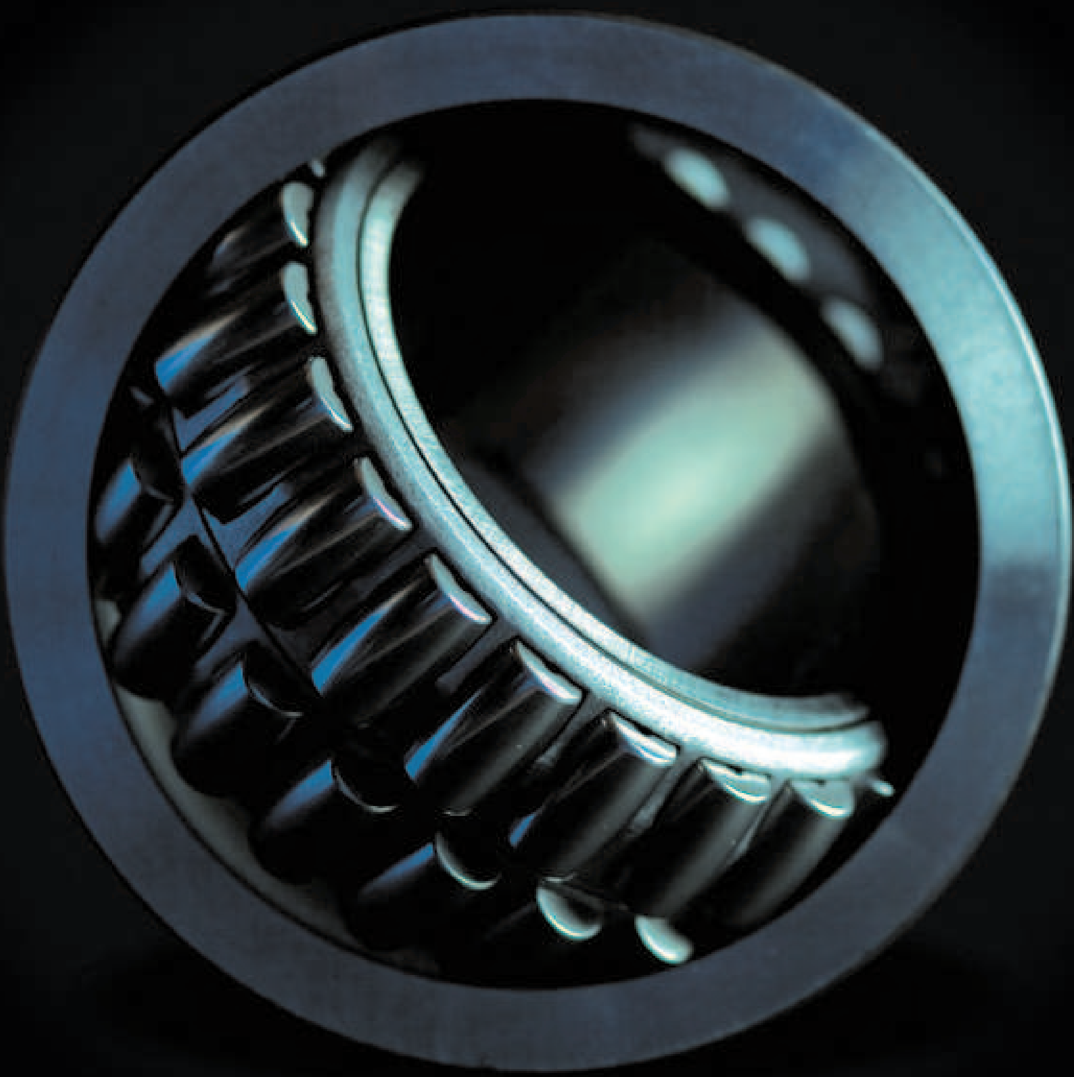
History is the basis of the present and a challenge for the **future**.

ZKL GROUP



Bearing maintenance handbook

MOUNTING AND DISMOUNTING OF ROLLER BEARINGS

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1. GENERAL INSTRUCTIONS

The purpose of the manual is to provide the operating technicians, assemblers, and maintenance employees in contact with the roller bearings with the basic manual for careful mounting.

Considering the large amount of various stock constructions, a special mounting procedure or specially adjusted or constructed mounting tools may be required in some cases.

The brochure includes the instructions for the mounting, dismounting, maintenance, and storage of the roller bearings. Each roller bearing type is suitable for a specific method of utilization and at the same time requires a specific mounting method, dismounting, maintenance, etc. The use of appropriate mounting procedures, suitable tools, and appropriate maintenance form a base for preventing the bearing damage during the mounting process, and achieving the bearing problem-free operation with the maximum bearing service life.

Important requirements include clean mounting tools, and the work performance in clean work environment. Any contamination has negative effects on the bearing behaviour during its operation, and accident of the bearing may occur depending on the origin.

The same conditions for clean environment must be adhered to during the preparation of all lubrication tools and parts related to the stock.

1.1 Bearings load and size

The roller bearings are basically divided according to the transmission of radial and axial load to radial, axial, and bearings transmitting combined load.

The bearings with the single-point contact are designed in particular for smaller and medium loads, on the contrary the line contact bearings are designed for high loads.

Radial load operates perpendicularly on the shaft axis, and axial load operates in the shaft axis direction. If both radial and axial loads are applied on the bearing, it includes a combined bearing load. It is therefore very important to select appropriate type for each application and bearing size.

The required bearing size is determined on the basis of externally acting forces and based on the durability and reliability demands of the seated bearing. The size, direction, purpose, and nature of the bearing load as well as the revolution operating speed are determinant when selecting the bearing type and size. Meanwhile, other special or important conditions of each individual case must be considered, e.g. operating temperature, spatial allowances, ease of installation, lubrication requirements, packing, etc., which can affect the selection of the most suitable bearing. Various types of bearings may, in many cases, be suitable for the given specific conditions.

In terms of the action of external forces and the function of the bearing in the respective node or unit, we distinguish two types of roller-contact bearing loads in bearing technology:

– If the bearing rings turn in relation to one another and the bearing is exposed, under such conditions, to external forces (which applies for the majority of bearing applications), we refer to this as a dynamic bearing load,

– If the bearing rings do not turn in relation to one another or turn very slowly, the bearing transmits oscillating motion, or external forces act for shorter period than the time of one bearing revolution, we refer to this as a static bearing load.

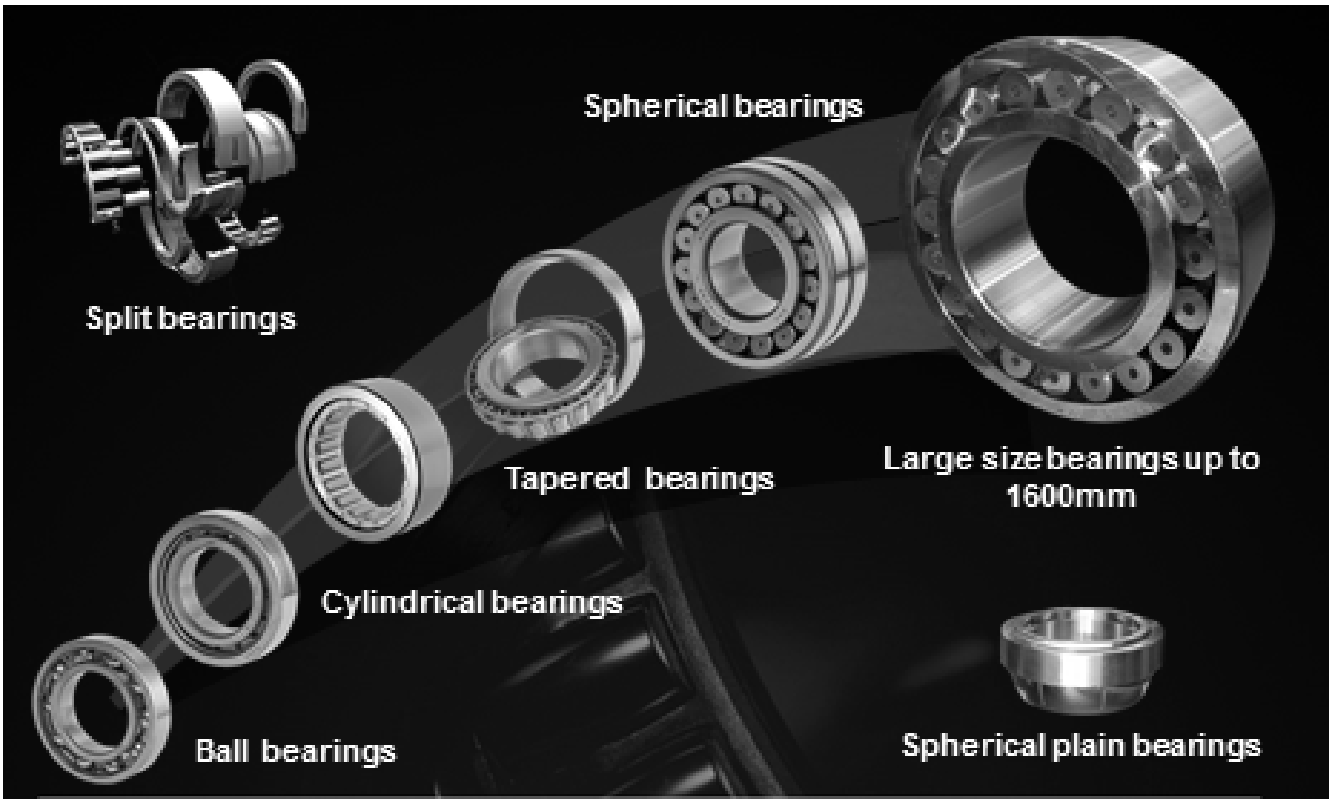
1.2 Criteria for selection and use of bearings

Rolling-contact bearings are an indispensable component of machinery, which are constantly subjected to the process of innovation. They enable mutual rotational motion of machine parts, while simultaneously transferring acting forces. They usually consist of two rings, roller-bearing cases, and a cage. Grease and packing elements are also an integral component of rolling-contact bearings. Proper rolling-contact bearing operation thus requires not only the selection of the proper type and size of bearing, but also the appropriate method of lubrication, heat dissipation, corrosion protection, and design to prevent entry of contaminants into the housing. The housing design a well as bearing connection dimension tolerances and supplemental lubrication method must be adequate. The correct installation, dismounting or de-installation procedure must also be designated to ensure proper bearing operation. A service manual and maintenance instructions should be provided in cases of complicated housing designs and where high operating reliability are needed.

These principles must particularly be observed in housings in which bearing price, high reliability, or costs associated with bearing installation and economic losses due to shutdown of equipment play a significant role. Such housings require a highly qualified approach in the design phase with the use of computations and testing.

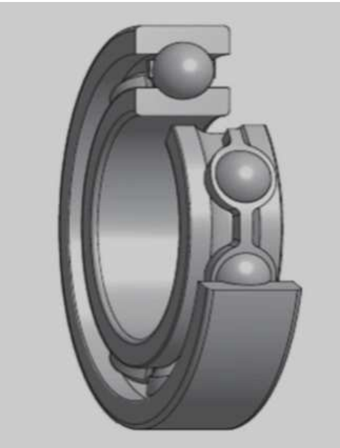
1.3 ZKL Production Program

1.3.1 ZKL Product Assortment



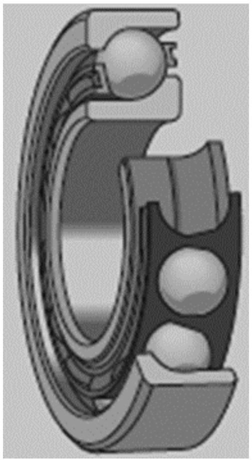
Radial bearings

Single-row ball bearings

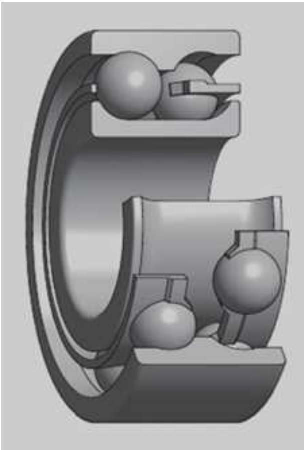


Due to the versatility of applications, single row ball bearings are among the most frequently used types of rolling bearings. They are made as non-separable without a filling slot. Simple design predetermines them for a wide range of operating conditions. They are provided with deep grooves in rings, diameters of which are just a little bigger than those of balls. Due to big ball diameters and high attachment, single row ball bearings feature relatively high dynamic load capacity in both radial and axial directions. Therefore they suit well combined load in both directions. In order to capture axial forces in high revolutions they conveniently substitute axial ball bearings.

Single-row angular-contact ball bearing

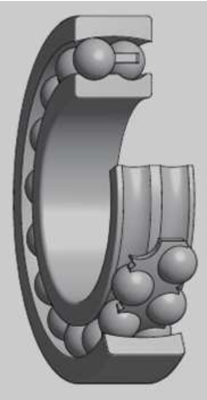


Double-row angular-contact ball bearing



Angular contact ball bearings have raceways of bearing rings designed so that the joins of their contact points and balls contain sharp angle, the so-called contact angle, with the vertical line towards the axis. The bearings are non separable. Separable are some special bearings, or bearings with multipoint contact of QJ type. These bearings are suitable for transfer of combined loads, the so-called simultaneously acting radial and axial loads. With increasing contact angle the axial load bearing capacity grows whilst the radial load bearing capacity slowly reduced.

Double-row self-aligning ball bearing



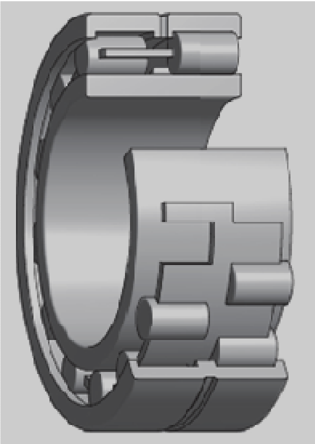
Double-row self-aligning ball bearings are designed with two rows of balls and round raceway on the outer ring, which enables certain tilting of the inner ring towards the outer ring around the bearing centre without impeding bearing function. Bearings are made with a cylindrical or tapered bore and are non-detachable. The self aligning ability, while maintaining

functionality, determines the bearing application in cases, where certain misalignment of bores in the bearing hubs or deflection and oscillation of the shaft are expected. Due to the small contact angle and imperfect adherence of the balls to the raceways, they are unsuitable for capturing greater axial forces.

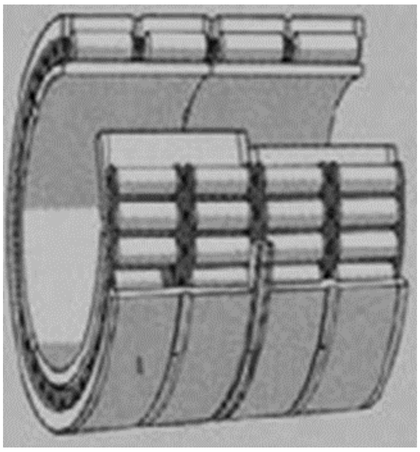
Due to the small adherence of balls on the outer ring spherical surface, self aligning ball bearings elicit little friction in comparison to other types of bearings and the heat generated is thus also less.

