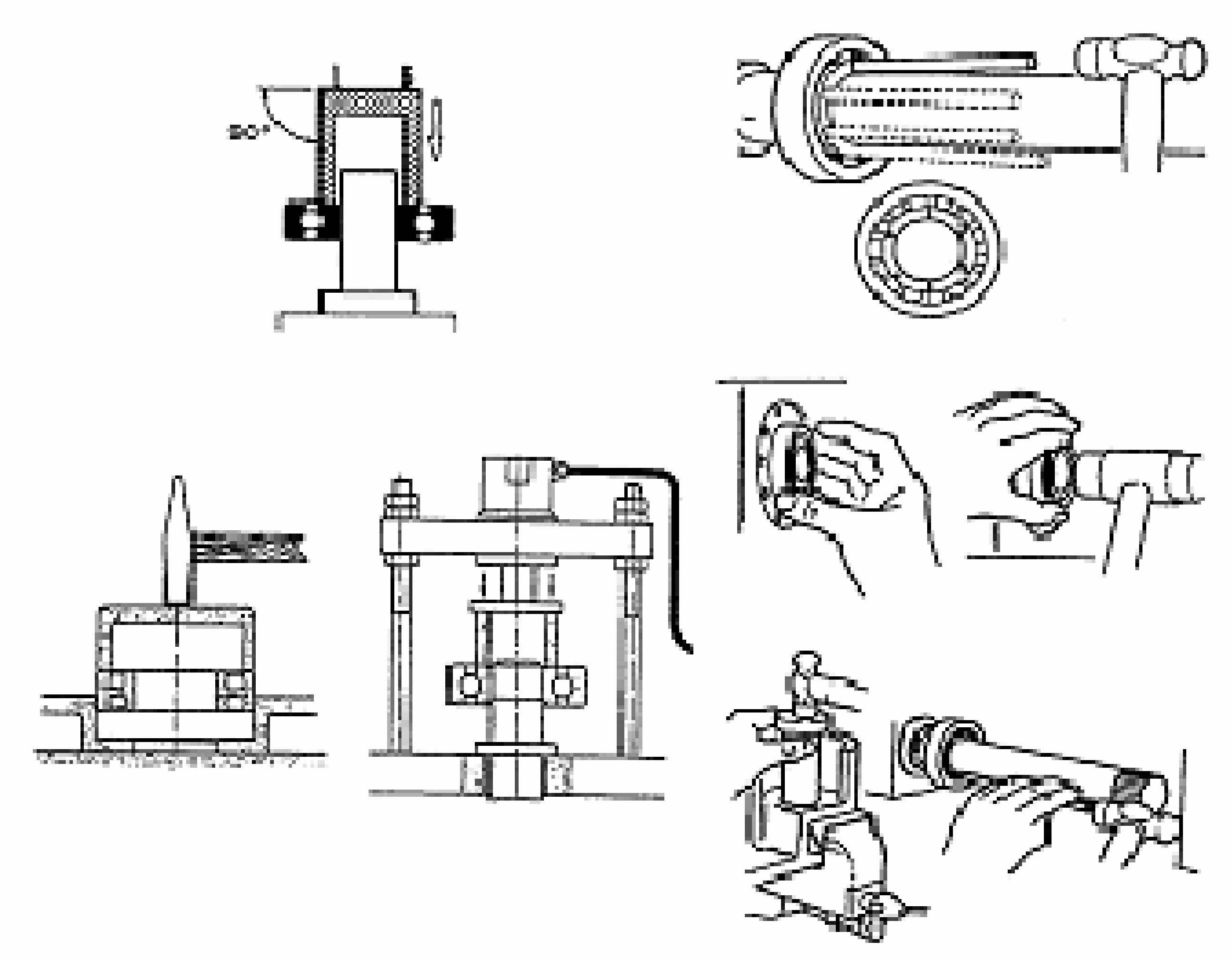


Figure 117: Examples of installation

7.4. REMOVAL

Like for installation, there are several methods for removing a bearing.

For free-fitting bushings, remove by hand.

To disengage a bearing (small size), you can proceed by striking lightly with a hammer, applied via an extraction drift (bronze drift) on the corresponding face of the bushing. You must take care to distribute the blows evenly around the whole circumference.

You can also use a mechanical (or hydraulic) extractor bearing directly on the face of the bushing to be removed.

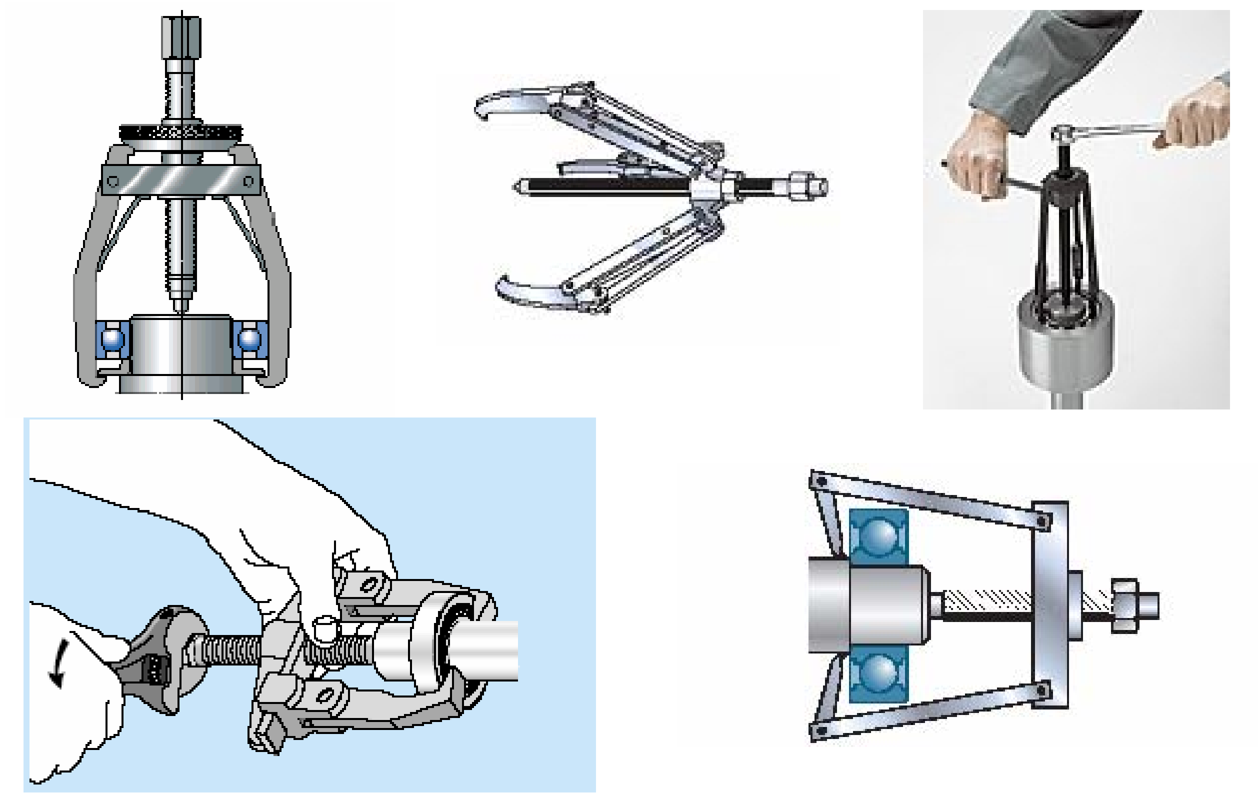


Figure 118: Different types of extractor

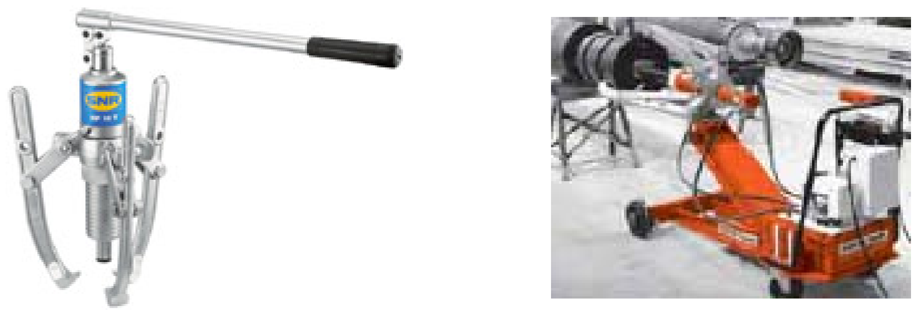


Figure 119: Hydraulic extractors

Figure 120: Installation and removal tools

The extraction of large-dimension tight-fitted bearings requires great force. The oil pressure method will be very useful in this case. But this means that distribution channels and grooves must have been provided for in the installation.

Holes allow a high pressure pump to be connected so that oil can be injected between the shaft bearing surface and the inner bushing. The bearing can be removed thanks to the elastic dilation of the inner bushing.

For bearings removed using this method, it is necessary to have a thrust nut, because the bearing is disengaged very brutally, it must therefore be blocked to prevent it from being ejected.

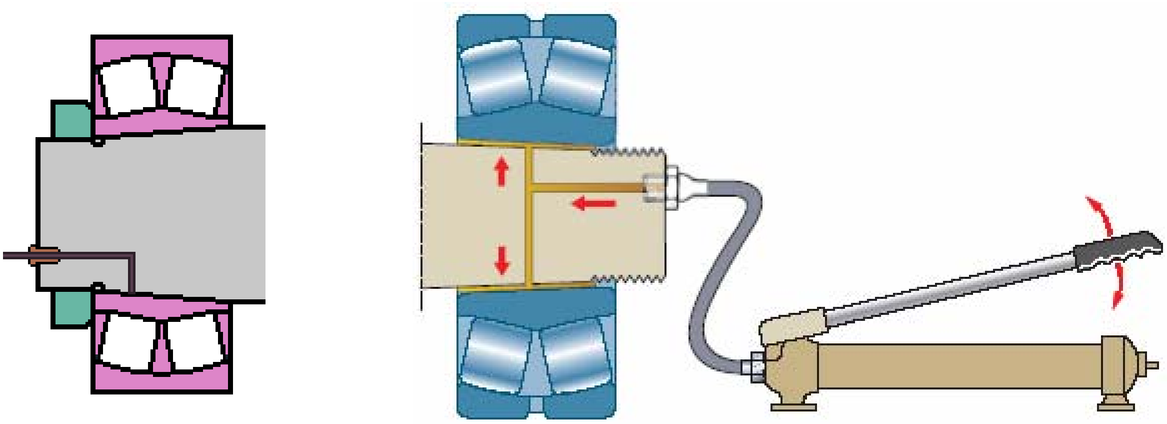


Figure 121: Extraction by oil pressure

7.4.1. Bearing tight-fitted on the shaft

If you do not have an extractor, you should use a vice. The inner bushing rests on a support above the jaws, and the shaft is suspended freely between them.