Single row cylindrical roller bearing

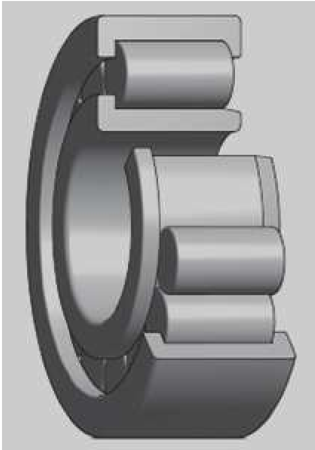
Double row cylindrical roller bearing



Four rowed roller roller



Single row full complement cylindrical roller bearing



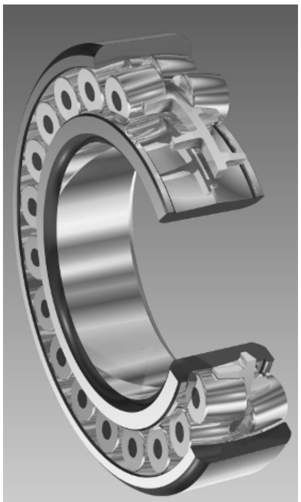
Cylindrical roller bearings are manufactured in many designs, dimensions and sizes. The most common designs are single row cylindrical roller bearings with cage. Single row cylindrical roller bearings are capable of transferring big radial loads and, in some design cases, they are capable of capturing even axial load. Cylindrical roller bearings can operate at high revolutions. The full complement design is capable of transferring big radial loads but at lower rpm.

Majority of design versions is separable which allows easier assembly and disassembly in location. In majority of cases the mutual axial displacement of the outer and inner ring is used when the axial shift of the shaft against the body is aligned inside the bearing without reducing the service life of the bearing. Axial displacement is mostly caused by thermal expansion of the shaft.

ZKL manufactures the following types of cylindrical roller bearings:

- single row cylindrical roller bearings
- double row cylindrical roller bearings
- single row full complement cylindrical roller bearings
- double row full complement cylindrical roller bearings
- multi row cylindrical roller bearings
- single row cylindrical roller bearings and bearing units for railway applications
- electrically insulated cylindrical roller bearings
- split cylindrical roller bearings.

Spherical roller bearings

Double row spherical roller bearings have two rows of spherical rollers with common spherical track in outer ring. This structure allows mutual tipping of rings. They can simultaneously transfer considerable radial and axial loads in both directions. Bearings are made with cylindrical and tapered bore. These bearings are suitable for locations where big loads act, and tipability has to be ensured bearings can thus eliminate movement and misalignment of shaft.

In the standard assortment, ZKL offer spherical roller bearings in several versions that differ in the structure of the inner ring, cage and cage guidance.

EMH – bearings with optimised design with symmetrical spherical rollers that brings higher load bearing capacity. Single piece crest massive brass cage led on the internal ring, in series 222 for bore diameter d ≤ 160 mm, and in series 223 for bore diameter d ≤ 130 mm the cage is led on spherical rollers

CJ – bearings with optimised design with symmetrical spherical rollers that brings higher load bearing capacity. Bearings have two cages pressed of steel plate with hardened surface that are guided by floating guide ring between both rows of spherical rollers centred on the inner ring.

EJ – bearings with optimised structure with symmetrical spherical rollers that brings higher load bearing capacity. Bearings have two cages pressed of steel plate with hardened surface. Bearing do not have a guide ring.

Tapered roller bearings

Single row tapered roller bearings are detachable. The inner ring with tapered rolls and cage forms one assembly unit: the outer ring a second. The structure with a large number of tapered rolls in a single row allows these bearings to achieve a high radial and axial load capacity. Raceway contact surface areas lie on straight lines, which intersect in the bearing axis. Modifying the contact surfaces of raceways or tapered rolls, resp., limits the formation of edge stress. Axial loading may only occur in one direction and its magnitude depends on the size of the contact angle, which is characterized by the coefficient e. Bearings with a larger contact angle (type 313 and 323B) and thus with a larger coefficient e are more suitable for greater axial forces. A loading with single row tapered roller bearings usually comprises a pair of bearings due to capturing of axial loads in both directions. Bearings are structurally designed to higher utility parameters with the designation A. Bearings are manufactured both in metric and imperial dimensions.

Thrust ball bearings

Single direction thrust bearings

Double direction thrust bearings

From a design perspective, thrust ball bearings are divided into single direction and double direction. Rings have flat seating surfaces. The rings in smaller bearings may alternatively have a round seating faces for seating in the hub. Rings must be supported such that all of the balls or loaded equally. Bearings cannot carry radial forces. The bearings can be disassembled; consequently, the rings and axial cages with balls can be taken apart.

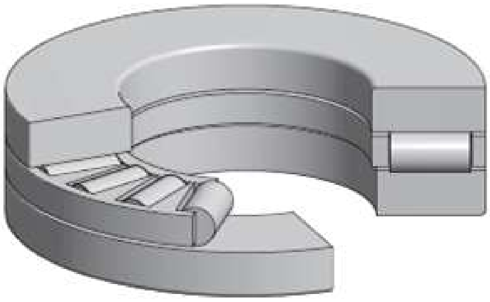
Single direction thrust bearings

Standard single direction thrust ball bearings are composed of a shaft and hub ring with races and of balls guided by a cage. Bearings only transfer axial loads in one direction.

Double direction thrust bearings

Standard double direction thrust ball bearings have two cages with balls between the centre shaft ring and two housing rings. The shaft ring has races on both sides and is fastened on the journal. Bearings are only capable of transferring axial forces in both directions. Housing rings and cages with balls have identical components as single direction bearings of similar dimensions.

Cylindrical roller thrust bearings

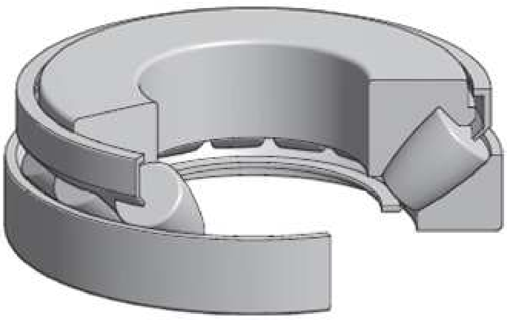


Cylindrical roller thrust bearings are design for solid and sustainable loadings and resistant to shock stressing. They are standardly offered as single direction bearings that can transfer axial loads only in one direction.

Bearings have a simple shape and can have a single row or double row design. They are used primarily in heavy-duty loadings, in which thrust ball bearings sometimes fail.

Cylindrical rollers with a modified surface that ensure optimal rolling without edge stressing are installed in the bearings.

Spherical roller thrust bearings



Spherical roller thrust bearings have a large number of asymmetrical spherical rollers with good adhesion to shaft and housing rings, making them suitable for capturing large axial loads as well as certain radial loads at relatively high speeds. Bearings are detachable, which can be utilized during installation. Bearings are manufactured with a pressed steel-sheet cage, which forms an integral unit with the shaft ring and spherical rollers. In addition, ZKL also manufactures bearings with a massive cage. A massive brass cage is guided by the sleeve fastened in the shaft ring bore and together also form an integral unit. The internal bearing design with massive cage requires oil lubrication. In other cases, the bearings may also be lubricated with greases – preferably with EP additives. In such cases, a sufficient amount of lubricant must be supplied into contact with the spherical roller faces and the guide flanges.

Labelling:

J	Bearing with cage made from steel sheeting
EJ	Optimized internal design with steel cage
M	Bearing with massive brass cage
EM	Optimized internal design with massive brass cage
EF	Optimized internal design with massive steel cage

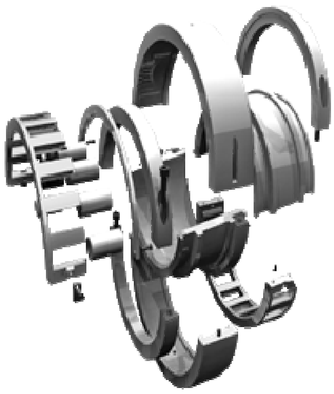
Split roller bearings

Our company currently devotes special attention to particular bearings, designed primarily for heavy industrial applications. Here we refer to split roller bearings, whose design and production technology are validated at ZKL on special cylindrical roller bearings and spherical roller bearings up to an outer diameter of 1600 mm.

Split roller bearings are preferred in settings, where axial installation of bearings in housings is unfeasible, which applies, for example, to multiple bearing shafts, crankshafts, long transmission shafting, or in cases, where installation of the bearing in the housing would be too time-consuming and where any prolonged shutdown of equipment could lead to large disruptions in operations.

The most commonly used split roller bearings in the world are single row cylindrical roller and double row spherical roller bearings. ZKL includes both of the specified assemblies in its production program. These bearings have a radially split outer ring, inner ring, and cage for guiding rolling elements.

Split single-row roller bearings



Split double-row spherical-roller bearings

The components of a double-row spherical-roller bearing and the bearing house

Lubrication of split bearings

Either an oil or grease lubricant may be used. The type of lubricant is selected, based on the operating conditions, the given maximum speed, the operating temperature, and the magnitude of the external load. The Technical and Consultation Services Department can assist in selecting a suitable lubricant.

Housings for split bearings

Comprehensive bearing loading solutions can be designed for individual split bearings and loadings, which consists of a split bearing, the bearing housing, the lubrication system, and bearing diagnostics per customer specifications. Comprehensive solutions may be applied to both new loadings, which are in the prototype design phase, as well as for existing loadings that require substitution of a regular non-split bearing for a split bearing. Complete specifications are needed in both cases to achieve the optimal loading design. A complete specifications form, on the basis of which we produce an optimal structural design of the given loading, is available from the supplier upon request or, as necessary, following consultation by the ZKL Technical and Consultation Services Department.

Bearing mounting

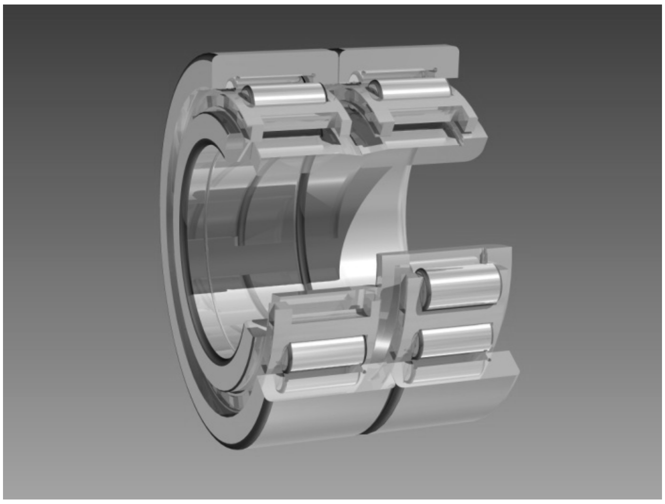
Installation of bearings into the loading should be performed by trained and experienced work personnel.

Bearings for railway applications

The product range of these bearings includes bearings for various types of drives, pumps, and fans, as well as for rail vehicle axles. ZKL is expanding its product line by the addition of compact tapered units as well as conventional and electrically insulated bearings for traction motors.

Axle bearings

The development and production of ZKL railway bearings meet CSN EN 12080 and UIC 510-1 standard requirements. Bearings are designed using modern engineering and computer programs. Parameters are verified through rigorous testing of bearings at testing stations according to ZKL methodology, UIC 515-5 and CSN EN 12082 standards.



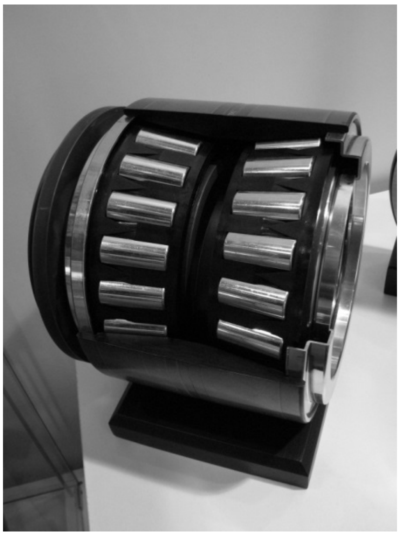
Axle bearings

Cylindrical roller bearings

They are particularly suitable for transferring high radial loads as well as shock axial loads at high revolution speeds. Bearings are manufactured with a massive brass cage or plastic cage.

Tabered bearing units TBU

These are special double row tapered roller bearings for supporting axles of high-speed personal and commercial rail vehicles.



Tabered bearing unit TBU

Spherical roller bearings

They are suitable for handling large radial forces. Their design also enables simultaneous transfer of substantial axial loads in both directions. The bearings are inclined; they are thus able to compensate for some misalignment or shaft deflection.

Bearings for traction motors

Traction motor bearings are usually single row ball bearings, for supporting reduced radial loads and high speed operation, or single row roller bearings for supporting high radial loads.


Bearings for traction motors

ZKL is offering its customers the following additional services:

- cooperation in bearing design for new fits
- cooperation in the design of assembly procedures
- cooperation in evaluating the after-operation condition of bearings and determining the causes of damage
- training bearing assembly workers.

1.4 Storage of bearings

ZKL bearings are stored and packed in such way the properties of the bearings remained maintained for the longest period possible. The precondition for fulfilling the goals is the compliance with the conditions for storing the bearings and handling them.

Relative air moisture in the warehouse should not exceed 60 %, and high temperature fluctuation should be avoided. The most suitable temperature scope for storing the bearings is 15 to 25°C.

The bearings should not be exposed to vibrations and shocks. During storage, the bearings must not be exposed to aggressive agents, such as gas, mist, and aerosols of acids, caustics, and salts. It is also necessary to prevent the effects of direct sun light which may result in high temperature fluctuation in the package. Large bearings, especially the lighter makes, must not ne stored in upright position. They should be placed horizontally in order to prevent the ring deformation. The bearings must not be stored in the shelves from fresh wood, and on stone floor. The bearings must not be stored in close vicinity to the heating or water piping.

Common preservation enables the bearing storage for up to 5 years, providing the above conditions are adhered to. Otherwise shorter storage period must be considered.

Exceeding the permissible storage period requires the inspection of the bearings prior to the mounting as regards the preservation and corrosion.

Bearings covered on both sides (2Z) or sealed (2RS) bearings should not be stored until the end of the storage period. Plastic lubricant filling can age during storage due to chemical and physical processes. The bearings can be functioning but the lubricant unsuitable for use. Recommended period for storing the bearings with plastic lubricant is two years.

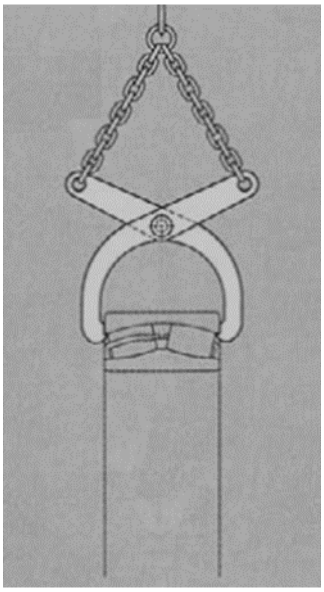
2. MOUNTING PREPARATION

2.1 Mounting workplace

The mounting workplace for series bearing mounting should be placed outside the common production and restricted solely for the mounting. The workplace must be sufficiently spacious, and in particular, no adjustment of the connecting parts can be performed in the shop. It must be placed away from the machining devices, and no welding and compressed air application can be performed in their vicinity. The workplace must not be exposed to the weather conditions, because the bearings are very sensitive to moisture, especially after washing.

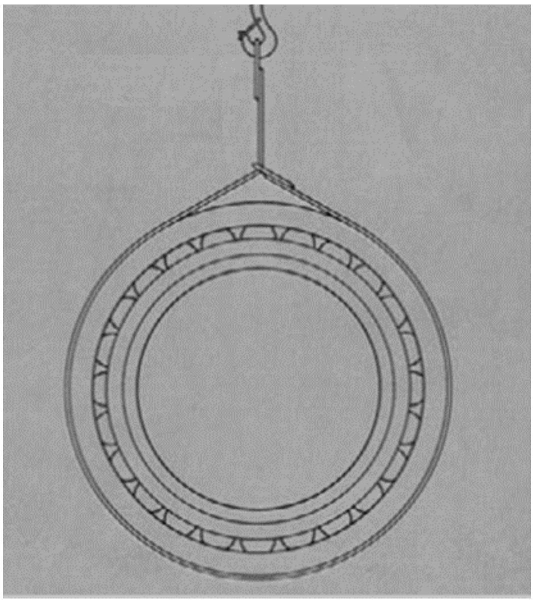
The workplace for the assembly of larger sized bearings must be equipped with the appropriate manipulating equipment – lifting tongs, hooks, binding gear, wire slings, and flexible suspensions.

Lifting tongs (hooks) have jaws which capture the bearing by the outer ring between the rollers. This tool is easier to use than binding gear.



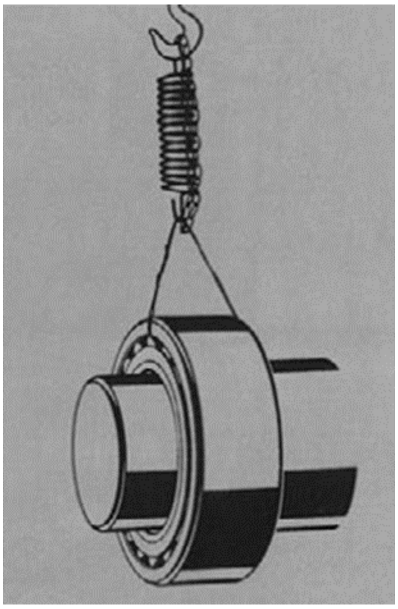
Lifting tongs

A clean belt of leather, steel, or copper can be used to form a suspension sling, which can serve as binding gear. A suspension sling can also be formed with a soft, clean piece of wire.



A suspension sling made from belt or wire

A spring suspension can make it easier to position the bearing correctly.



Suspension spring

2.2 Bearing marking inspection

Prior to the bearing mounting commencement, the assembler must check, if the marking on the bearing or the box complies with the specification on the drawing.

2.3 Work procedure

Prior to the beginning of each mounting, it is necessary to specify work procedure based on the drawing documentation, to be used for individual work tasks.

If the bearing mounting requires special provisions, different to the common practise, the assembler must have available a derailed mounting manual including common work procedure plus required tool common devices for the mounting, e.g. transport tools, special mounting agents, measuring tools, heating tools, special tools, type and amount of greasing agents, etc.

It basically comprises four various mounting methods: Mechanical, hydraulic, pressure oil method, and heat method which are then used for the corresponding stock on the cylindrical or conic journal, fastening and lamping casing.

The assembly of smaller bearings can include mechanical tools, large bearings require pressurized oil.

The selection of appropriate mounting method is facilitated in the table below.

LOCATION	Ød of the bearing (mm)	Mounting tools			
		Mechanical	Hydraulic	Pressurized oil	Heating agents
Cylindrical journal	<80	recommended	unsuitable	unsuitable	recommended
	80-200	unsuitable	unsuitable	unsuitable	recommended
	>200	unsuitable	unsuitable	unsuitable	recommended
	Roller bearings of all sizes	recommended	unsuitable	unsuitable	recommended
Conic journal	<80	recommended	recommended	recommended	unsuitable
	80-200	recommended	recommended	recommended	recommended
	>200	unsuitable	recommended.+.recommended		recommended
Clamping casing	<80	recommended	recommended	unsuitable	unsuitable
	80-200	unsuitable	recommended	unsuitable	recommended
	>200	unsuitable	recommended + recommended		recommended
Fastening casing	<80	recommended 1)	recommended	unsuitable	unsuitable
	80-200	recommended	recommended	unsuitable	recommended
	>200	unsuitable	recommended	unsuitable	recommended

1) For double-row self-aligning ball bearings

Correct function of the bearings is subject to correct mounting method and use of appropriate tools. The assembly should be performed in clean, dust-free environment.

External overlapping bearing rings are commonly cold mounted. Internal overlapping rings are cold and hot mounted.

Smaller bearings are mostly cold mounted by means of press or mounting casing and a hammer. The mounting of greater bearings is simpler, providing the bearings are heated prior to the mounting.

2.4 Bearing preparation for mounting

ZKL bearings are placed in original packages protected from corrosion by means of preservation agent for 5 years, providing appropriate storage is ensured. New bearing can be unpacked from the original package just before the assembly, and must be well protected from contamination. The corrosion preventative agent should not be removed from the bearing, just wash the internal ring hole and the surface of the external ring with technical petrol or similar solvent on the same base, and dry. During cleaning, use smooth cloth, never use cleaning wool!

If the package is damaged, i.e. the bearing contamination could have occurred during storage, the bearing requires washing prior to the mounting. The bearings can be washed with various cleaning agents, organic, inorganic or inflammable.

The bearings are washed in suitable cleaning vessel using a brush;, one bearing ring is turned during the washing process. If one bath is not sufficient, more baths are used as per the contamination level.

After washing the bearing must be immediately preserved with oil or grease, depending on the type of greasing to be used during operation. During the preservation, one bearing ring is rotated slowly in order to prevent the contact of both rings' rotation routes and the surface of the rolling units with the preservation agent.

The rolling units must not be subjected to any additional adjustments, e.g. lubricant bores, groves, recesses, etc., because it would result in released tension in the rings causing premature bearing damage. Additionally, there is a risk of bearing contamination with chips or grinding dust.

If the bearings require complicated and time demanding mounting, which could include long-term bearings exposure to external air, the bearings must be protected, even for cases of interrupted mounting in progress.

During the bearing handling, it is suitable to use gloves and lifting devices which simplify the bearing handling and increase the work safety. If it is necessary to lift the bearings in vertical position, we recommend their suspension on the steel belt or strap on the external ring circumference, not in one point. We recommend fitting large bearings for lifting in horizontal position with thread bores for the suspension lugs to simplify the subsequent handling; available upon special order. The suspension screws must be loaded solely in the shank axis direction.

2.5 The set parts' preparation for mounting

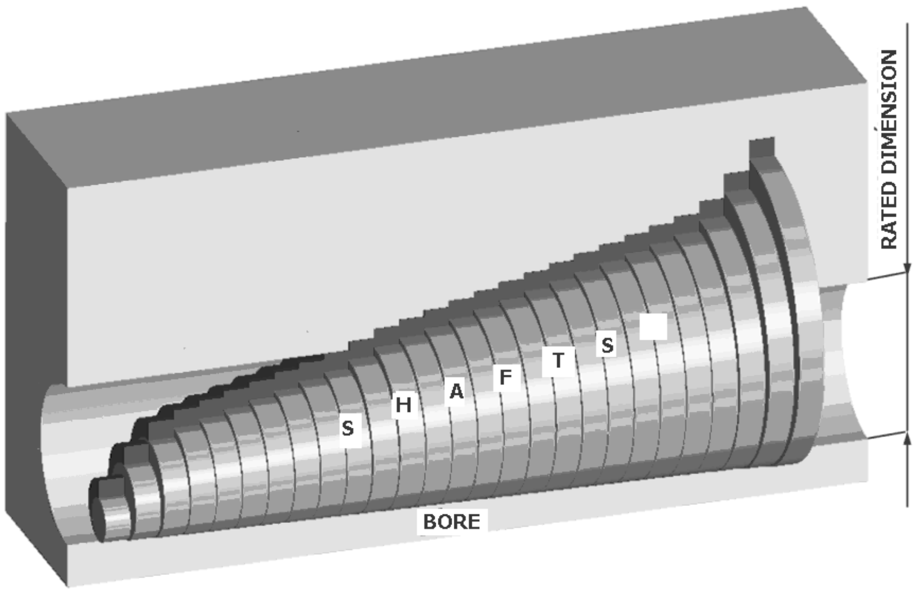
Prior to the mounting, all respective parts must be thoroughly clean, and burr-free, bruise-free after machining. Untreated surfaces of the rolling stock components' interior part must be absolutely clean, perfectly free from the residues of forming sand, and protected with the paint finish. It is necessary to clean all lubrication bores and threads. All sharp edges must be removed.

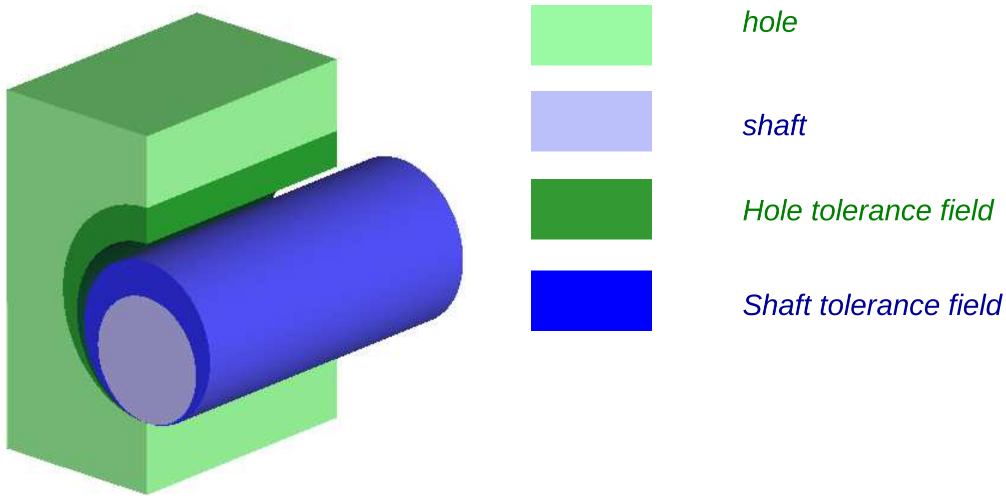
The device or the machine for the bearing assembly must be maintained clean, in particular in locations for the bearing mounting. The machine parts susceptive to penetrating contamination and moisture, must be covered with suitable material (e.g. wax coated paper, plastic foil, etc.).

Clean the shaft and ensure the shaft and other components are clean and dry. Check the sealing and if damaged or old, replace them with new ones.

Prior to starting the assembly, it is necessary to check the compliance with the specified tolerances, geometric accuracy, and the bearing contact surface quality on the shaft and the unit. The dimension accuracy of the roller bearings does not require inspection prior to the assembly.

The tolerance filed position for the bores and shafts





2.5.1 The shaft shape inspection

Reliable operation of the bearings requires the elimination of the bearing assembly on the shafts where the geometric shape accuracy is not guaranteed or they are bent, etc. It is necessary to check the shaft carefully prior to the assembly.

Depending on the shaft size, it is possible to check the shape accuracy in the tips on the lathe fig. 1 or in the supports using the arrow indicator or micro-meter.

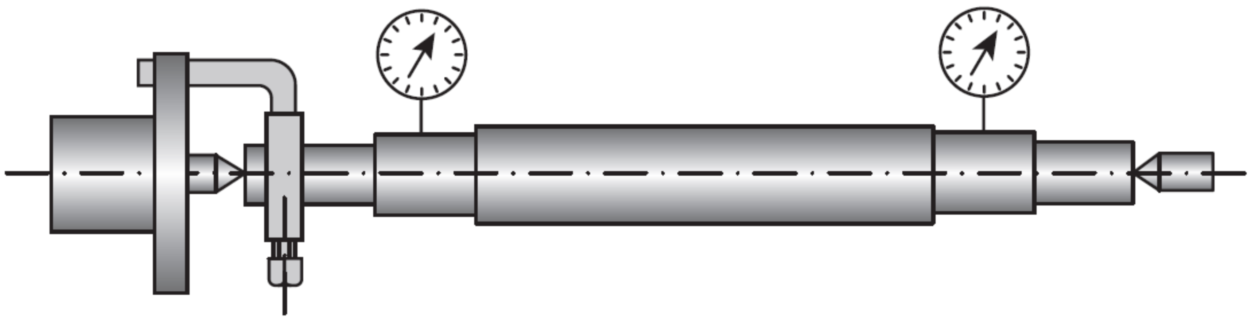


Fig. 1. The shaft geometric shape inspection

During the inspection, it is necessary to make sure, the indicator is fixed and its axis is perpendicular to the shaft axis. If the shaft is not bent and its geometric shape, i.e. out-of-roundness and conic shape of the contact surfaces for the bearings is within permitted limits, the shaft is suitable for mounting.

The contact surfaces for the bearings on the shafts must be grinded. Prior to the mounting, the surfaces must be carefully checked and possible burrs or grinding particles removed.

If the bearings on shafts are secured with the nut, the thread on the shaft must be cleaned in order to remove contamination which could later penetrate the bearing. All grooves and recesses on the shaft must be carefully cleaned.

2.5.2 The inspection of the contact surfaces for the shaft bearings

Suitable diameter tolerances of the contact surfaces for the shaft bearings are specified in table 1. The limit deviations of the recommended journal diameter tolerances for diameters from 1 to 1250 mm are specified in table 2.

Table 1. Recommended tolerances of journal diameters for radial bearings (applies for full steel shafts)

Tolerances of journal diameters for radial bearings (applies for full steel shafts)					
Service conditions	Examples of location	Journal diameter [mm]			
		Ball bearings	Cylindrical, needle 1), tapered bearings	Spherical roller bearings	Tolerance
Inner race spot load					
Small and normal load Pr ≦0.15 Cr	Free wheel, pulleys belt pulleys		All diameters		g6 2)
Big impact load Pr>0.15 Cr	Wheels of conveyance trolleys, tension pulleys				h6
Circumferential load of inner race or uncertain way of loading					
Small and variable load Pr ≦0.07 Cr	Conveyers, fans	(18) to 100 (100) to 200	≦ 40 (40) to 140	- -	j6 k6
Normal and big load Pr > 0.07 Cr	General engineering, pumps, combustion engines, transmissions, woodworking machines	≦ 18 (18) to 100 (100) to 140 (140) to 200	- ≦ 40 (40) to 100 (100) to 140 (140) to 200 > 200	- ≦ 40 (40) to 65 (65) to 100 (100) to 140 > 140	j5 k5 (k6) 3) m5 (m6) 3) m6 n6 p6
Extremely big load, shocks heavy service conditions Pr > 0.15 Cr	Axle bearings of rail vehicles, traction motors rolling mills	- - -	(50) to 140 (140) to 500 > 500	(50) to 100 (100) to 500 > 500	n6 4) p6 4) r6 (p6) 4)
High location accuracy at small load Pr ≦ 0.07 Cr	Machine tools	≦ 18 (18) to 100 (100) to 200	- ≦ 40 (40) to 140 (140) to 200	- - - -	h5 5) j5 5) k5 5 m5)
Axial load exclusively			All diameters		j6
Bearings with tapered bore and with adapter or withdrawal sleeve or dismantling sleeve					
All ways of loading	General locations, axle bearings of rail vehicles, Unexacting locations		All diameters		h9/IT5 h10/IT7

1) Does not apply to needle bearings without rings

2) For bearings tolerance f6 can be selected to ensure axial shift

3) Tolerance in brackets is selected usually for single row tapered roller bearings or at low frequency revolutions where clearance diffusion does not have major significance.