The extraction force is exerted with a hammer (or a hydraulic press).

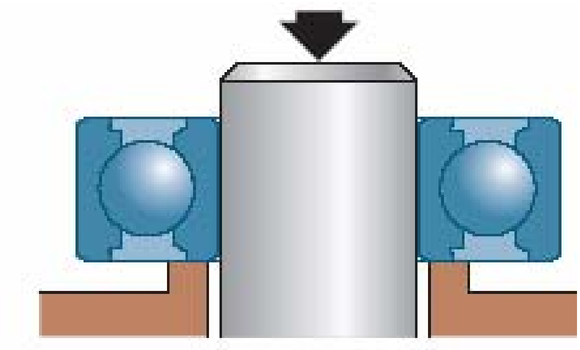
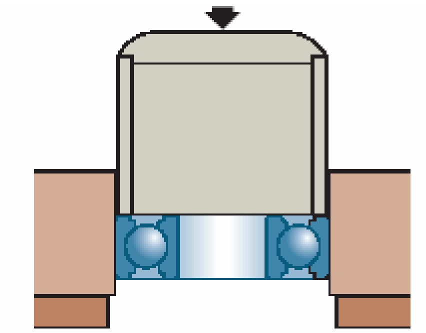


Figure 122: Bearing tight-fitted on the shaft

7.4.2. Bearing tight-fitted in the housing



The removal force is exerted on one of the faces of the outer bushing using a bush.

You just have to hit it with a hammer to extract the bearing.

Figure 123: Bearing tight-fitted in its housing

7.4.3. Bearing tight-fitted on its shaft and in its housing

You must allow the shaft to follow the bearing when you extract the latter from its housing. The force must be exerted on the outer bushing and not on the shaft.

The bearing must then be "torn out" of the shaft using an extractor or an extraction drift.

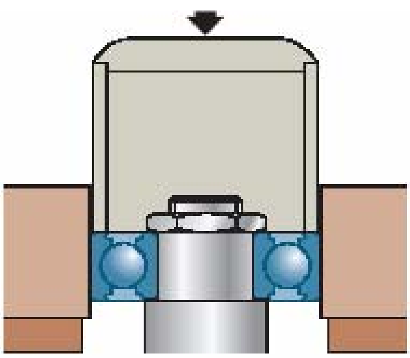


Figure 124: Bearing tight-fitted on its shaft and in its housing

7.4.4. Some examples of removal

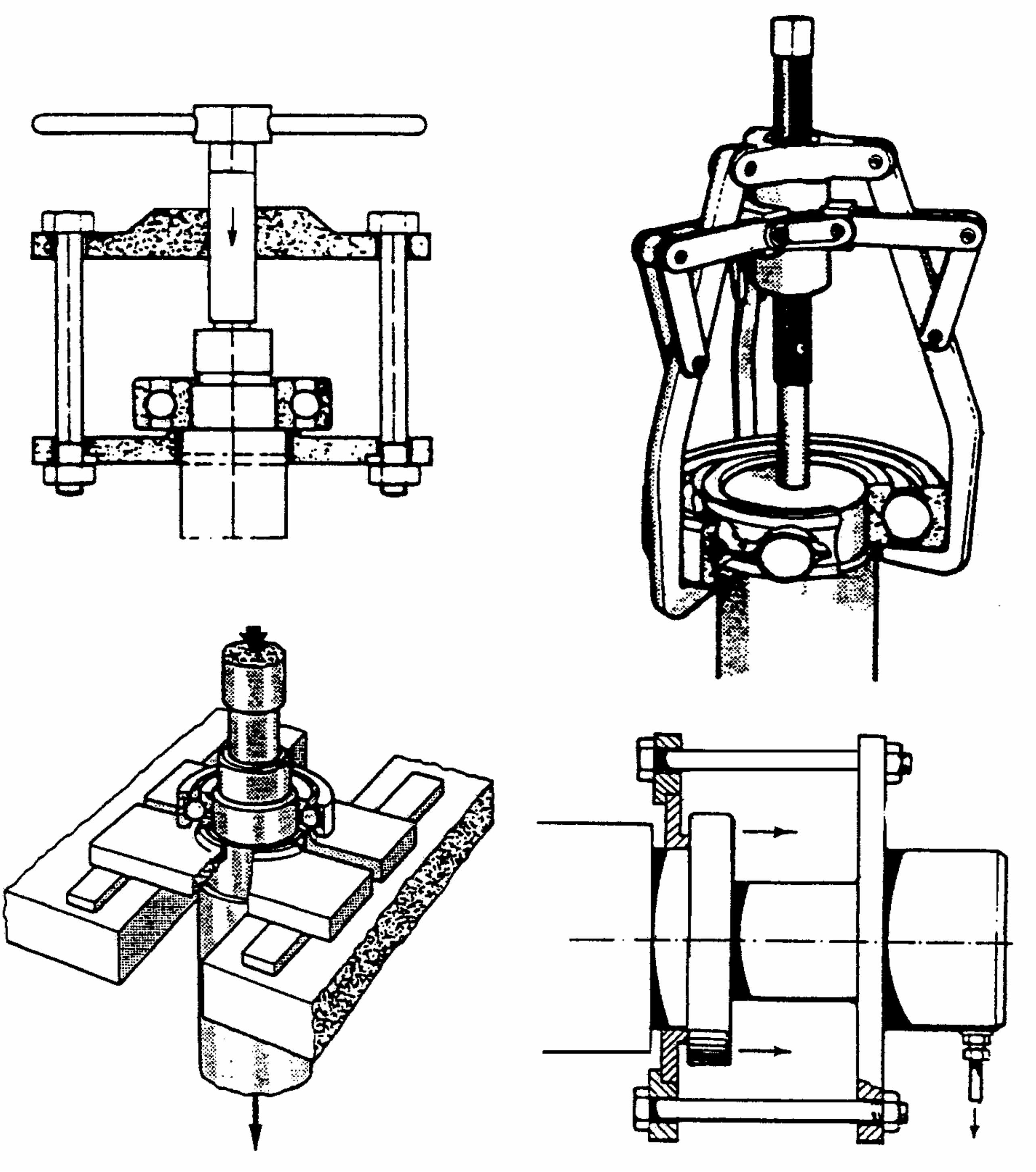


Figure 125: Removal methods

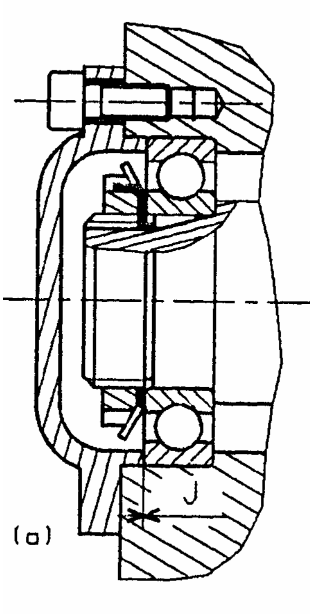
7.5. IMMOBILISING BEARINGS

Even by choosing the bearing correctly, its functions will not be correctly fulfilled if the shaft and/or housing in which it is mounted is not correctly designed.

To minimise the lamination phenomenon (crushing of the material) between the surfaces submitted to heavy loads, we must eliminate the play of the rotating bushing with respect to the load.

- The bushing that rotates with respect to the direction of the load applied to the bearing is tight fitted >> it must be perfectly immobilised axially.
- The bushing that is fixed with respect to the direction of the load applied to the bearing, must be fitted with play. It ensures the axial positioning of the rotating assembly with respect to the fixed part.

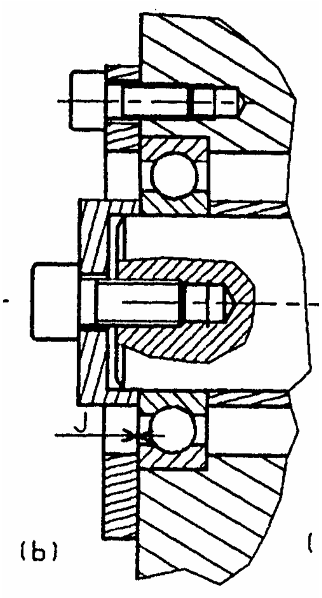
In most installations, the bushes that are tightened radially (rotating with respect to the load direction) must also be blocked axially. The shoulders are used to position the installation axially whereas the caps, elastic rings, etc. are used to hold the installation in position axially.



Axial immobilisation of the outer bushing by means of a cap held by screws

Axial immobilisation of the inner bushing by a castellated nut

Figure 126: Bearing immobilisation (1)

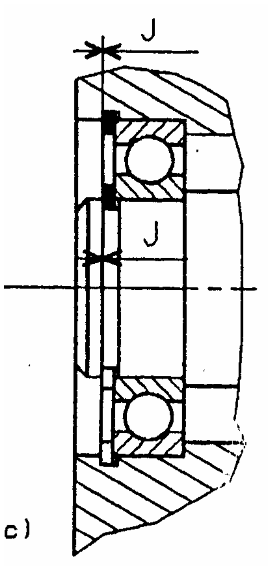


Axial immobilisation of the outer bushing by a washer held by screws

Axial immobilisation of the inner bushing by a washer held by a screw (*)

Figure 127: Bearing immobilisation (2)

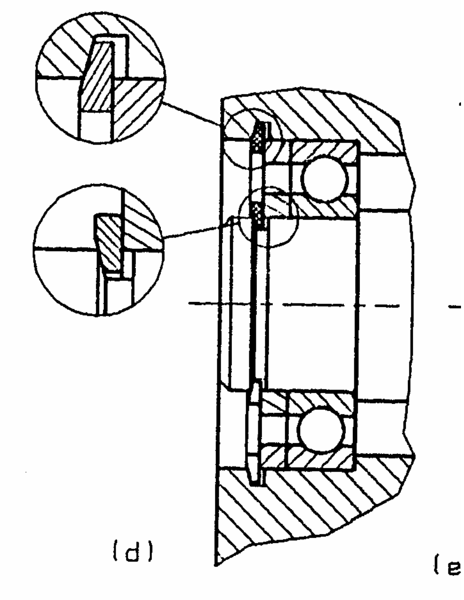
(*) For a rotating shaft, the washer must be centred to avoid any imbalance phenomenon. For a large Ø shaft, the washer may be fixed with several screws carefully distributed in holes tapped in the end of the shaft.