4) Bearings with increased radial clearance have to be used

5) Tolerances for single row ball bearings of accuracy P5 and P4 are stated in chapter 12.2

Table 2. Limit deviations of journal diameter tolerances in [µm]

Limit deviations of journal diameter tolerances																	
Nominal diameter of journal		f6		g5		g6		h5		h6		j5		j6(js6)		k5	
over	to	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower
mm		µm															
1	3	-6	-12	-2	-6	-2	-8	0	-4	0	-6	2	-2	4	-2	4	0
3	6	-10	-18	-4	-9	-4	-12	0	-5	0	-8	3	-2	6	-2	6	1
6	10	-13	-22	-5	-11	-5	-14	0	-6	0	-9	4	-2	7	-2	7	1
10	18	-16	-27	-6	-14	-6	-17	0	-8	0	-11	5	-3	8	-3	9	1
18	30	-20	-33	-7	-16	-7	-20	0	-9	0	-13	5	-4	9	-4	11	2
30	50	-25	-41	-9	-20	-9	-25	0	-11	0	-16	6	-5	11	-5	13	2
50	80	-30	-49	-10	-23	-10	-29	0	-13	0	-19	6	-7	12	-7	15	2
80	120	-36	-58	-12	-27	-12	-34	0	-15	0	-22	6	-9	13	-9	18	3
120	180	-43	-68	-14	-32	-14	-39	0	-18	0	-25	7	-11	14	-11	21	3
180	250	-50	-79	-15	-35	-15	-44	0	-20	0	-29	7	-13	16	-13	24	4
250	315	-56	-88	-17	-40	-17	-49	0	-23	0	-32	7	-16	16	-16	27	4
315	400	-62	-98	-18	-43	-18	-54	0	-25	0	-36	7	-18	18	-18	29	4
400	500	-68	-108	-20	-47	-20	-60	0	-27	0	-40	7	-20	20	-20	32	5
500	630	-76	-120	-	-	-22	-66	-	-	0	-44	-	-	22	-22	-	-
630	800	-80	-130	-	-	-24	-74	-	-	0	-50	-	-	25	-25	-	-
800	1000	-86	-142	-	-	-26	-82	-	-	0	-56	-	-	28	-28	-	-
1000	1250	-98	-164	-	-	-28	-94	-	-	0	-66	-	-	33	-33	-	-

Table 2. Limit deviations of journal diameter tolerances in [µm]

Limit deviations of journal diameter tolerances																	
Nominal diameter of journal		k6		m5		m6		n6		p6		h91)		IT5	h10[1)]		IT7
over	to	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower		upper	lower	
mm		µm															
1	3	6	0	6	2	8	2	10	4	12	6	0	-25	4	0	-40	10
3	6	9	1	9	4	12	4	16	8	20	12	0	-30	5	0	-48	12
6	10	10	1	12	6	15	6	19	10	24	15	0	-36	6	0	-58	15
10	18	12	1	15	7	18	7	23	12	29	18	0	-43	8	0	-70	18
18	30	15	2	17	8	21	8	28	15	35	22	0	-52	9	0	-84	21
30	50	18	2	20	9	25	9	33	17	42	26	0	-62	11	0	-100	25
50	80	21	2	24	11	30	11	39	20	51	32	0	-74	13	0	-120	30
80	120	25	3	28	13	35	13	45	23	59	37	0	-87	15	0	-140	35
120	180	28	3	33	15	40	15	52	27	68	43	0	-100	18	0	-160	40
180	250	33	4	37	17	46	17	60	31	79	50	0	-115	20	0	-185	46
250	315	36	4	43	20	52	20	66	34	88	56	0	-130	23	0	-210	52
315	400	40	4	46	21	57	21	73	37	98	62	0	-140	25	0	-230	57
400	500	45	5	50	23	63	23	80	40	108	68	0	-155	27	0	-250	63
500	630	44	0	-	-	70	26	88	44	122	78	0	-175	30	0	-280	70
630	800	50	0	-	-	80	30	100	50	138	88	0	-200	35	0	-320	80
800	1000	56	0	-	-	90	34	112	56	156	100	0	-230	40	0	-360	90
1000	1250	66	0	-	-	106	40	132	66	186	120	0	-260	46	0	-420	105

The journal inspection can be performed by the calliper gauge, micrometer figure 2 or another suitable measuring tool of required accuracy.

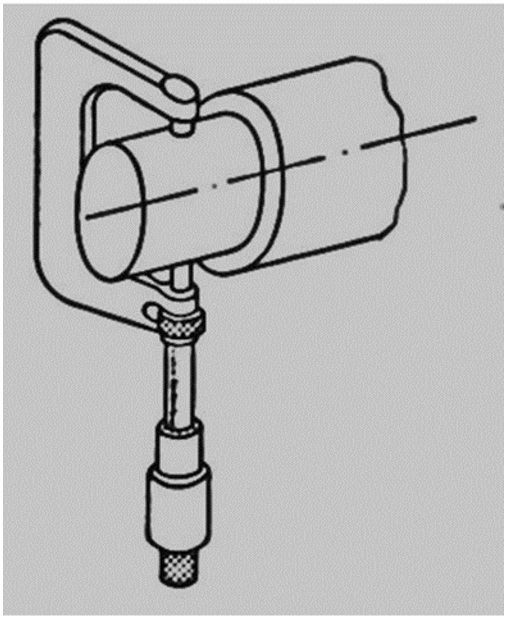


Fig. 2. The shaft diameter inspection with micrometer

During the journal inspection, perform measuring at two levels perpendicular to the journal axis. 4 measuring processes are performed at each level figure 3.

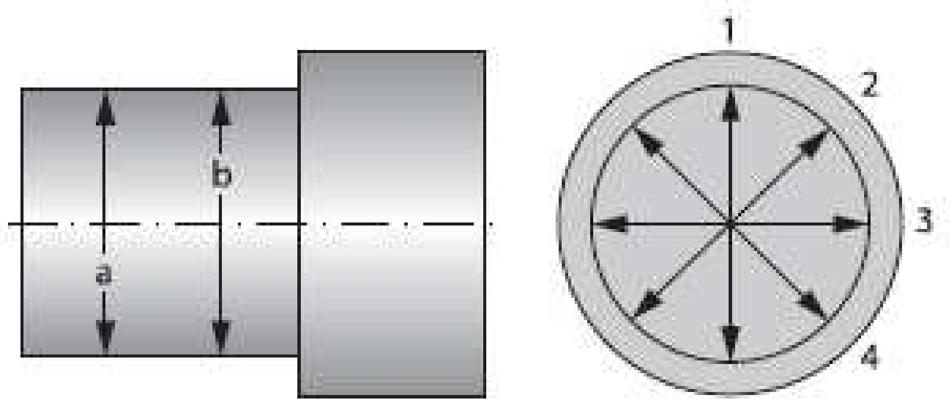


Fig. 3. The measuring locations during shaft inspection

The carefully completed measuring detects all potential deviation from the geometric shape, e.g. individual vaulted or concaved locations, roundness or conic shape. The bearings must not be mounted on the shafts with oval, conic or vaulted contact surface exceeding the permitted deviations.

If the workshop drawing does not specify any special regulations, the rule applies that oval and conic shape must not exceed one half of the tolerance field.

If the shaft fulfils all above specified requirements, the fitting and roundness inspection is performed on the shaft transfer point. It is very important the fitting front parts were as accurately as possible perpendicular to the cylindrical contact surface axis for the bearing. Correct operation of the roller bearings, in particular during high axial forces and high rpm, requires the fitting front part and the round transfers on the shaft to be correctly designed and accurately manufactured. The fitting front parts must not contain any slots, other damages, and the bearing ring must fit with the full front surface. The fitting front parts must be accurately perpendicular to the cylindrical contact surface axis for the bearings. If the fitting front parts are not perpendicular, additional tension may occur in the bearing. The accuracy requirements are strict as regards single row roller bearings which sense the axial load. In such cases, the failed perpendicularity of the support front part to the axis must not exceed 0,02/100 mm. The measuring method of the fitting front part perpendicularity is displayed on figure 4.

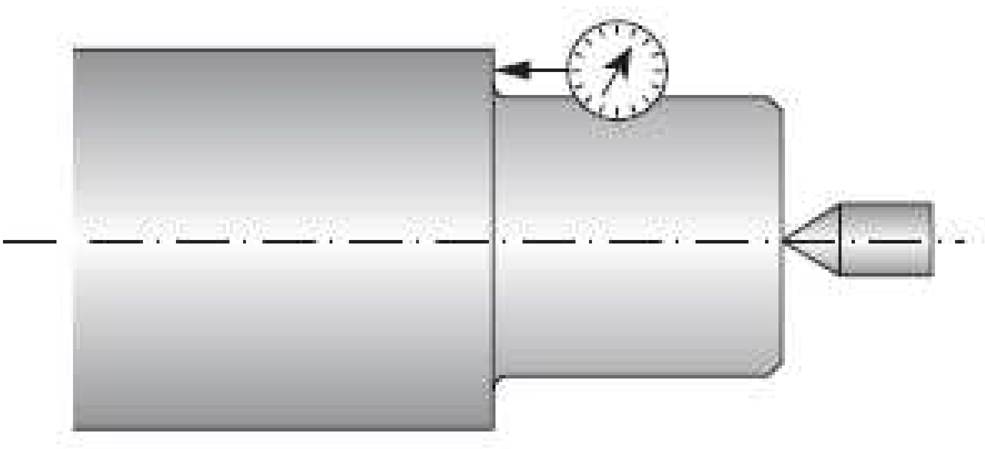


Fig. 4. The front part perpendicularity inspection by fitting the arrow deviation indicator

The fitting height on the shaft is also significant. Excessively high fitting makes the bearing dismounting complicated, on the contrary, low fitting may cause a risk of the front part pressing during axial loads and impacts, or incorrect fitting on the bearing ring round part.

Additionally, it is necessary to check the transfer roundness between the journal and the fitting. Small tolerance is required between the bearing ring internal roundness and the journal roundness.

Conic journals (mostly cone 1 : 12) check with the cone calibre for fitting with the full surface.

Additionally to the support front part perpendicularity and the fitting height, it is necessary to check the roundness on the transfer between the journal and the fitting front part, figure 5. Small tolerance is required between the bearing ring internal roundness and the transfer roundness between the journal and the shaft fitting front part. More suitable construction of the transfer between the journal and the fitting front part is displayed on figure 6.

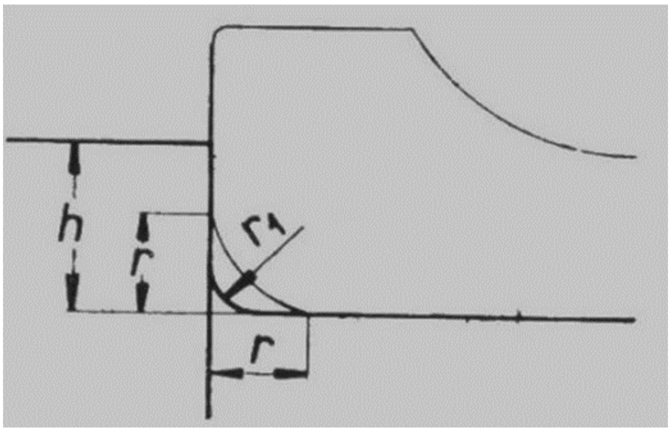


Fig. 5. Transfer roundness between the journal and the fitting front

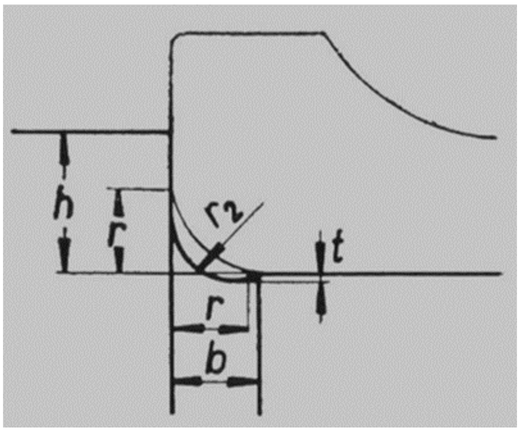


Fig. 6. Transfer between the journal and the fitting front formed by the recess

Suitable support heights of the fittings and the roundness diameter of the transfer between the journal and fitting front part are specified in table 3.

Table 3. Roundness size and fitting height in [mm]

Rated roundness dimension r	Height h_{min}	r_{1max}	t	r_2	B
		Fig. 5.	Fig. 6.		
0,5	1	0,3			
1	2,5	0,6			
1,5	3	1	0,2	1,3	2
2	3,5	1	0,3	1,5	2,5
2,5	4,5	1,5	0,4	2	3
3	5	2	0,5	2,5	4
3,5	6	2	0,5	2,5	4
4	7	2,5	0,5	3	4,5
5	9	3	0,5	4	6
6	11	4	0,6	5	7,5
8	14	5	0,6	6	8,5
10	18	6	0,6	7	10

2.5.3 Bearing body inspection

The bearing body inspection is subject to the same principles as for the shaft. Suitable tolerances of the contact surfaces for the bearings in the unit are specified in table 4.

The limit deviations of the recommended bore diameter tolerances for diameters from 6 to 1.600 mm are specified in table 5.

Table 4. Recommended tolerance of diameters of radial bearing body holes[1)]

Tolerance of diameters of radial bearing body bores (applies to bodies of steel, alloy and cast steel)				
Service conditions	Sliding ability of outer racew	Body	Examples of location	Tolerance
Circumferential load of outer ring				
Big shock load Pr > 0.15 Cr Thin-walled elements	Does not slide	Single piece	Hubs with roller bearings, crank pin bearings	P7
Normal and big load Pr > 0.07 Cr	Does not slide		Hubs with roller bearings travelling wheels of cranes, crank shaft bearings	N7
Small and variable load Pr ≦ 0.07 Cr	Does not slide		Converyer rollers, tension pulleys	M7
Uncertain way of loading				
Big shock load Pr > 0.15 Cr	Does not slide		Traction motors	M7
Big and normal load Pr > 0,07 Cr	Usually does not slide	Single piece	Electromotors, pumps, fans, crank shafts	K7
Small and variable load Pr ≦ 0.07 Cr	Usually sliding		Electromotors, pumps, fans, crank shafts	J7
Accurate locations				
Small load Pr ≦ 0.07 Cr	Usually does not slide Sliding Slightly pushing	Single piece	Roller bearings for machine tools, ball bearings for machine tools, small electromotors	K6 [1)] J6 [2)] H6
Spot load of outer ring				
Optional load	Slightly pushing	Single piece or two piece	General engineering axle bearings of rail vehicles	H7 [3)]
Small and normal load Pr ≦ 0.15 Cr	Slightly pushing	Single piece or two piece	General engineering less exacting mechanical eingineering Paper machine drying cylinders, big electromotors	H8 G7 [4)]

1) For big load, stronger M6 or N6 tolerances are selected. For cylindrical roller bearings with tapered hole, tolerances K5 or M5 are selected.

2) Tolerances for single row ball bearings of accuracy P5 and P4 are specified in the bearing catalogue ZKL

3) For bearings with outer diameter D < 250 mm with thermal difference between outer race and body above 10 °C, tolerance G7 is selected.

4) For bearings with outer diameter D > 250 mm with thermal difference between outer race and body above 10 °C, tolerance F7 is selected.