Axial immobilisation of the outer bushing by an elastic ring

Axial immobilisation of the inner bushing by an elastic ring

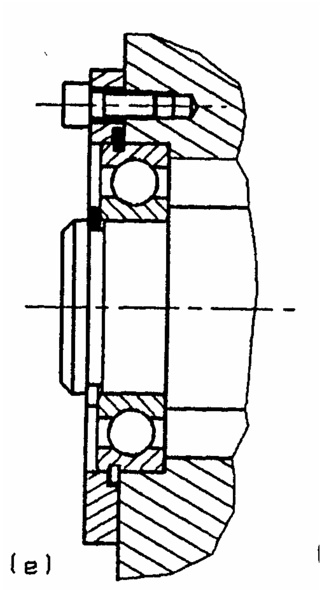
Figure 128: Bearing immobilisation (3)



Axial immobilisation of the outer bushing by a chamfered elastic ring (elimination of the axial play between the bearing and the borehole)

Axial immobilisation of the inner bushing by a chamfered elastic ring (elimination of the axial play between the bearing and its contact on the shaft)

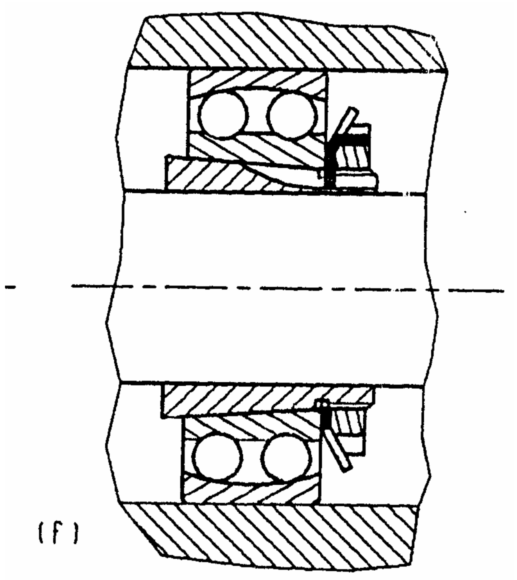
Figure 129: Bearing immobilisation (4)



Axial immobilisation of the outer bushing by a ring provided on the bearing's outer bushing

Axial immobilisation of the inner bushing by an elastic ring

Figure 130: Bearing immobilisation (5)



Axial immobilisation of the inner bushing by a tapered tightening collar (making it possible to avoid machining a shoulder on a long shaft)

Figure 131: Bearing immobilisation (6)

7.5.1. Examples of axial immobilisation of outer bushings

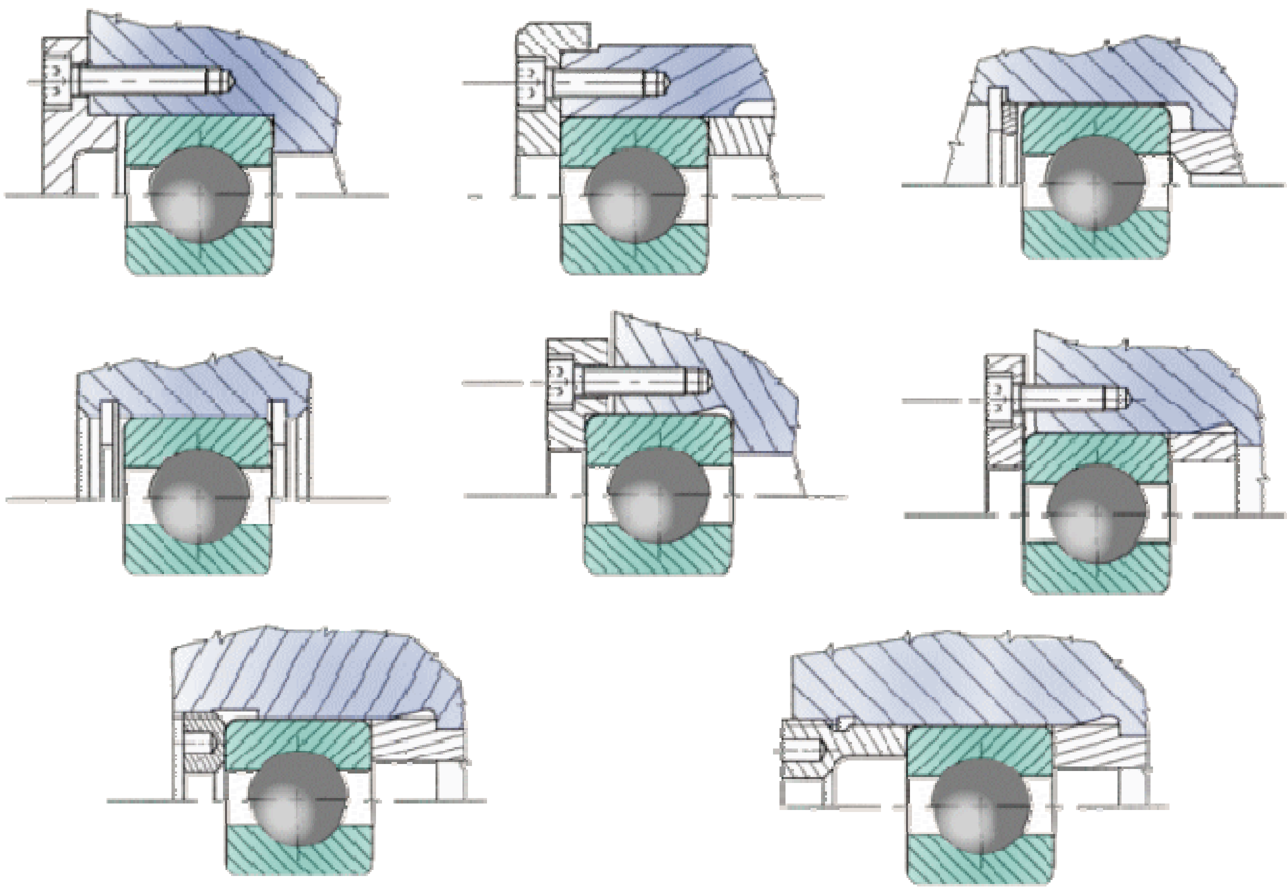


Figure 132: Immobilisation of outer bushings

7.5.2. Examples of axial immobilisation of inner bushings

7.5.2.1. In the middle of the shaft

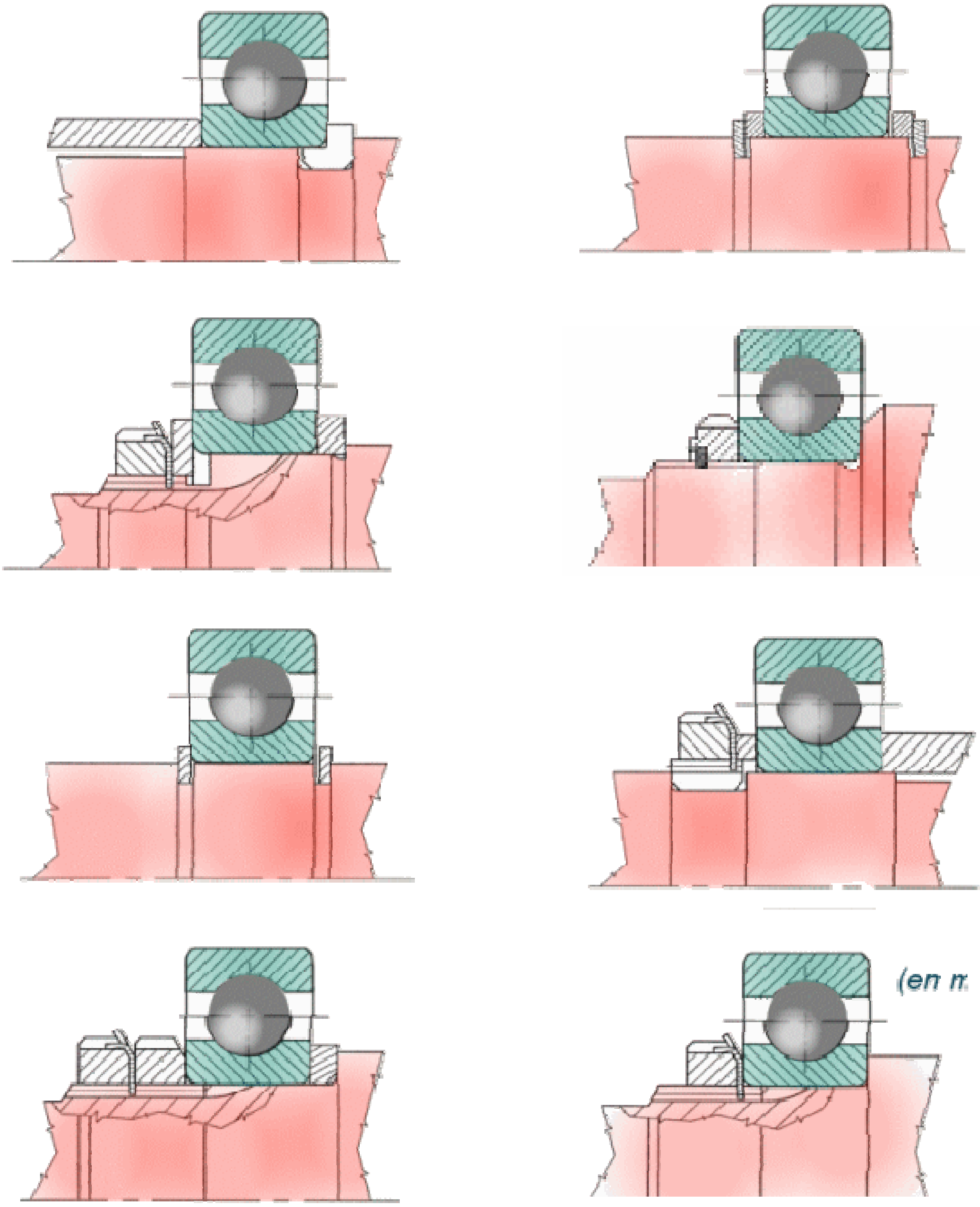


Figure 133: Immobilisation of inner bearings in the middle of the shaft

7.5.2.2. On the end of the shaft

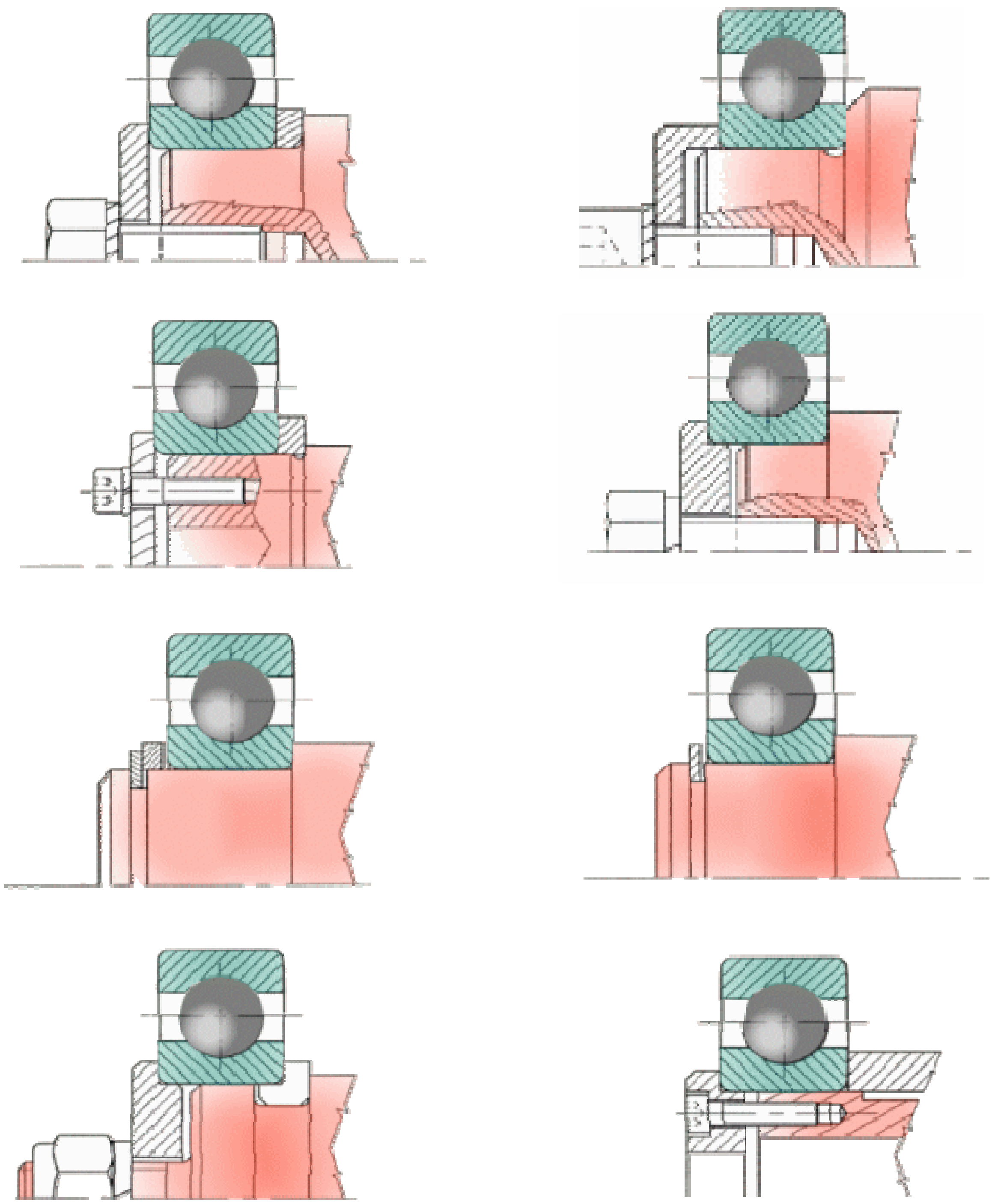


Figure 134: Immobilisation of inner bushings on the end of the shaft

7.5.3. Tightening nut and lock washer

In order to block a bearing axially, you can also use a tightening nut accompanied by a lock washer (case of locking an inner bushing). Loosening is not possible with this method.

7.5.3.1. Tightening nut

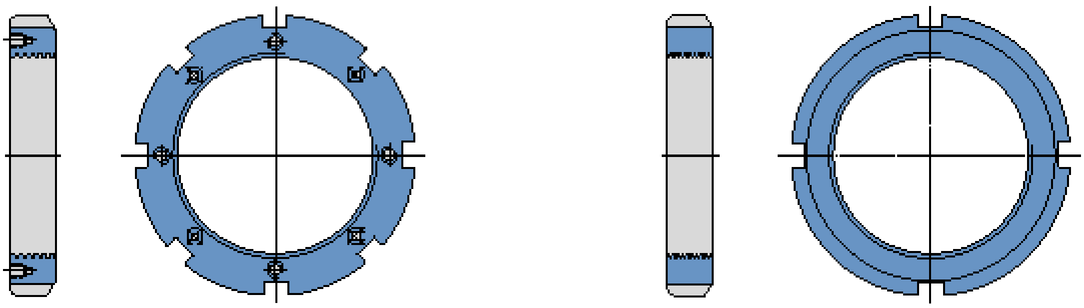


Figure 135: Tightening nut

7.5.3.2. Lock washer

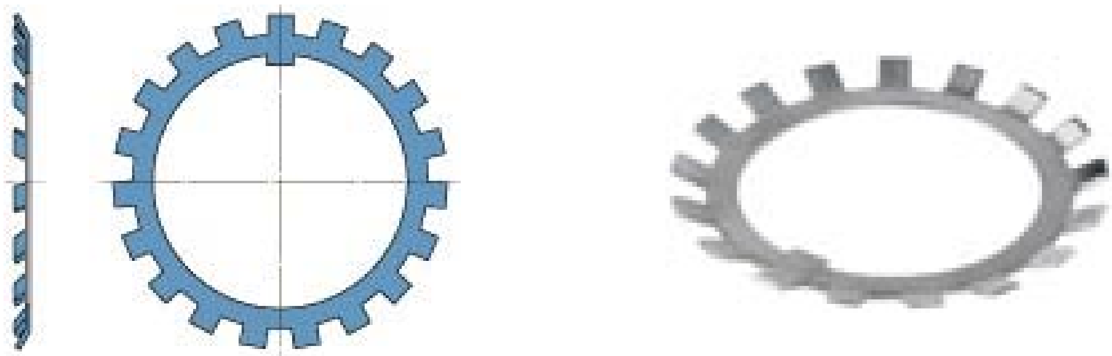


Figure 136: Lock washer

Figure 137: Elastic rings (circlips)

8. LUBRICATION METHODS

To ensure that bearings have an optimum efficiency, they must be lubricated in such a way as to avoid any direct contact between the rolling elements (bearing races and cages), prevent wear (bearing service life) and protect the surfaces against corrosion.

This paragraph applies to bearings without integrated sealing, therefore for bearings without seals or flanges. For the sealed version, the bearings are lubricated for life.

There are a large number of greases and oils for lubricating bearings. There are also solid lubricants (installation subject to extreme temperature conditions).

Favourable operating temperatures are obtained when the bearing receives the minimum amount of lubricant required for reliable lubrication.
Larger quantities of lubricant will be required if it has to fulfil other functions such as sealing or heat removal.

The lubricating power of a grease or oil decreases over time (aging, contamination). Grease will therefore have to be added (or even completely replaced), and the oil filtered and changed periodically.

8.1. LUBRICATION WITH GREASE

Grease is used to lubricate bearings under normal operating conditions.

It has the advantage of being more easily retained in the installation (especially if it is an upright installation), it protects against contaminants, humidity and water.

Too much grease will cause the operating temperature to rise, above all at high rotation speeds. Only the bearing must be filled (the free space in the bearing block must only be 50% filled with grease).

If the bearings must rotate at very low speeds, while being protected against contamination and corrosion, the bearing block should be completely filled with grease.

Greases that get softer risk seeping out of the installation, and those that harden at low temperature may hinder bearing rotation. The consistence of the greases used to lubricate bearings must not vary excessively with the temperature.

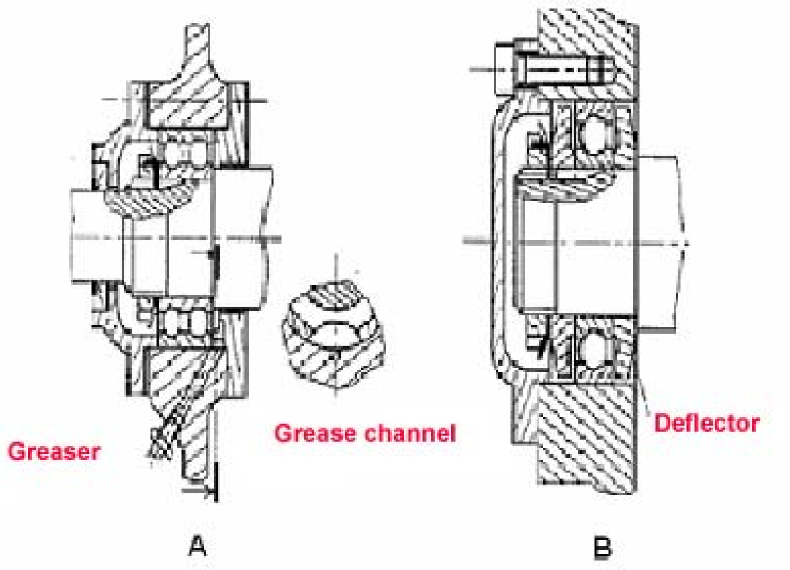
A grease consists of a thickener, metallic soap or other, a mineral-based or synthetic oil and additives. The properties of greases therefore depend mainly on the base oil, the thickener and the nature of the additives.

In applications subject to vibrations, the grease is worked severely. In this case, a very consistent grease must be used. But a firm grease is not sufficient to guarantee correct lubrication. Greases with a good mechanical stability shall be used.

Grease ages and oxidises quickly as the temperature rises.

Bearings must be re-lubricated if the grease's service life is shorter than that of the bearing. A grease's service life depends on several factors:

- Bearing's rotation speed
- Loads supported
- Temperature
- Quality of the grease
- Bearing's dimensions
- Environment



***A** : assembly including a greasing channel* ***B** : assembly including a deflector (to retain the grease during rotation)*

Figure 138: Lubrication with grease

The grease can be renewed by dismounting the bearing block or by using a greasing system: greasing channel, union and pump (in this case, when greases is injected the new grease drives out the old grease). The grease ejection port must be free, so to avoid any accumulation of lubricant, and prevent impurities or old grease from remaining inside the bearing block.

8.1.1. Grease selection criteria

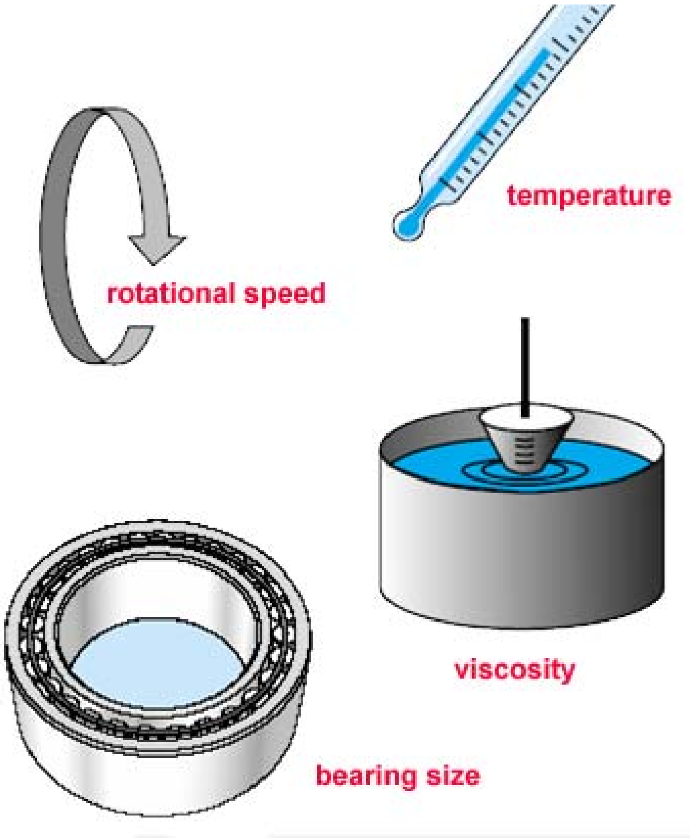


Figure 139: *Grease selection factors*

Criteria for selecting a type of grease:

- Bearing size
- Rotation speed
- Utilisation temperature
- Grease viscosity

8.1.2. Compatibility between greases

From time it may be necessary to replace one grease with another one to correct a problem caused by a product in service. If the thickening agents are incompatible, the properties of the mixture will be less good than those of each of its constituents alone. The old grease will then have to be completely removed.