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Table 5. Limit deviations of bore diameter tolerances in [µm]

Limit deviations of bore diameter tolerances															
Nominal diameter of bore		F7		G6		G7		H6		H7		H8		J6(Js6)	
over	to	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower
mm		µm													
6	10	28	13	14	5	20	5	9	0	15	0	22	0	5	-4
10	18	34	16	17	6	24	6	11	0	18	0	27	0	6	-5
18	30	41	20	20	7	28	7	13	0	21	0	33	0	8	-5
30	50	50	25	25	9	34	9	16	0	25	0	39	0	10	-6
50	80	60	30	29	10	40	10	19	0	30	0	46	0	13	-6
80	120	71	36	34	12	47	12	22	0	35	0	54	0	16	-6
120	180	83	43	39	14	54	14	25	0	40	0	63	0	18	-7
180	250	96	50	44	15	61	15	29	0	46	0	72	0	22	-7
250	315	108	56	49	17	69	17	32	0	52	0	81	0	25	-7
315	400	119	62	54	18	75	18	36	0	57	0	89	0	29	-7
400	500	131	68	60	20	83	20	40	0	63	0	97	0	33	-7
500	630	146	76	66	22	92	22	44	0	70	0	110	0	22	-22
630	800	160	80	74	24	104	24	50	0	80	0	125	0	25	-25
800	1000	176	86	82	26	116	26	56	0	90	0	140	0	28	-28
1000	1250	203	98	94	28	133	28	66	0	105	0	165	0	33	-33
1250	1600	235	110	108	30	155	30	78	0	125	0	195	0	39	-39

Table 5. Limit deviations of bore diameter tolerances in [µm]

Limit deviations of bore diameter tolerances															
Nominal diameter of bore		J7(Js7)		K6		K7		M6		M7		N7		P7	
over	to	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower
mm		µm													
6	10	8	-7	2	-7	5	-10	-3	-12	0	-15	-4	-19	-9	-24
10	18	10	-8	2	-9	6	-12	-4	-15	0	-18	-5	-23	-11	-29
18	30	12	-9	2	-11	6	-15	-4	-17	0	-21	-7	-28	-14	-35
30	50	14	-11	3	-13	7	-18	-4	-20	0	-25	-8	-33	-17	-42
50	80	18	-12	4	-15	9	-21	-5	-24	0	-30	-9	-39	-21	-51
80	120	22	-13	4	-18	10	-25	-6	-28	0	-35	-10	-45	-24	-59
120	180	25	-14	4	-21	12	-28	-8	-33	0	-40	-12	-52	-28	-68
180	250	30	-16	5	-24	13	-33	-8	-37	0	-46	-14	-60	-33	-79
250	315	36	-16	5	-27	16	-36	-9	-41	0	-52	-14	-66	-36	-88
315	400	39	-18	7	-29	17	-40	-10	-46	0	-57	-16	-73	-41	-98
400	500	43	-20	8	-32	18	-45	-10	-50	0	-63	-17	-80	-45	-108
500	630	35	-35	0	-44	0	-70	-26	-70	-26	-96	-44	-114	-78	-148
630	800	40	-40	0	-50	0	-80	-30	-80	-30	-110	-50	-130	-88	-168
800	1000	45	-45	0	-56	0	-90	-34	-90	-34	-124	-56	-146	-100	-190
1000	1250	52	-52	0	-66	0	-105	-40	-106	-40	-145	-66	-171	-120	-225
1250	1600	62	-62	0	-78	0	-125	-48	-126	-48	-173	-78	-203	-140	-265

The external bearing ring simply adapts to the contact surface shape in the body, it is therefore necessary the surface was exactly cylindrical. The inspection is performed by micrometer length gauge or flat calibre. During the contact surface inspection, perform measuring at least at two levels perpendicular to the unit axis. 4 measuring processes are performed at each level, see figure 7.

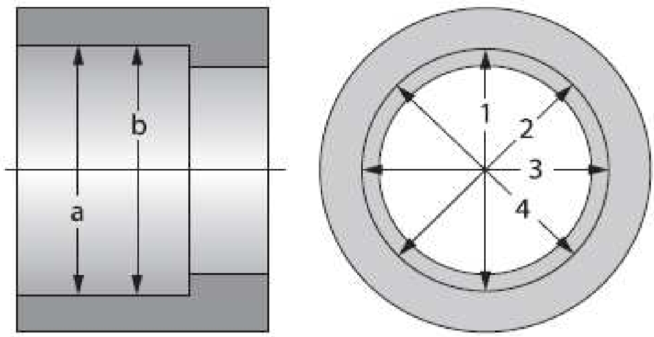


Fig. 7. The measuring locations during the bearing body bore inspection

If the bearing body complies with the inspection, the body is inspected for the perpendicularity and support height for the guiding bearing.

The transfer between the cylindrical surface and the support front part is performed by means of two methods displayed on figures 8 and 9.

Suitable support heights and the length measuring dimensions on figure 8 and 9 are specified in the table 6.

Joint bearing boxes for the assembly of single row ball or roller bearings require the inspection of mutual coaxial contact surfaces for the bearings. Maximum permitted misalignment without significant effects on reduced service life of single row roller and ball bearings for horizontal machines is 3‘.

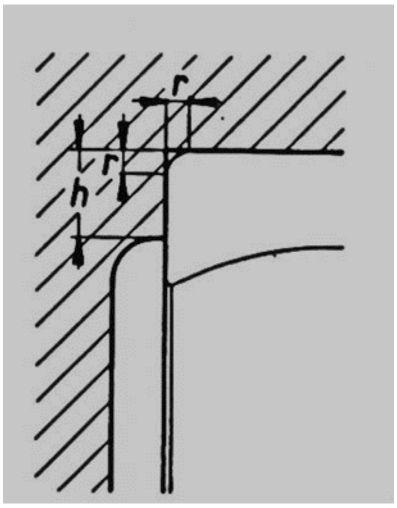


Fig. 8. Support height and transfer completion between the cylindrical contact surface and the front of the guiding body support

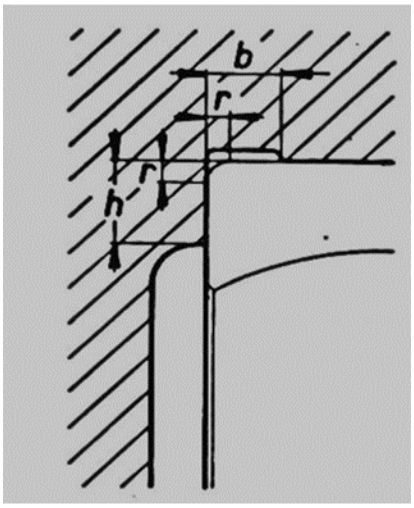


Fig. 9. Support height and transfer completion between the cylindrical contact surface and the front support formed by recess at the guiding bearing

Table 6. Recess size and support height in [mm]

Rated roundness dimension r	Support height h_{min}	b
0,5	1	1
1	2,5	2
1,5	3	2,5
2	3,5	3
2,5	4,5	4
3	5	4,5
3,5	6	5
4	7	6
5	9	8
6	11	10
8	14	13
10	18	16

Prior to inspecting the bores in separate bearing bodies, it is necessary to check the accuracy of the dividing surfaces of both bearing body parts. Both halves of the bearing body are fully fastened, and the spirometer is used for checking the contact on the full contact surface. The division parts must be carefully machined, free from slots, cracks, corrosion, and must fit within the full contact surface.

3. BEARING MOUNTING

During the bearing mounting, it is necessary to avoid direct strokes on the ring, cage or rolling body flanges. Force required for pressing or removing the bearing must not be in any case transferred from one ring on the second ring over the rolling units. It means it is not permissible to press or foul the bearing where the internal ring requires solid fitting on the journal, using pressure or strokes on the external ring and vice versa.

The bearing outer rings are usually cold-mounted. Inner rings located with an overlap can be either cold- or hot-mounted. Small bearings can be cold-mounted using a press, or a sleeve and a hammer. Large bearing are easier to mount using pressure oil, hydraulic device, or heating the bearing.

3.1 Cold assembly of the cylindrical roller bearings

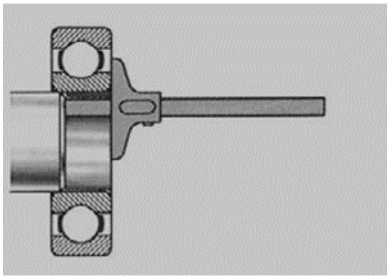
Most cylindrical roller bearings are pressed on the shaft which slightly overlaps the bearing bore. Force required for pressing depends on the overlapping and the internal ring dimensions.

The journal and the bearing bore must be cleaned prior to the assembly with clean cloth and carefully treated with oil. Small and medium bearings up to the bore diameter about 70 mm are commonly cold mounted. First bearing ring to be assembled is the ring for solid fitting. It is used during cold mounting for pressing the bearing on the tube journal or the mounting casing, which fits on the internal ring front part within the full circumference. The casing on the other side is fitted with full stamped bottom which guarantees the balanced force transfer on the full front part of the bearing internal ring. If the mounting casings are used frequently or are designed for series mounting, they are fitted with replaceable bottom parts from harder material than the tube or replaceable plugs with the stamping head, figure 10. The casing inner diameter is slightly larger than the bearing bore. The casing external diameter must not be greater than the bearing internal ring flange in order to prevent the cage damage.

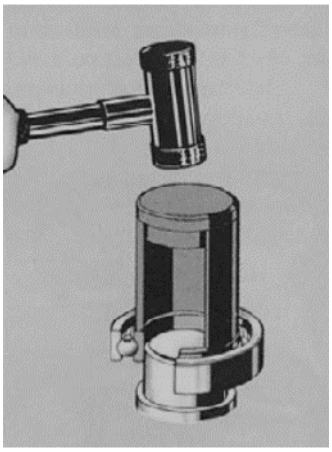
The contact surface is lubricated prior to the mounting with smooth oil in order to facilitate the assembly and prevent the damage of the shaft or the body.

During series mounting, the mechanical or hydraulic presses are used for pressing the bearings on the journal, applying gradual pressure on the casing front part centre and pressing the bearing to the required location. Individual mounting enables the bearing fitting on the journal using light hammer strokes on the casing centre. Simple hammer can be used. Oft metal hammers are not suitable since a part of metal may splinter and penetrate the bearing.

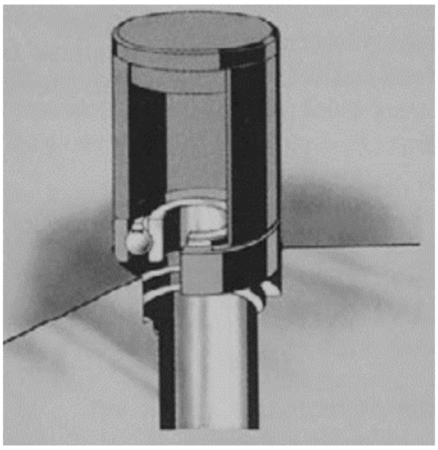
During assembly, the bearing rings, cage, or rollers should never be subjected to direct hammer strokes. The ring might break and damage parts of the bearing, or metal particles might splinter. Mounting force must never be applied to a ring which is not being mounted.



Making sure the ring is mounted perpendicular to the shaft.



Fit with overlap on the shaft.



Fit with overlap in the body.

If the inseparable bearing inner ring is to be fixed on the journal, and the external ring in the body should be shifting, press the bearing on the shaft first, figure 10, and then slide it together with the shaft in the body, figure. 11.

If inseparable bearing with overlapping is mounted in the shaft and the body, the mounting force must be balanced on both rings. The inseparable bearing rings can be mounted independently.

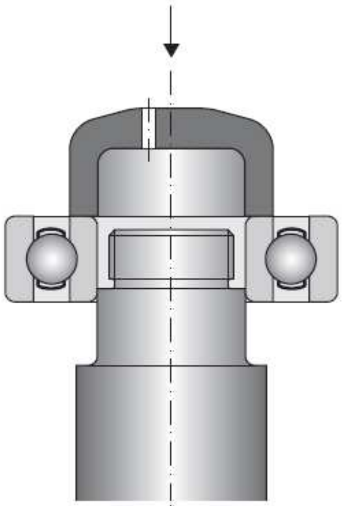


Fig. 10. Mounting single row ball Bearing on the journal (example)

If both bearing rings are solid fitted, they must be mounted at the same time. In such case it is suitable to use mats fitting both bearing rings, figure 11, figure11a.

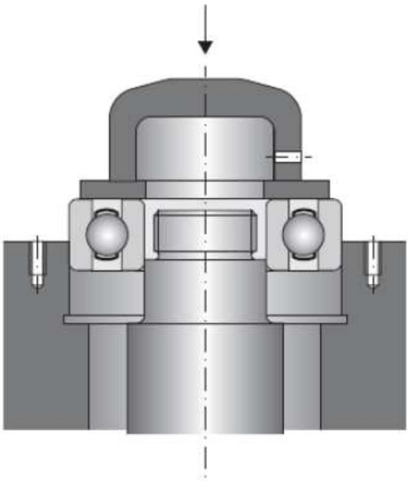


Fig. 11. Mounting the inseparable bearing (example)

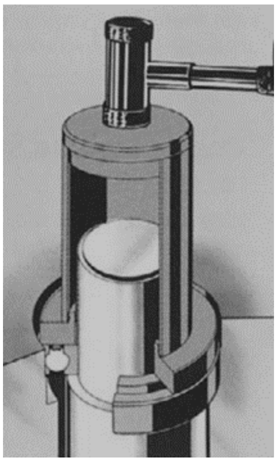


Fig. 11a. Mounting the inseparable bearing (illustration)

Separable bearings, e.g. single row roller bearings, include simpler mounting, because each ring can be mounted separately. Pressing external bearing ring in the body is displayed on figure 12.

After pressing both rings, the shaft with the bearing ring is inserted in to the roller annulus in the body, figure 13.

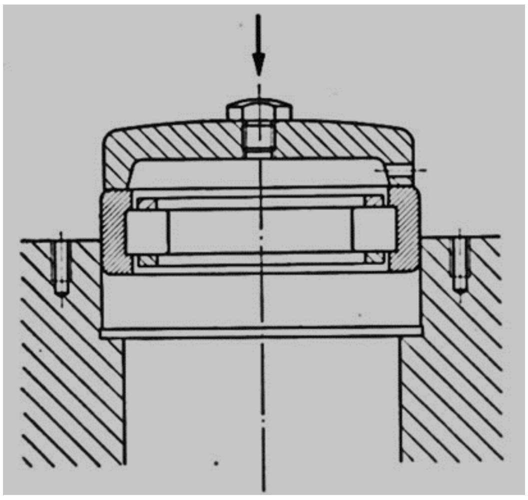


Fig. 12. Pressing the external bearing ring in the body (example)

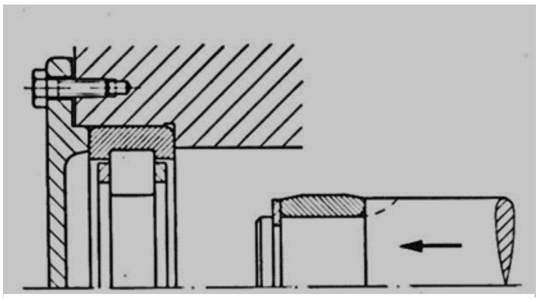


Fig. 13. complete location of separable bearings (example)

Prior to inserting the inner ring into the roller annulus, it is suitable to use additional guiding ring in the annulus area (cover lid is not assembled), in order to prevent damage to the rotation routes by the aligned rollers – transverse lines.

3.2 Hot assembly of the cylindrical roller bearings

Since the mounting of roller bearings of large and medium sizes, placed on the shaft with overlapping, is complicated, the bearings are heated in hot oil baths. Transformer oil is most frequently used for heating the bearings. Oil can be replaced with water with added 5% drilling oil or 0.1 % sodium nitrate.