The compatibility between greases also depends on the temperature because the more the temperature rises, the greater the compatibility problems

Greasing can also be carried out automatically. Automatic greasers are installed at the places to be lubricated in the installation (bearing blocks, bearings, etc.).

8.1.3. Manual greasing method

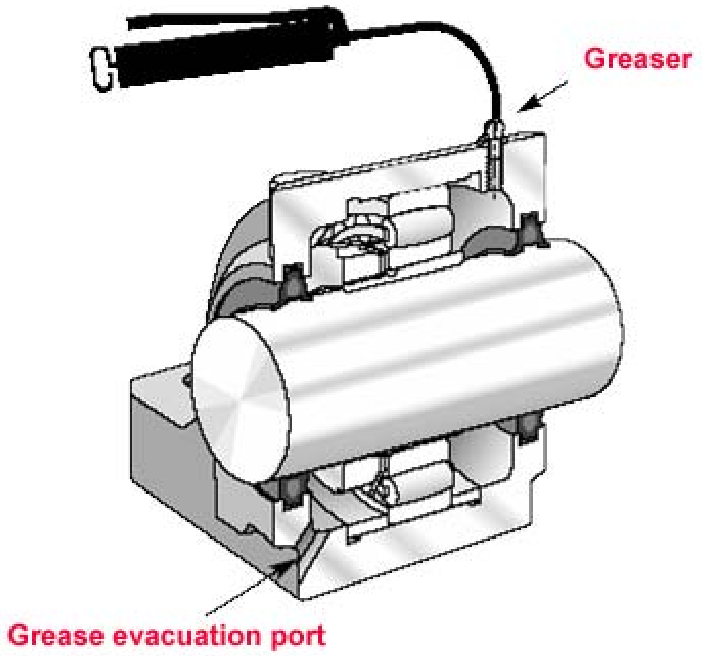


Figure 140: Manual greasing principle

Figure 141: Types of greasers found on an installation

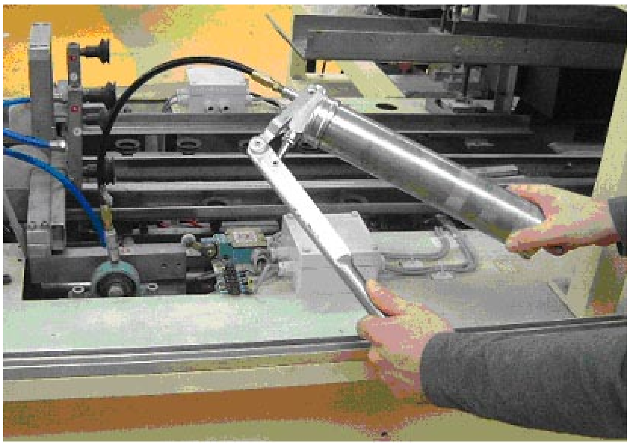


Figure 142: Manual grease pump

Caution: always take the greatest care when you use a pneumatic grease pump.

The installation's seals may be damaged because of the pressure of the compressed air.

Figure 143: Pneumatic grease pump

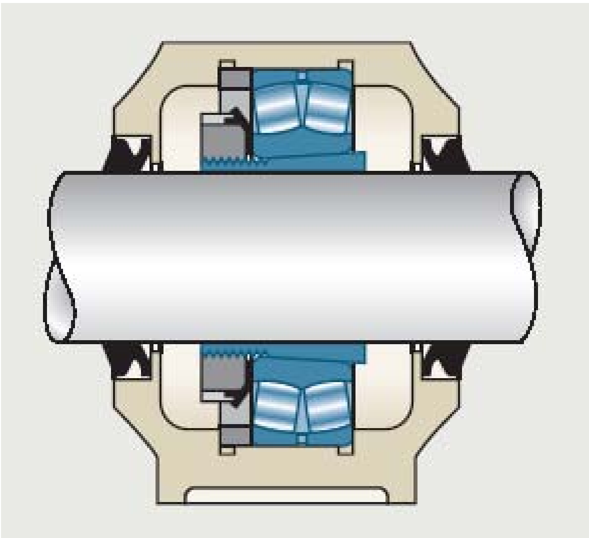


Figure 144: Manual greasing when shutdown

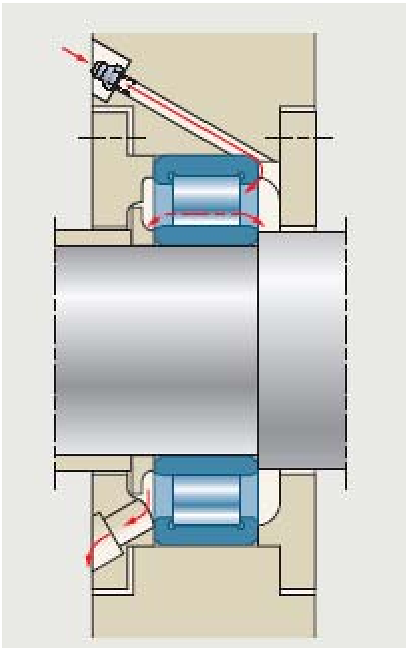


Figure 145: Manual greasing in operation with a grease pump

8.1.4. Automatic greasing method

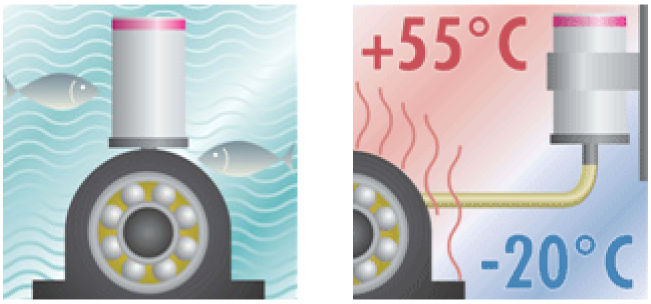


Figure 146: Automatic greaser on an installation

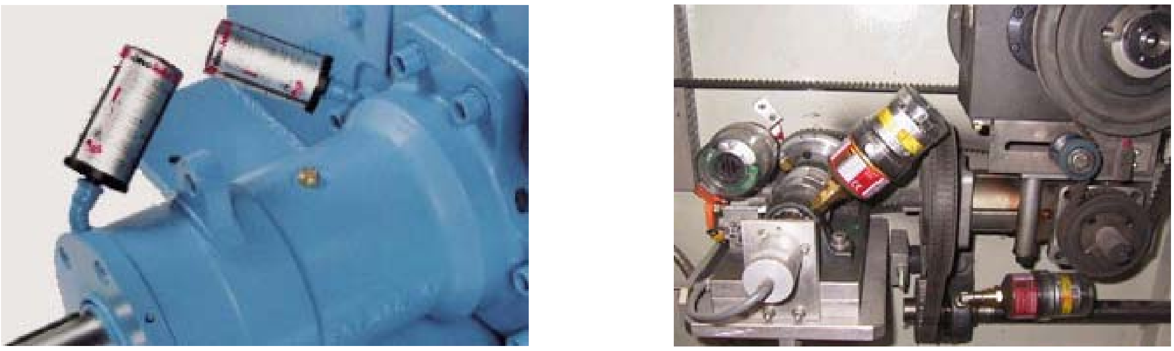


Figure 147: Automatic greasing principle

After putting into service, the cartridge produces a propulsion gas, generating a pressure that causes the piston to move and then expel the grease.

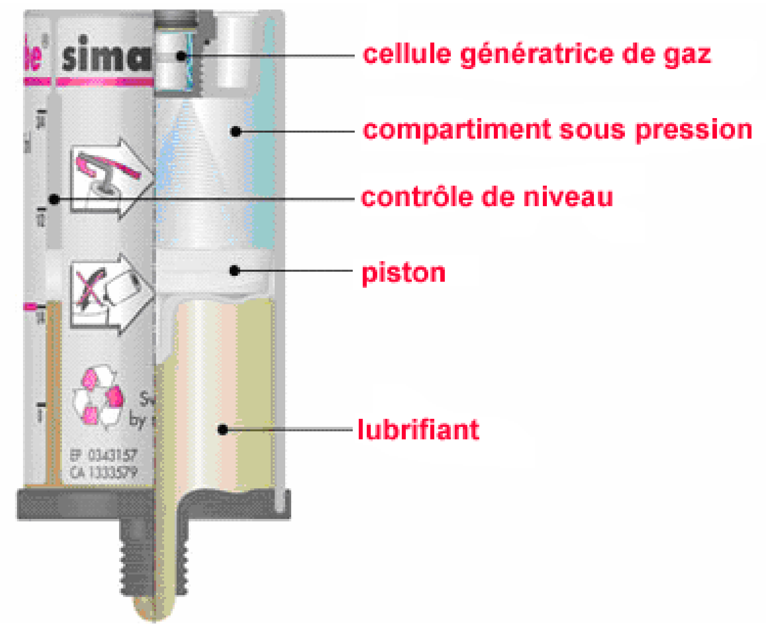


Figure 148: Automatic greasing cartridge

Figure 149: Example of an automatically lubricated bearing block

8.1.5. Advantages and drawbacks

Advantages of lubrication with grease:

- Easy to ensure sealing
- Simple setup
- Easy handling
- Installation cleanliness
- Possibility of pre-greased bearings

Drawbacks of lubrication with grease:

- Lower evacuation of heat
- Higher friction coefficient
- Need for a grease retainer
- If replacement of the grease load, disassembly of the bearing and washing
- Impossible to check the level (scheduled greasing)

8.2. LUBRICATION WITH OIL

Lubrication with oil is necessary when the rotation speeds or operating temperatures are too high for grease to be used.

This is also so when the lubricant contributes to bearing block cooling (heat evacuation) or if nearby elements (gears) are also lubricated with oil.

In general, pure mineral oils are used (that must of course be clean). Oils containing specific additives (good behaviour at extreme pressures, resistance to aging) are only used in special cases.

The oil is chosen according to the viscosity required to ensure lubrication of the bearing at the operating temperature. The viscosity depends on the temperature and decreases when the temperature increases.

There are several processes for lubricating with oil:

- Oil mist
- Oil circulation
- Trickling and projection
- Oil bath
- Lost oil
- Automatic gravity oilers

The renewal of oil depends on the mechanical and heat constraints, and on the quantity concerned. Frequent renewals must be scheduled in harsh operating conditions.

For lubrication by oil circulation and by oil spraying the intervals depend on the rotation frequency of the total quantity of oil in the circuit and the presence of a cooling system.

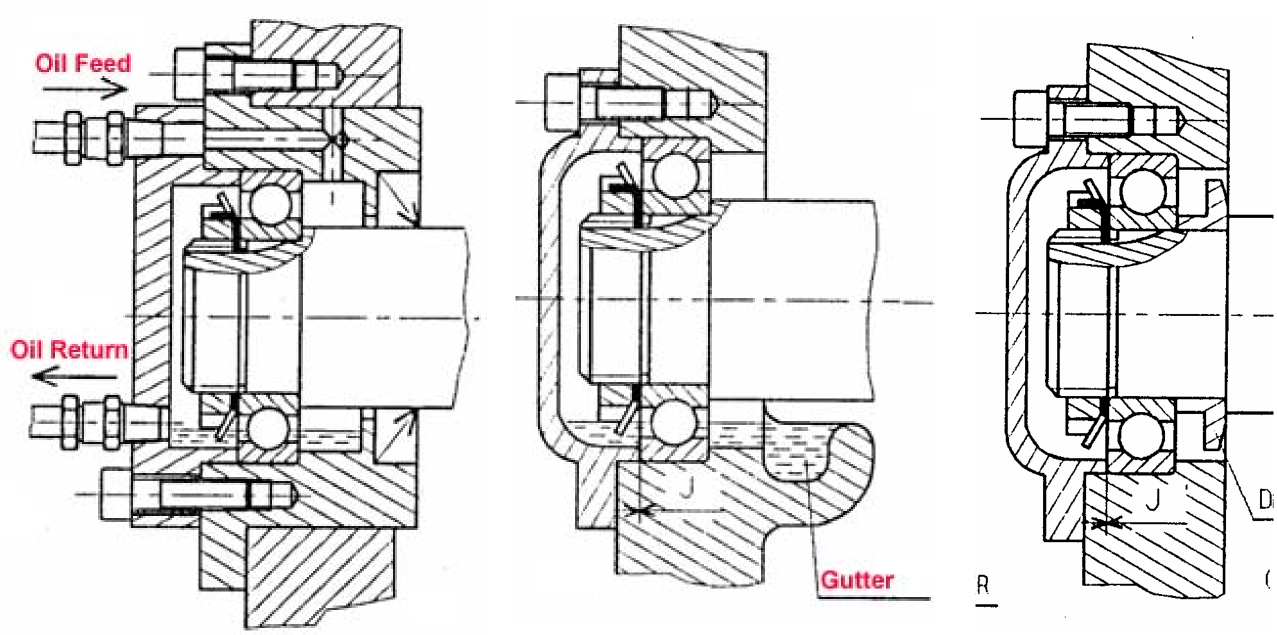


Figure 150: Different oil lubrication methods

8.2.1. By oil mist

This type of lubrication requires a large installation (spraying of a mixture of air+oil). It is reserved for the bearings of machine-tools rotating at high speeds.

Pressurised oil mist reaches every part of the bearing, it also contributes to the evacuation of heat from the installation and prevents the entry of foreign matter.

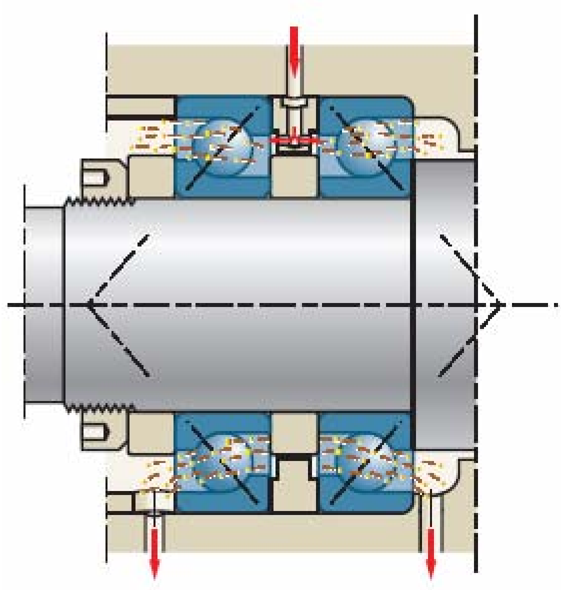


Figure 151: Lubrication by oil mist

8.2.2. By oil circulation

This type of lubrication requires a constant flowrate oil pump and jets placed appropriately in a circuit.

The oil may be filtered and cooled to obtain a higher performance.

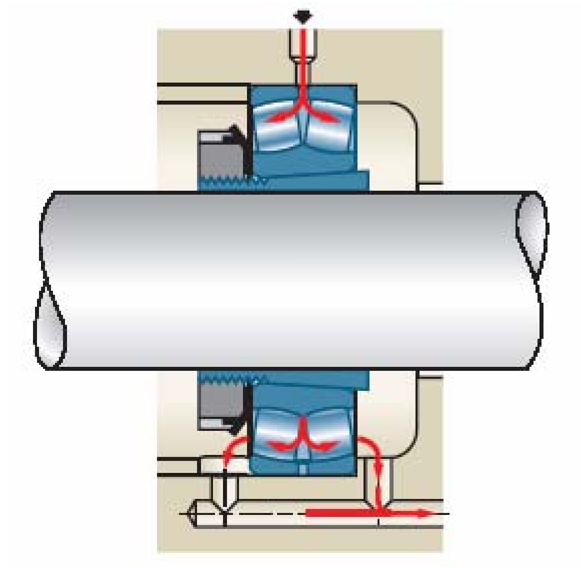


Figure 152: Lubrication by oil circulation

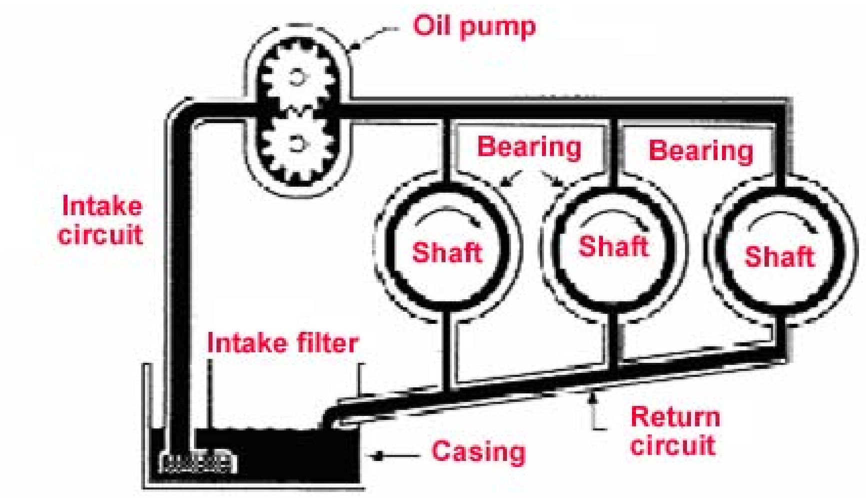


Figure 153: Intake circuit and return circuit

8.2.3. By trickling and projection

Projection is generally ensured by the gears.

Deflectors may be used to direct the oil towards the bearing.

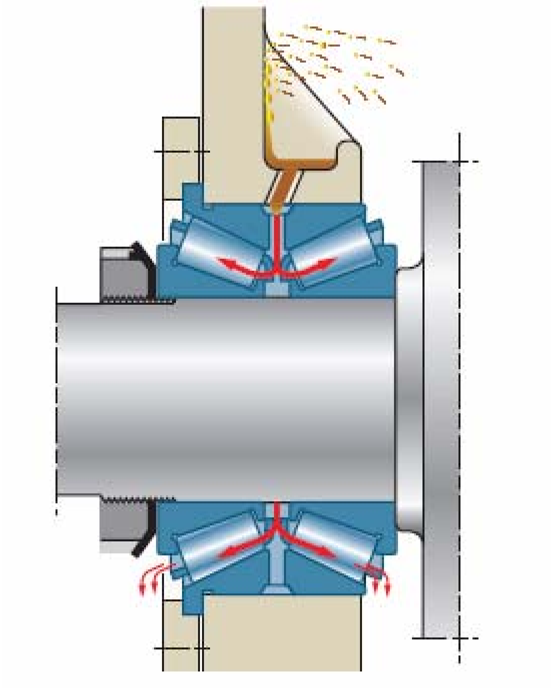
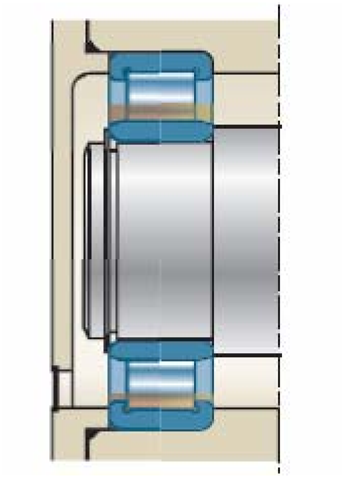


Figure 154: Lubrication by trickling and projection

8.2.4. By oil bath

The oil level must not exceed the centre of the lowest ball (or roller). For the bearings that are not situated in the lower part of the mechanism, retrieval systems – called gutters – will be required that are filled by projection, or oil circulation will have to be ensured by pumping.



If too much oil is projected, this may be limited by a deflector.

This process is used in closed and sealed installations.

As the evacuation of heat is reduced because the installation is closed, the rotation speed will be low.

Figure 155: Lubrication by oil bath

8.2.5. Lost oil

Used on installations rotating at high speed, so the oil that has already been used must be evacuated.

An oiler is placed in the upper part and the oil flows off by gravity.

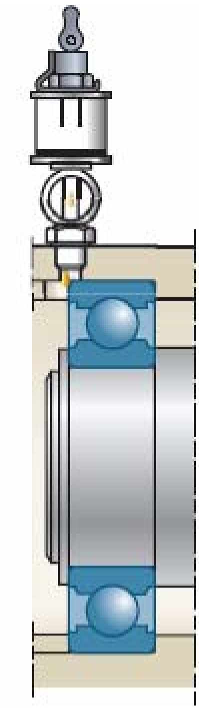


Figure 156: Lost oil lubrication

8.2.6. Automatic gravity oilers

Like for greasing, there are automatic oilers. They have the same function as the greasers and like them, they are located in the installation at the places to be lubricated.