The bearings are heated in metal vessel of suitable dimensions. In order to prevent the bearing overheating, they are placed on metal sieve or grate placed above the vessel bottom, preventing direct contact of the bearings with the heated surface and overheating, figure 14.

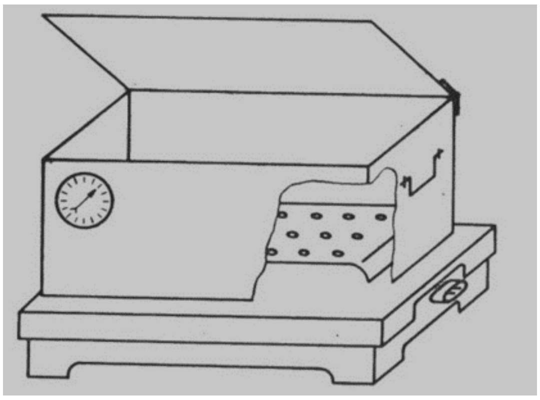


Fig. 14. Vessel for heating the bearings in oil bath

The vessel and oil must be absolutely clean. During heating, it is necessary to permanently check the temperature of the oil bath and prevent oil overheating with the hazard of inflammation. The bearings are heated by 50 to 60 °C above the ambient temperature, i.e. oil heating to 70 to 80 °C.

With common room temperature, it is sufficient for the bearing to be inserted on the journal. The bearings should be heated to temperature up to + 100 °C, also due to safety reasons and increased service life of oil.

The mounting of heated bearings or rings requires skilled employees. The bearing is removed from the bath, left to drain, and the bearing bore must be cleaned with clean cloth. Prior to the bearing mounting on the shaft, it is lubricated with the mounting paste (the mounting paste is used for all solid and shifting sets - it facilitates the mounting, restricts the occurrence of the contact corrosion, and facilitates the subsequent dismounting from the set). The heated bearing is then quickly and in one stroke shifted on the shaft in such way to fit with the full front surface of the inner ring on the support front. Apply mild screwing rotation of the bearing or the ring to facilitate the mounting on the shaft. Use protection gloves or cloth during the mounting, not cleaning wool. After cooling the bearing must be fitted by means of the mounting casing, and use the card gauge to check if the bearing internal ring fits the support front on the full circumference.

Heating smaller number of smaller bearings should be performed by electrical heating hob with adjustable thermostat. Several bearings can be heated at the same time and maintained at required temperature until the mounting. It is recommended to check the required temperature by means of thermometer.

Higher numbers of bearings or more bearings of several sizes should be heated in electrical furnace. The furnace must be kept absolutely clean in order to reduce the risk of contamination. The bearings are maintained at required temperature until the mounting. The furnace should be fitted with adjustable regulation (thermostat) and enforced air circulation (fan) in order to ensure balanced bearing heating.

Small, medium, and larger bearings which are assembled with the overlapping can be quickly and without a risk heated by induction heating device with automatic demagnetising. The device for induction heating of smaller bearings is displayed on figure 15a, device for induction heating of bearings up to bore diameter max. 300 mm is displayed on figure 15b.

Fig. 15a Device for induction heating of smaller bearings

Fig. 15b. Device for induction heating of bearings up to bore diameter max. 300 mm

Heating large bearings is displayed on figure 15c, using the induction heating option.

Fig. 15c. Device for induction heating of large bearings

Heating large bearings is also displayed on figure 16, which also includes the tool for lifting the heated bearing from the oil bath.

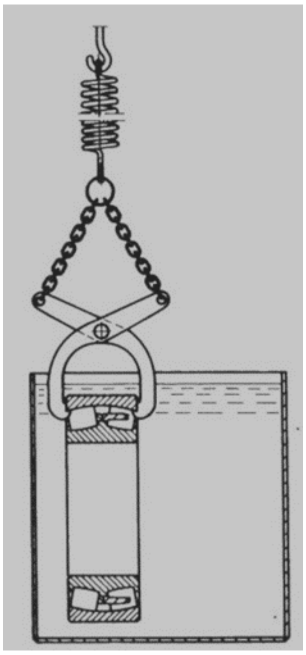


Fig. 16. Heating large bearings in oil bath

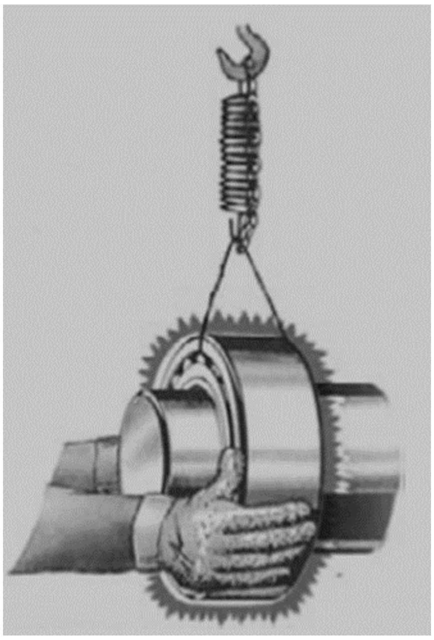


Fig. 16a. Heating large bearings in an oil bath – lifting gear

When manipulating a heated bearing, use protective gloves. Push the bearing firmly to the stop so the inner ring is tight against the shoulder – see fig. 16 a.

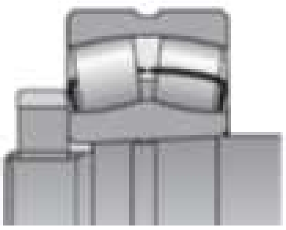
During the large bearing fitting on the journal using a crane, it is recommended to use springs inserted between the clams and the hook. The spring enables accurate setting of the required bearing height during fitting on the journal. After fitting, the inner ring must be immediately axially pressed to the support in order to enable its fitting on the shaft supports after cooling.

If the external bearing ring is to be fixed in the body, the body should be heated prior to the assembly. If the body has irregular shape, unbalanced heating may result in adverse deviations. In order to prevent this, the bearing should be cooled by carbonic acid ice. Temperatures below – 50 ^{0}C cause fragile and breaking material!

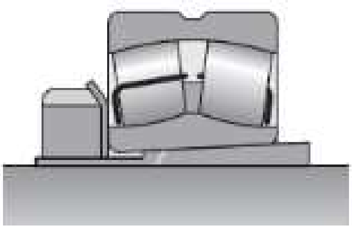
NEVER HEAT THE BEARING IN OPEN FIRE!

3.3 Mounting the tapered roller bearings

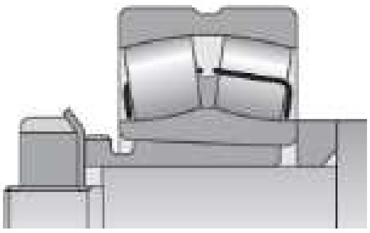
Bearings with a tapered hole are fixed onto a cylindrical journal (shaft) using a tapered sleeve or removable tapered-sleeve adapter, or directly fixed onto a tapered journal.



Tapered journal



Tapered sleeve



Removable tapered-sleeve adapter

The overlap in the inner ring depends on how far the ring moves on the tapered journal or sleeve. It is important to observe the radial clearance reduction principle – see table No. 7. In selecting the outer ring fit, follow the principles which apply for bearings with cylindrical holes.

The bearings in question are mostly self-aligning ball bearings or spherical-roller bearings. Use of sleeve simplifies assembly and disassembly, and reduces demands on high precision machining of the journal surface underneath the bearing. Reliable fixation can be achieved either by pressing the inner ring on using a nut, or by inserting the sleeve sufficiently far – see fig. 16b. In all cases, the inner ring expands, which reduces the radial clearance in the bearing.

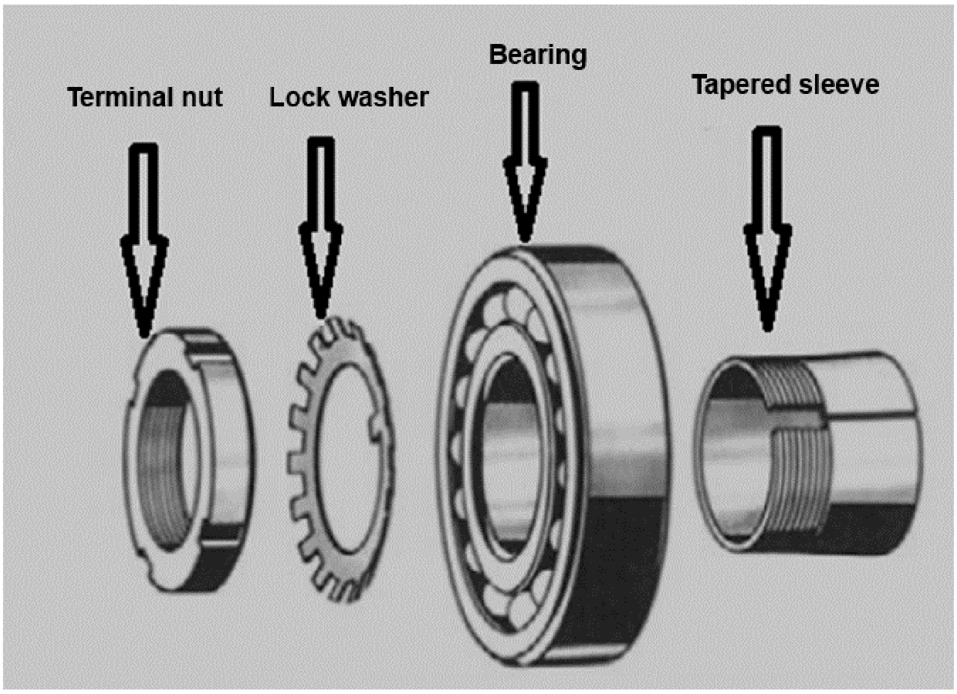


Fig. 16b. Mounting a bearing with a tapered hole using a tapered sleeve

The inner bearing ring is always mounted with overlap. The overlap size depends on how the bearing moves on the cone and how the inner ring expands. For this reason, reduction of radial clearance is a measure of the overlap size. Information on the recommended radial clearance reduction and axial displacement is given in Table 7.

Use of tapered sleeve mounted against the shoulder requires a thrust collar. The thrust collar must be designed so that the tapered sleeve could move underneath the thrust collar during assembly, and release the bearing. If the shaft is smooth with no shoulder on it, put the sleeve on the shaft in the position marked before disassembly, or find a suitable position for the bearing in the body by means of measuring. In some cases, it may be necessary to do a test assembly to find the right position for the sleeve.

The movement of the tapered sleeve along the shaft can be made easier by opening the slot in the sleeve using a screwdriver.

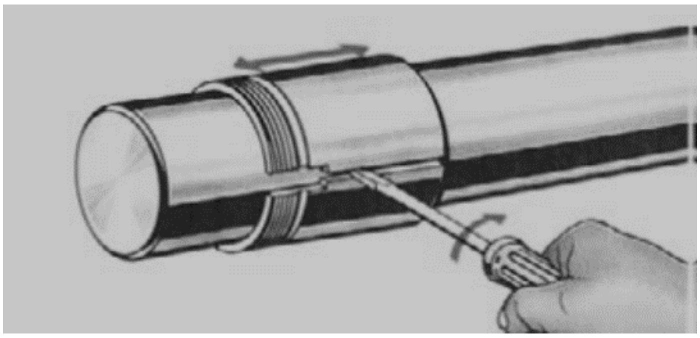
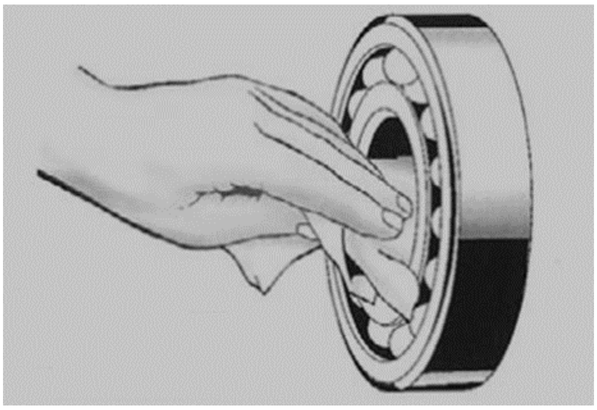


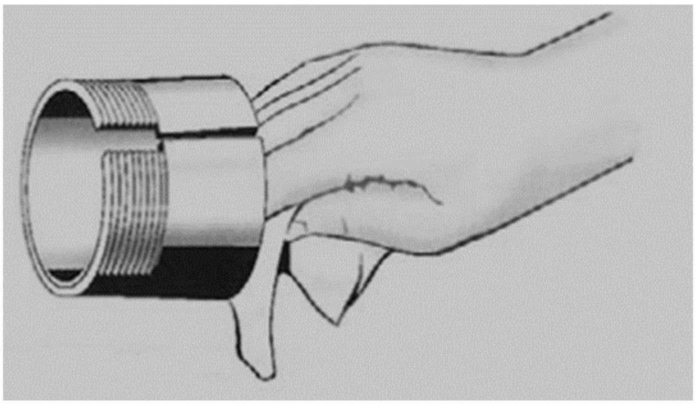
Fig. 16c. Using a screwdriver to open the tapered sleeve

3.3.1 Mounting self-aligning ball bearings using tapered sleeves

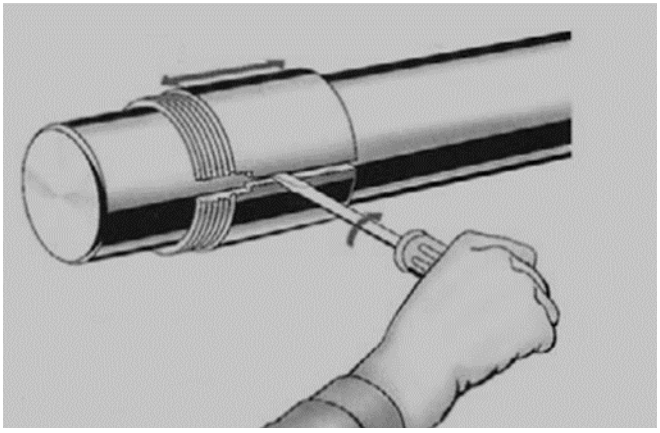
When mounting double-row self-aligning ball bearings, the tapered sleeve nut can be tightened to the point that the outer ring can turn freely, but tilts with some resistance. Self-aligning ball bearings are often mounted on tapered sleeves against a thrust collar. The bearing cannot be expected to lean against the thrust collar at the moment the bearing radial clearance attains the correct value. For this reason, first fit the bearing freely on the tapered sleeve so that it leans against the thrust collar. Then draw the tapered sleeve underneath the bearing using a nut and a spanner until there is sufficient overlap of the bearing on the sleeve. An easy method of mounting bearings on tapered sleeves is based on the tightening angle, by which the nut is tightened as described below. Prior to assembly, coat the nut face facing the bearing with mounting paste and the outside surfaces of the shaft and the sleeve with thin oil. Fit the bearing on the sleeve and screw on the nut. By tightening the nut by the given angle, the bearing will move onto the tapered sleeve surface. Since the bearing, while moving onto the sleeve, has a tendency to tilt, we recommend relocating the spanner after tightening, to the groove located 180 degrees from the one at which the nut was tightened, and striking the spanner lightly. That straightens the bearing on the sleeve. Screw off the nut, insert the lock washer, screw the nut back on, tighten, and secure it with the lock washer. Check the radial clearance.