Figure 157 : Automatic oilers

8.2.7. Advantages and drawbacks

Advantages of lubrication with oil:

- Check of the lubricant (level and condition)
- Evacuation of heat
- Good penetration into the bearings

Drawback of lubrication with oil

- Problem of lubrication when the installation is started up
- At the time of prolonged shutdowns, poor protection against oxidation and humidity
- Absolute sealing of the installation

8.3. LUBRICATION WITH SOLID OIL

There are bearings lubricated for life with a lubricant that does not have the appearance of grease or of oil.

This is a bearing called a "solid oil bearing". It is the French bearing manufacturer, SKF, that developed this system.

The lubricant is retained in a spongy polymer material saturated with lubricating oil. This material completely fills the bearing's inner volume while holding the cage and roller elements captive. It uses the cage as strengthening element and rotates with it.

By releasing oil, the solid oil system provides the correct lubrication to the rolling bodies and to the bearing races during operation.

When the temperature rises, the oil is directed to the surface. The oil's viscosity decreases as the temperature rises. When the installation is shutdown, the excess oil is re-absorbed by the polymer matrix.

This process was developed for cases where it is impossible to lubricate with grease or oil.

This bearing will be used in the case where, due to a lack of accessibility, it is impossible to re-lubricate the bearings, or in cases where an excellent protection against contaminants is essential.

Figure 158: Solid oil bearing

Furthermore, this process has numerous advantages:

- The supply of oil to the bearing is greater than with a conventional lubrication
- The contaminants remain outside
- Maintenance not required (no re-lubrication)
- The lubricant remains in place
- Resists most chemical agents
- Withstands high accelerations

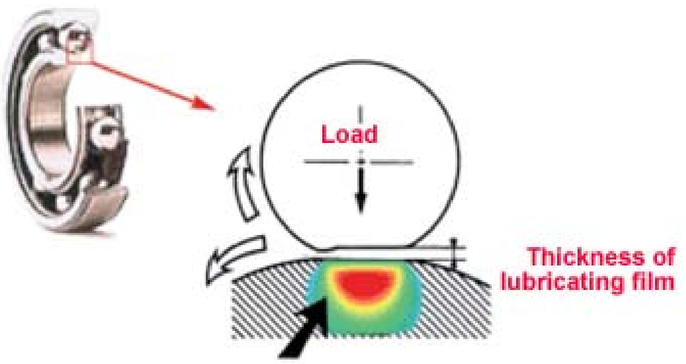
9. BEARING SERVICE LIFE

Each bearing is designed to be used in a given environment. It is a wear part, which has a given life expectancy and, by definition, is destined to suffer a "natural death".

The length of a bearing's life corresponds to its capacity to withstand fatigue.
To be more precise, it corresponds to the number of bearing revolutions before signs of chipping appear, that is to say the alteration of the surface condition of the bearing races or of the rolling parts.

Figure 159: Damaged bearing

The rolling parts create great cyclic compression and shear constraints on the race. The bearing bushings become cracked with the repeated passing of the rolling parts.



The contacts between the rolling parts and the bushings generate great loads:

- Compression on the surface
- Shearing beneath the surface

Figure 160 : Constraints on the bearing

The length of the bearing's life corresponds to its capacity to withstand these constraints.

The service life is a forecast, an estimate. It is based on the fact of having conditions that create cracking.

Certain parameters, usually abnormal ones, may cause a failure, or even the early deterioration of a bearing, in particular:

- Poor lubrication
- Contamination/pollution
- Incorrect installation

Figure 161: Chipping of an inner bushing further to incorrect installation

- Poor maintenance

- Fatigue
- Defective alignment
- Passing of an electric current

Figure 162 : Ball after passing of an electric current

On the left, a ball through which an electric current has passed.

<u>Friction torque:</u>

Friction torque is an important criterion for a bearing's satisfactory operation and the length of its life. It depends on the load applied on the balls, the rotation speed and the lubricant's properties.

These factors have an influence on the bearing's resistance to rotation:

- Resistance to rolling: depends on the roughness and geometry of the ball races and balls, and also on the load applied.
- Resistance of the seal (with contact where applicable): depends on the surface condition of the inner bushing's outer Ø and on the rotation speed.
- Resistance of the cage: depends on the shape and quality of the cages.
- Resistance of the lubricant: depends on the viscosity, filling dose, rotation speed.

Furthermore, a distinction must be made between 2 different friction torques:

- **Starting torque**: torque required to put the bearing into rotation;
- **Rotation torque**: torque required to maintain the bearing in rotation

10. BEARING MAINTENANCE

10.1. MEASUREMENT OF THE VIBRATIONS

A bearing has a limited life. To optimise this, it is necessary to have indicators characterising its condition and to regularly monitor the way it evolves in operation.

In this way, it is possible to identify any damage and schedule corrective maintenance operations at the best moment.

Vibration measurement and monitoring represents an effective way of verifying production equipment and determining its degree of wear.

Vibration follow-up on a rotary machine makes it possible to:

- diagnose the source of a problem, and determine the urgency of repairs
- know the degree of wear of a rotary machine in operation
- optimise technical shutdowns
- improve production tool reliability
- identify any imbalance, misalignment, defective bearings

10.2. LUBRICATION AND MAINTENANCE

This is a key element for the correct operation of a bearing. 70% of bearing failures are due to lubrication problems.

Bearings with seals are pre-lubricated, so there is no need to lubricate them after installation. However, in the case of open bearings, it is essential to lubricate them after installation and also in operation.

You must always use the bearing grease best suited to the application, so as to optimise the length of the bearing's life.

Lubrication ensures:

- Evacuation of heat (lubrication with oil)
- Longer service life
- Protection against corrosion

- Protection against external contamination
- Reduced friction/wear

For re-lubrication, that is to say lubrication in operation, it is very important to apply the right quantity of grease at the appropriate intervals.

Insufficient or excessive greasing, or an inappropriate lubrication method may shorten the life of bearings.

Figure 163: Grease and a bearing

Many premature bearing failures are due to inappropriate lubrication.

Conventional greases (multipurpose) are not suited to the specific needs of bearings and may have dramatic consequences for them.

Figure 164: Detail of greasing

The amount of grease depends on the size of the bearing. If no instructions concerning lubrication are given, here is a simple way of determining the amount of grease you should use:

$$Gp = 0.005 * D * B$$

Gp = amount of grease per top-up (in grams)
D = external Ø of the bearing (in mm)
B = width of the bearing (in mm)

For example, for a Ø 90 bearing with a width of 15, you will need:

Gp = 0.005 * 90 * 15 = 6.75 g of grease

When a bearing has to be re-lubricated frequently, grease may accumulate in the bearing block and, in the long term, cause a failure. This can be avoided by removing any excess grease via a grease valve.

This grease valve often consists of a disc that rotates with the shaft and forms a narrow passage with the body of the bearing block.

The excess grease is removed by the rotating disc and expelled through the port at the rear of the bearing block.

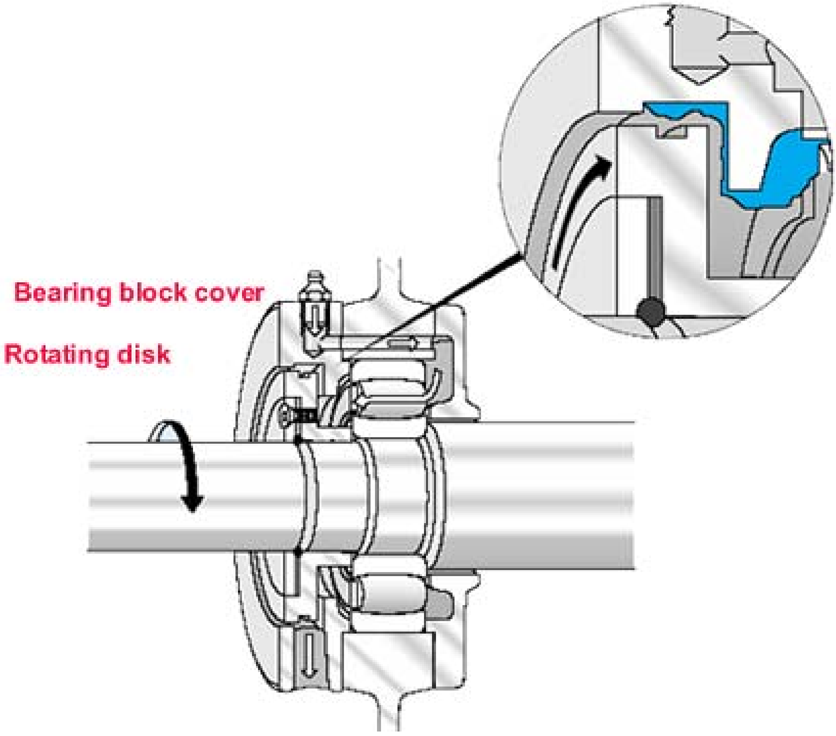


Figure 165: Detail of greasing

Grease must always be kept in its original packing. Never leave grease without any protection (foreign matter, grinding iron filings, etc.). Unprotected grease will very quickly become dirty.

10.3. MONITORING AND MAINTENANCE

Generally, the bearing in operation does not require any specific monitoring, apart from the scheduled topping up with lubricant required for the installation's satisfactory operation.

In certain installations, a bearing failure may have serious consequences for safety (aeronautics, nuclear power stations etc.). It may also have repercussions on the economy (production shutdown).

This is why it is necessary to monitor and maintain the bearings.

The most commonly used means of verification concerns vibration analysis. This can be done in a rough and ready way (listening with a stethoscope, a metal rod) or using more sophisticated means (frequency and amplitude analyser) that will make it possible to raise the alarm.

The main factors for ensuring high-quality verifications are the maintenance operator's experience and qualifications.

10.3.1. Bearing damage

There are several criteria for detecting bearing damage initiation:

- vibration
- noise
- temperature

Further to a problem with a bearing you must carry out an investigation.

This will be a source of information concerning the bearing's installation conditions, and its operating conditions.

This investigation must be carried out methodically and with great precision.