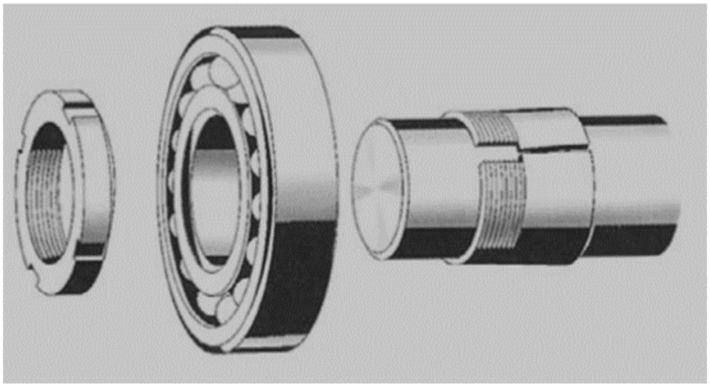
Wipe the preservative off the sleeve and bearing hole surfaces, then coat the sleeve outer surface lightly with thin mineral oil.



The thread and face of the nut leaning against the bearing should be coated with mounting paste or similar lubricant.

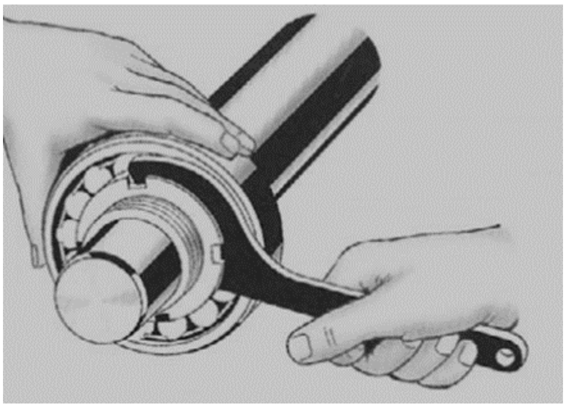


Open the sleeve lightly and fit it on the shaft in the correct position.

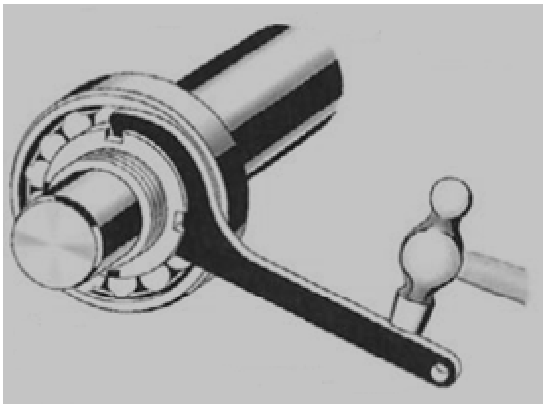


Fit the bearing on the sleeve and screw on the nut with the chamfered face towards the bearing. Tighten the nut so that there is maximum contact between the sleeve, the shaft and the bearing, while making sure the bearing does not move onto the sleeve.

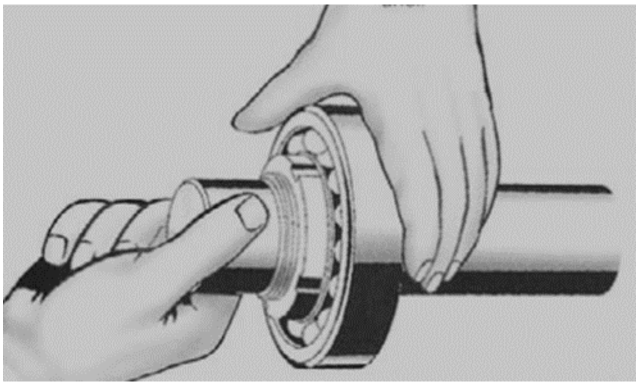
Fit the bearing on the sleeve and screw on the nut with its chamfered side towards the bearing. Tighten the nut so there is full contact between the sleeve, shaft, and the bearing, while making sure the bearing does not move onto the sleeve.



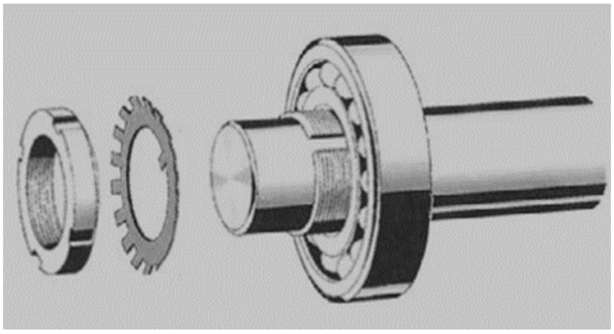
Use a hook spanner to turn the nut.



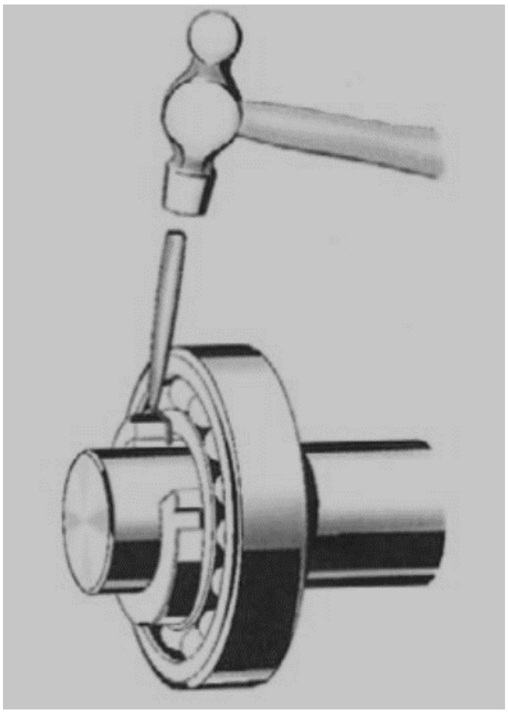
To obtain the correct overlap, tighten the nut by the required angle, relocate the spanner by 180 degrees, and tighten the nut by a few more degrees with hammer strokes.



A self-aligning ball bearing with normal radial clearance is correctly mounted, if the outer bearing ring is turning lightly but is tilting with some resistance.



Screw off the nut, fit the lock washer, and retighten the nut to stop the bearing from moving on any further on the shaft.



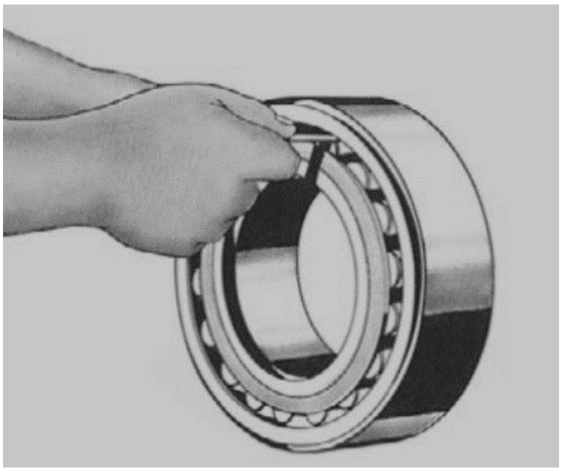
Secure the nut by bending one of the teeth of the lock washer into the nut groove, but do not loosen the nut so the tooth gets into the groove.

If the nut is mounted from the inner side of the bearing, the lock washer must be fitted together with the nut. The surfaces which slide against one another during tightening must be lubricated.

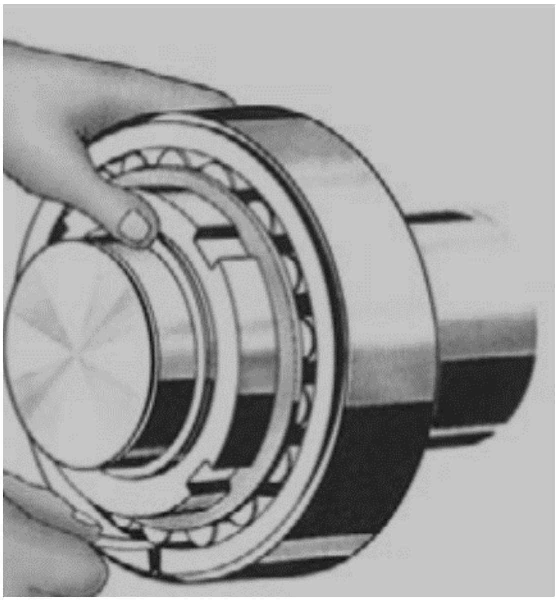
A popular method for mounting bearings with conical bores correctly and reliably is based on measuring the axial displacement of the inner bearing ring on the conical surface. The recommended values of the displacement are given in Table 7. When using the above methods, fit the self-aligning bearing on the conical journal or sleeve far enough for the bearing to touch the surface along the full circumference. Then tighten the nut to eliminate the clearance. This is how you achieve a sufficiently firm coupling, and the resulting clearance will correspond to the table mean values. See the figure below showing one of the methods of measuring the radial clearance of a self-aligning ball bearing. Insert the washer A between the bearing and the lock or thrust nut to ensure the correct alignment of the outer ring with respect to the inner one. The dial indicator M held to the bearing outer ring can be used to measure the radial clearance of the bearing. Press the outer ring upwards in perpendicular direction to the shaft axis.

3.3.2 Assembly of spherical-roller bearings with tapered bore

A double-row spherical-roller bearing is fitted with a larger overlap. Since reduction of radial clearance is a measure of the overlap size, use a feeler gauge to measure the value of radial clearance before assembly. Put the bearing on a mat and turn the inner ring over several times. Insert the feeler gauge between the highest spherical roller and the outer ring raceway. In this position, use thicker and thicker feeler gauges, until you feel light resistance during measuring.

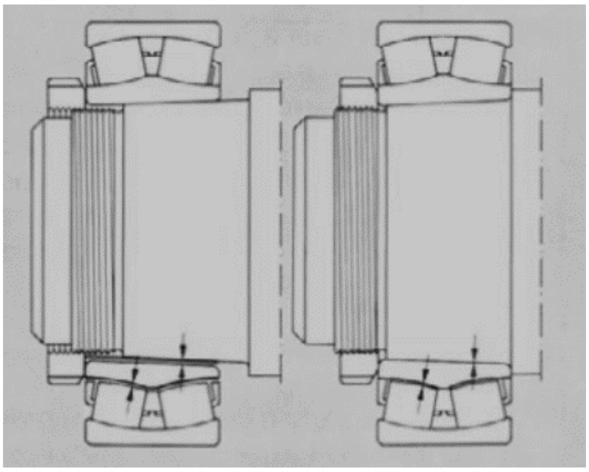


Fit the bearing on the shaft and during moving the bearing along on the shaft, check the reduction of radial clearance below the lowest spherical roller according to Table 7.

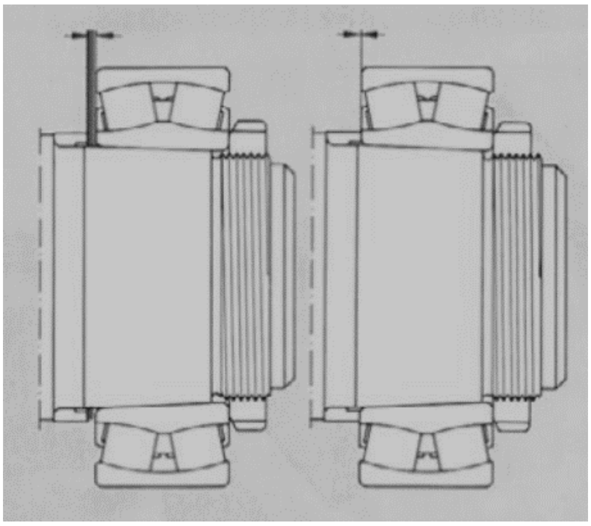


Use the minimum values of radial clearance reduction for bearings with the initial clearance close to the lower limit. In this way, the minimum admissible clearance will be observed. When mounting bearings with radial clearance greater than normal (C3, C4), we recommend using the upper half of the scope of radial clearance reduction to obtain the correct overlap on the shaft.

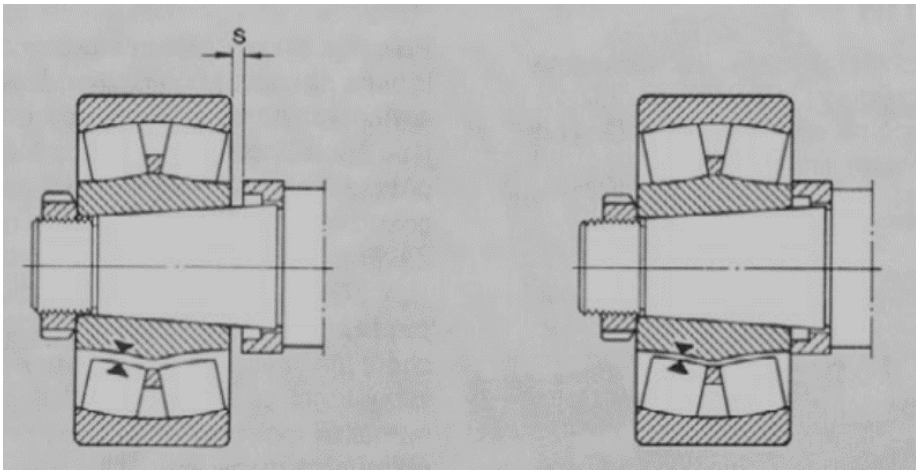
The size of the overlap depends on how far the bearing moves on the tapered surface. During moving the bearing on the shaft, the radial clearance is gradually reduced as the inner ring expands.



For small spherical-roller bearings, or where there is not enough space for measuring, check the axial displacement instead of the radial clearance reduction, see Table 7.



Reduction of radial clearance and axial displacement



Assembly of self-aligning spherical-roller bearings with tapered bore

The reliability of fixation is checked according to the reduction of radial clearance using feeler gauges, or by measuring the axial displacement of the inner ring on the journal or tapered sleeve. The initial position for measuring this displacement is achieved when the contact surfaces (of the ring, sleeve, shaft) abut against one another on entire surface of the bearing. The values for the assembly of double-row spherical-roller bearings with tapered bore are given in Table 7.

Small bearings of bore diameter up to 80 mm can be pressed onto the tapered journal, tapered sleeve – see fig. 17, or removable tapered-sleeve adapter – see fig. 18, using a terminal nut tightened with a mounting spanner. Prior to assembly, the contact surfaces must be coated with oil.

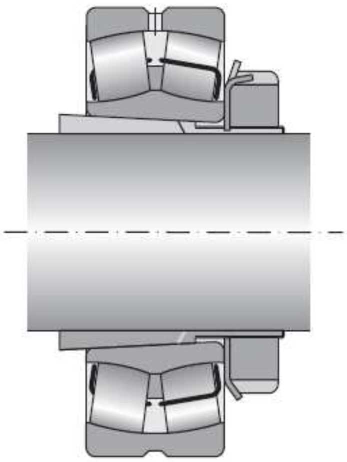


Fig. 17

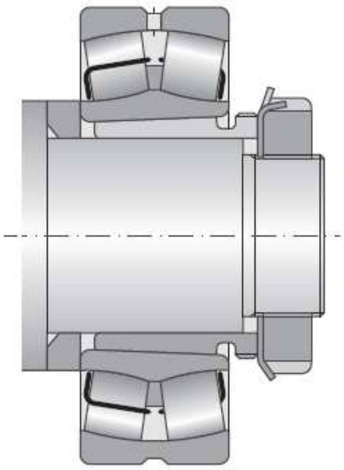


Fig. 18

Larger bearings require a greater mounting force, and this is why the hydraulic nut or the pressure oil method should be used in their assembly, when high-pressure oil is introduced between the contact surfaces of the ring and journal – see fig. 19. This creates an oil film which reduces the friction between the contact surfaces. This method can also be used for the assembly, using tapered sleeves or removable tapered-sleeve adapters adapted to this method. We recommend using oil of viscosity 300 mm^2/s at 20º C.