Before removal (installation in operation):

- Identify the noises
- Vibrations
- Temperature
- Level of lubricant

- Cleanliness

During removal (installation shutdown)

- Removal of the bearing block caps, seals (do not clean them)
- Remove the lubricant (grease or oil) if there is any left

These parts must be put away with care because they will have to be examined later on:

- Check (and note) the tightening torque at removal
- Check the bearing's axial and radial position (make marks)
- Check the condition of the parts around the bearing

After removal

- Visual inspection of the installation
- Disassembly of the bearing
- Inspection of its components
- Check of the lubricant (look for foreign matter)

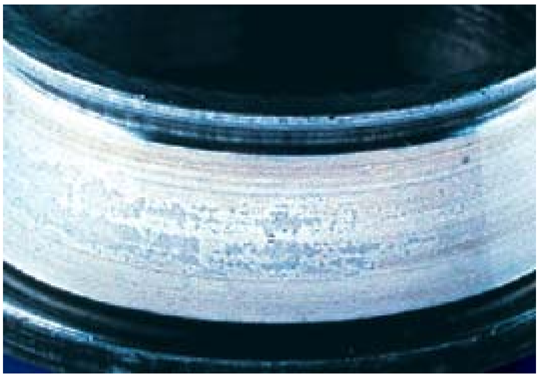
10.3.2. Aspects of deterioration

10.3.2.1. Fatigue chipping

Cracking, removal of matter

Figure 166: Removal of matter

10.3.2.2. Surface chipping



Stains on the surface due to the tearing off of metal

Figure 167: Surface chipping

10.3.2.3. Seizing

Peened zones with the removal of matter

Brown traces due to heating

Deformation of the rolling bodies

Micro-fusion

Figure 168: Seizing

10.3.2.4. Deformation imprint

Ball or roller imprints

Shiny bottom of the imprint

The matter is pushed back

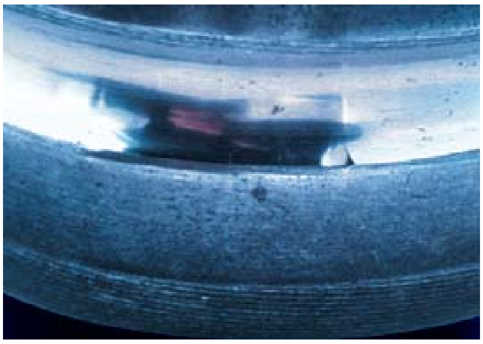
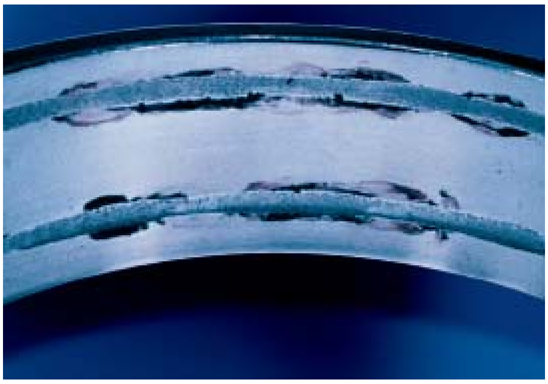


Figure 169: Deformation imprint

10.3.2.5. Wear



General wear of the rolling part

Grey colour (abrasive contamination)

Figure 170: Wear

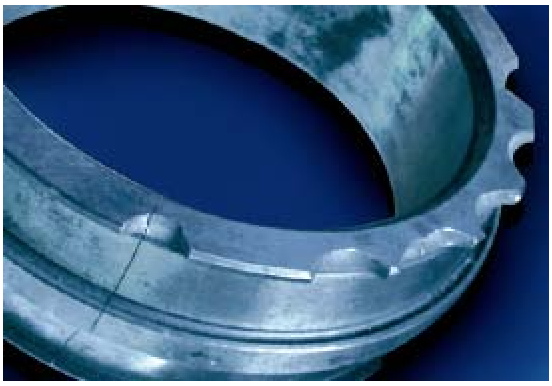
10.3.2.6. Craters and grooves

Pitting with well-defined edges

Succession of narrow strips due to the passing of an electric current

Figure 171: Grooving

10.3.2.7. Impacts, cracks, breakages



Violent shocks

Cracks

Removal of surface matter

Broken bushings

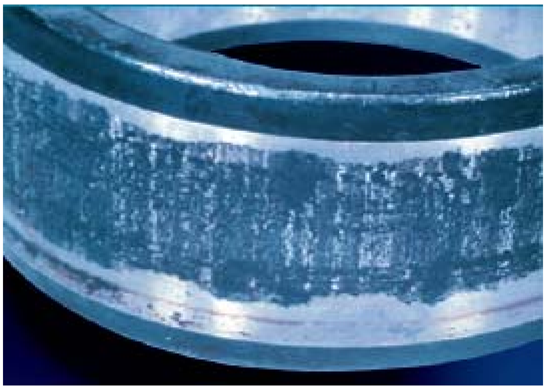
Figure 172: Breakages

10.3.2.8. Contact corrosion

Red or black colouring on the contact surfaces, in the borehole and on the outer Ø.

Figure 173: Contact corrosion

10.3.2.9. Corrosion



Oxidation (localised or general) inside and outside the bearing.

Figure 174: Corrosion

10.3.2.10. Damage to the cages

Wear

Breakage

Deformation

Figure 175: Breakage

10.3.3. Origins of damage

There are four main causes of damage:

1. **Poor installation conditions**
    - Contamination at time of installation
    - Insufficient and/or unsuitable means and methods
    - Forced installation
    - Poor lubrication
    - Misalignment

2. **Operating conditions**
    - Excessive vibrations
    - Excessive speeds
    - Frequent overloading
    - Shaft bending

3. **Environmental conditions**
    - Air temperature too low or too high

- Passing of an electric current
- Contamination (dust, water, chemical products, etc.)

4. Lubrication

- Poor quality of the lubricant
- Inappropriate lubricant
- Too high or insufficient greasing frequency

The bearing must be stored in its original packing, which must only be opened when the bearing is to be used.

To summarise, to ensure effective maintenance it is essential to be extremely vigilant concerning the greases used, to adopt greasing frequencies and quantities and types of grease suited to each piece of equipment.

Furthermore, if vibration monitoring is included in the maintenance of the various machines to be monitored, do not forget to note the various parameters recorded when measuring the values.

The table on the next page summarises the main causes of deterioration that may occur on a bearing. It may also help the maintenance operator to determine the possible origin of a problem.

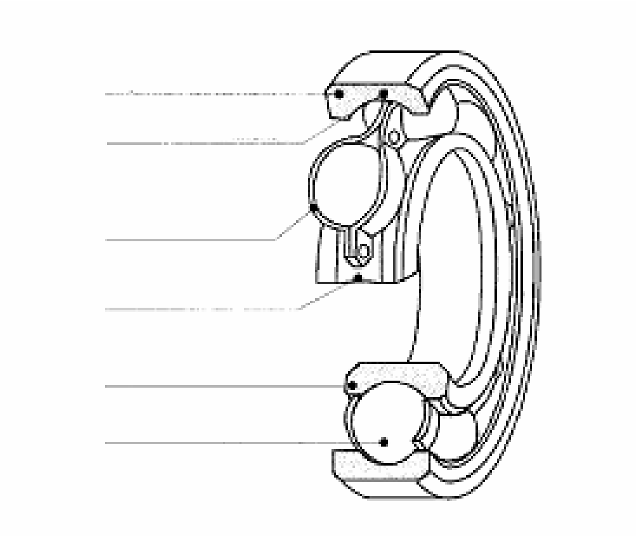
Origin	Fatigue chipping	Surface chipping	Seizing	Rolling part imprints due to deformation / tearing	Rolling part imprints due to abrasion	Wear – Foreign object imprints	Craters - Grooves	Traces of shocks – Cracks - Breakages	Contact corrosion	Corrosion	Damage to the cages
Installation											
Lack of care				■		■		■			
Impacts				■				■			■
Housing or contact surface defects	■		■								■
Over-tight fitting	■										■
Too loose fitting									■		
Misalignment	■										
Operation											
Overloading	■										
Vibrations					■						
Excessive speed			■								
Environment											
Temperature too low			■								
Passing of an electric current							■				
Water contamination										■	
Dust contamination						■					
Lubrication											
Inappropriate lubrication		■									■
Lack of lubricant	■		■								■
Excess lubricant			■								

Table 5: Summary of the main causes of damage to bearings

11. EXERCISES

1. Give the composition of a bearing

2. Complete the diagram



3. Give the possible bearing manufacturing methods

4. What is the role of heat treatment?

5. What are the loads acting on bearings? (explain)

6. Diagram (symbol) of a bearing with one row of balls

7. List the main families of bearings

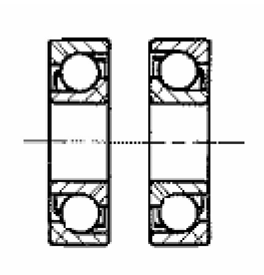
8. What type of bearing is this?

9. What type of bearing is this?

10. Definition of a thrust bearing

11. List the different possible setups with angular contact bearings

12. What type of setup is this?



13. For a "rotating shaft" setup, which bushing will be installed with a tight-fit?

14. What is the maximum bearing heating temperature?

15. What are the advantages of lubrication with oil?

12. GLOSSARY

13. LIST OF FIGURES

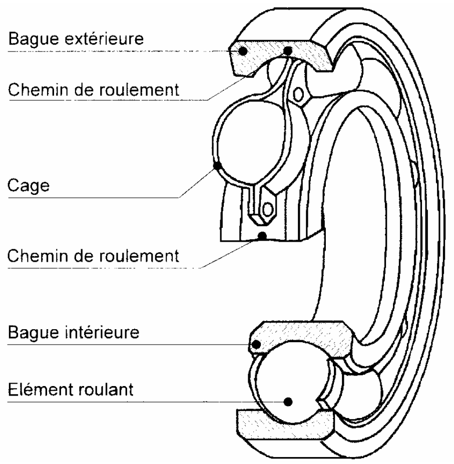
14. LIST OF TABLES

15. ANSWERS TO THE EXERCISES

1. Give the composition of a bearing

    The outer bushing
    The inner bushing
    The balls (or rollers)
    The cage

2. Complete the diagram



Outer bushing
Bearing race

Cage

Bearing race

Inner bushing
Roller element

3. Give the possible bearing manufacturing methods

    Removal of matter (turning/undercutting)
    By deformation (rolling/forging/stamping)

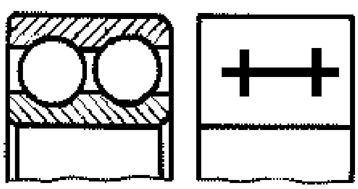
4. What is the role of heat treatment?

    Increase the hardness of the matter

5. What are the loads acting on bearings? (explain)

    Radial >> perpendicular to the shaft's centreline
    Axial >> parallel to the shaft's centreline
    Combined >> radial + axial

6. Diagram (symbol) of a bearing with one row of balls



7. List the main families of bearings

Ball bearings
Roller bearings

8. What type of bearing is this?

Angular contact ball bearing

9. What type of bearing is this?

Bearing on spherical roller swivel

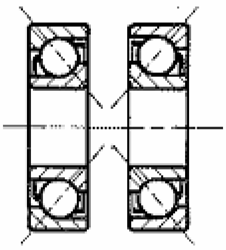
10. Definition of a thrust bearing

Part designed to limit the travel of a moving part

11. List the different possible setups with angular contact bearings

"X" installation
"O" installation

12. What type of setup is this?



"X" installation

13. For a "rotating shaft" setup, which bushing will be installed with a tight-fit?

    The inner bushing

14. What is the maximum bearing heating temperature?

    Conventional >> 130° C
    Life-lubricated, with flange >> 80° C

15. What are the advantages of lubrication with oil?

    Possibility of checking the lubricant (level/quality)
    Evacuation of heat
    Good penetration into the bearing