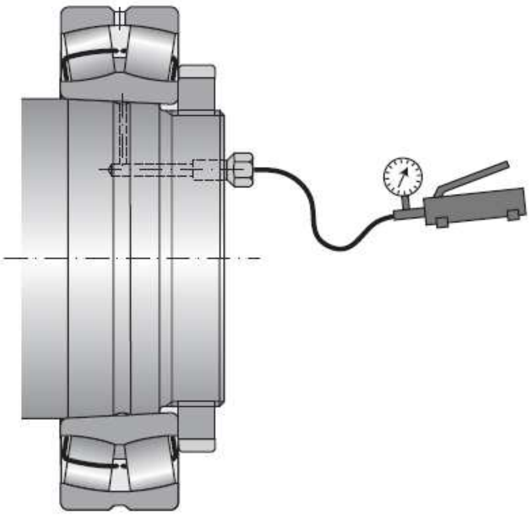
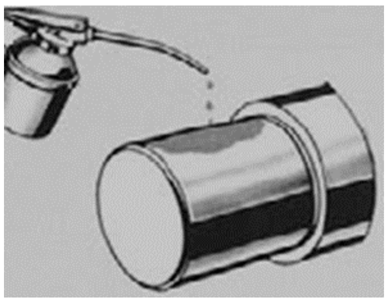


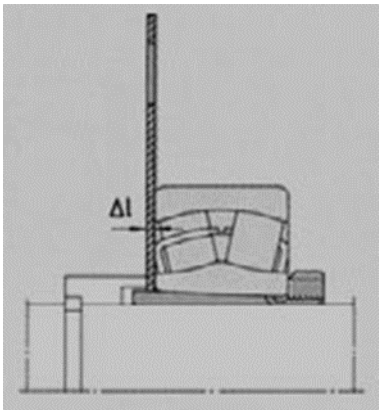
Fig. 19

3.3.3 Cold assembly of spherical-roller bearings on tapered sleeves

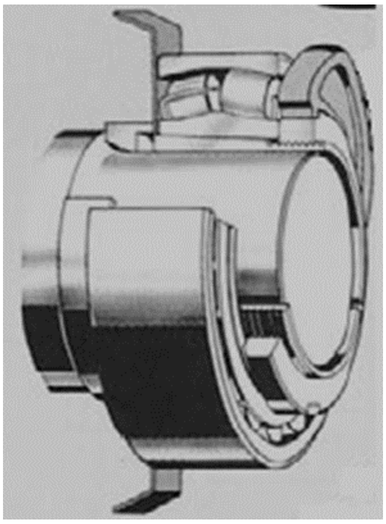
First choose a suitable method for checking the position of the bearing on the sleeve: either by measuring the reduction of radial clearance, or measuring the axial displacement on the sleeve during assembly, see Table 7. Coat the thread and face of the nut facing the bearing with molybden-sulfide paste, or other lubricant designed for lubricating sleeves and joint mechanisms. Coat the outer surfaces of the shaft and sleeve with thin oil.



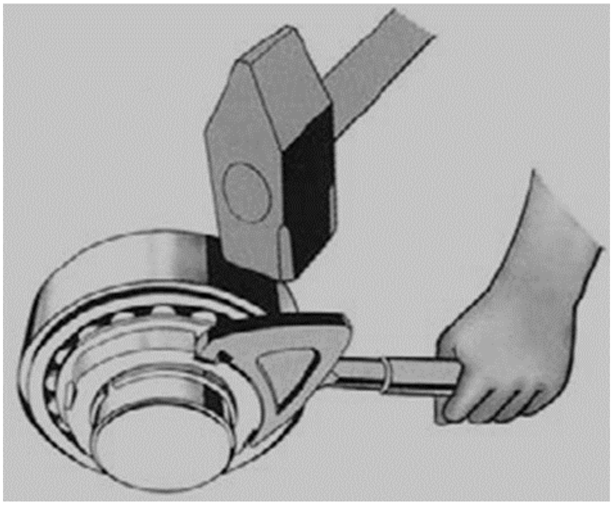
Assembly can be made easier by using feeler gauges or calibrated distance washers of thickness equal to the required axial displacement.



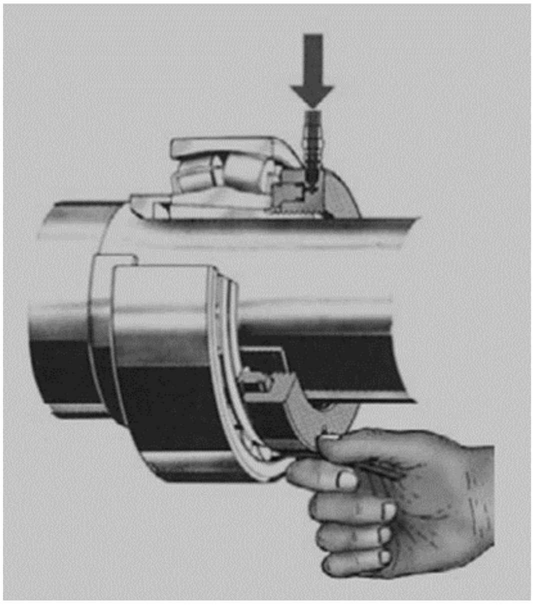
Insert the tapered sleeve under the thrust collar, attach the washers to the collar, and press fit the bearing onto the sleeve, until it presses down the washers. Tighten the terminal nut with a spanner, until the bearing starts to clamp the washers, but while you are still able to withdraw the washers. After withdrawing the washers, fit the bearing onto the sleeve by tightening the nut using a spanner by the pre-set axial displacement, until the bearing is tight against the thrust collar. Screw off the nut, fit the lock washer, screw the nut back on, tighten, and lock. Check the residual radial clearance in the bearing.



Small and medium-sized spherical-roller bearings can be fitted on tapered sleeves using a terminal nut and a spanner.



Larger-sized spherical-roller bearings with internal diameter ≥ 50 mm can be easily and reliably mounted using a hydraulic nut.



Tab. 7. Assembly of double-row spherical-roller bearings with tapered bore

Assembly of double-row spherical-roller bearings with tapered bore										
Bore Diameter		Reduction of radial clearance		Axial displacement on 1:12 taper				Minimum admissible radial clearance of bearing with clearance		
d				on shaft		on sleeve				
over	*to*	*min*	*max*	*min*	*max*	*min*	*max*	*normal*	*C3*	*C4*
mm		*µm*		*mm*				*µm*		
30	40	20	25	0,35	0,4	0,35	0,45	15	20	40
40	50	25	30	0,4	0,45	0,45	0,5	20	30	50
50	65	30	40	0,45	0,6	0,5	0,7	25	35	55
65	80	40	50	0,6	0,75	0,7	0,85	25	40	70
80	100	45	60	0,7	0,9	0,75	1	35	50	80
100	120	50	70	0,75	1,1	0,8	1,2	50	65	100
120	140	65	90	1,1	1,4	1,2	1,5	55	80	110
140	160	75	100	1,2	1,6	1,3	1,7	55	90	130
160	180	80	110	1,3	1,7	1,4	1,9	60	100	150
180	200	90	130	1,4	2	1,5	2,2	70	100	160
200	225	100	140	1,6	2,2	1,7	2,4	80	120	180
225	250	110	150	1,7	2,4	1,8	2,6	90	130	200
250	280	120	170	1,9	2,7	2	2,9	100	140	220
280	315	130	190	2	3	2,2	3,2	110	150	240
315	355	150	210	2,4	3,3	2,6	3,6	120	170	260
355	400	170	230	2,6	3,6	2,9	3,9	130	190	290
400	450	200	260	3,1	4,1	3,4	4,4	130	200	310
450	500	210	280	3,3	4,4	3,6	4,8	160	230	350
500	560	240	320	3,7	5	4,1	5,4	170	250	360
560	630	260	350	4	5,4	4,4	5,9	200	290	410
630	710	300	400	4,6	6,2	5,1	6,8	210	310	450
710	800	340	450	5,3	7	5,8	7,6	230	350	510
800	900	370	500	5,7	7,8	6,3	8,5	270	390	570

3.3.4 Hot assembly of spherical-roller bearings on tapered sleeves

For heating bearings, devices such as induction heating, oil bath, or heating furnace with an adjustable thermostat can be used. For heating bearings in an oil bath, always use clean oil with inflammation point 250º C. Make sure the whole bearing is submerged in oil and the oil is not overheated. Oil bath heating is a great method which heats the bearing uniformly while simultaneously protecting it against corrosion.

During the hot assembly of bearings on tapered sleeves, measure the axial displacement from the nut face. Prior to heating, fit the bearing on the sleeve, screw on the nut, and tighten lightly to ensure full contact between the bearing, the sleeve, and the journal. Measure the distance between the thread end of the sleeve and the nut, and increase it by the value of axial displacement. This is the final distance where you will be mounting the bearing. After heating the bearing, fit it on the sleeve in the required position. After clamping, release the nut, insert the washer, retighten the nut, and secure. After the bearing cools off, measure the radial clearance in the bearing.

3.3.5 Hot assembly of spherical-roller bearings on removable tapered-sleeve adapters

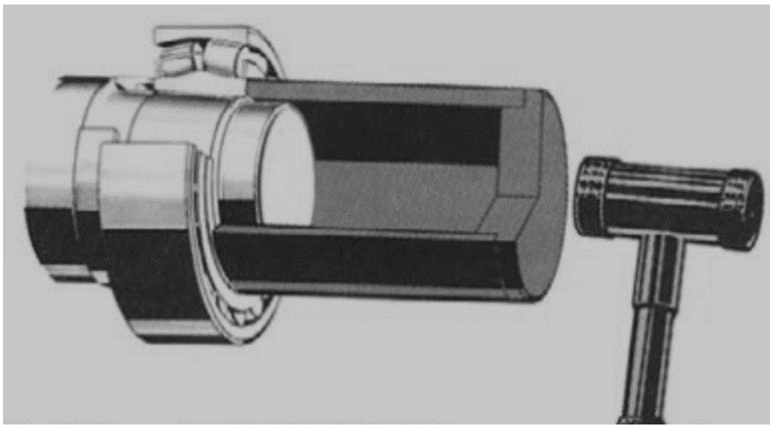
Where cold-assembly methods cannot be used, heat the bearing prior to assembly. For heating bearings, methods such as induction heating or oil bath heating are suitable.

For the hot assembly of bearings on removable tapered-sleeve adapters, use a feeler gauge or calibrated distance washer of thickness equal to the value of axial displacement.

Insert the adapter under the cold bearing so there is full contact. Screw the nut onto the adapter, leaving a space corresponding to the value of axial displacement, see Table 7. Use a distance washer to determine the distance. Lock the nut in this position, or mark its position on the adapter. Heat the bearing to temperature approx. 80 ^{0}C higher than the shaft temperature, but the temperature must never exceed 120 ^{0}C. Press the adapter with the nut in the marked position under the bearing heated to the mounting temperature, until the nut rests on the bearing. Hold the adapter in this position, until it cools off. After the mounted bearing cools off, check the residual radial clearance in the bearing. If the radial clearance is too small, adjust the mounting distance. First use the nut to dismount the bearing, then heat the bearing again, and repeat the assembly procedure.

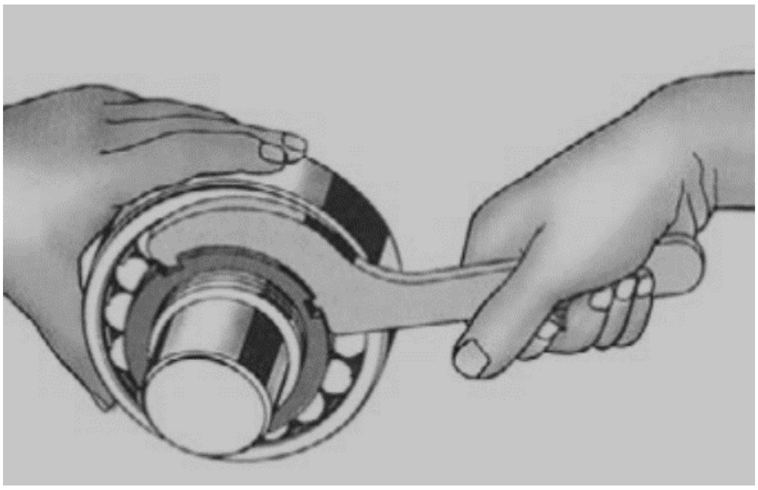
3.3.6 Cold assembly of bearings on tapered journals

Small bearings can be fitted on the tapered journals by hammer strokes on the mounting sleeve applied to the inner ring. Coat the journal with thin oil to protect it against any damage.

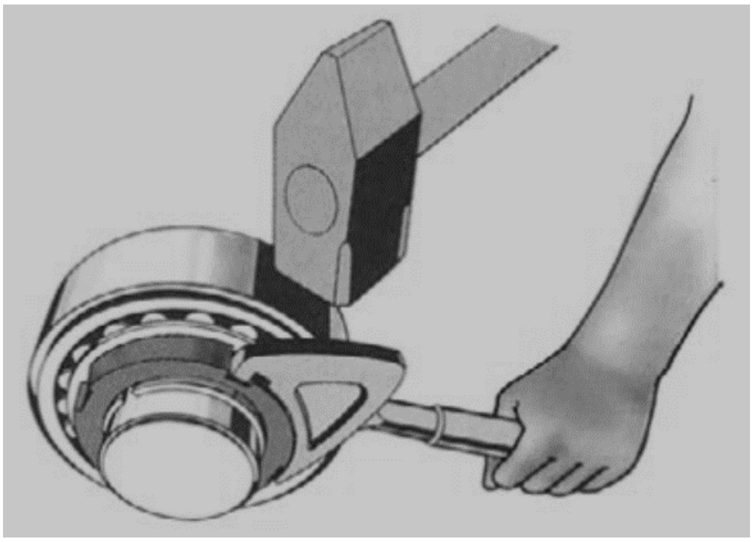


Assembly of smaller sized bearings using a striking sleeve and a hammer with damping effect

If the shaft is threaded, small sized bearings can be fitted on the shaft using a terminal nut and a mounting spanner. Terminal nuts are designed to transmit mounting force. Check residual radial clearance after assembly.



Assembly of smaller bearings using a terminal nut and a hook spanner



Assembly of medium-sized bearings using a terminal nut, solid spanner, and hammer

Use a mounting sleeve and a hammer with damping effect. Move the bearing by hammer strokes to the prescribed distance – see Table 7.

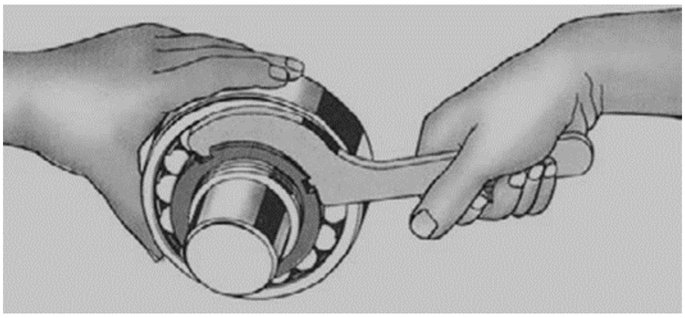
For self-aligning ball bearings, check the radial clearance by turning and tilting the bearing. The bearing must turn freely, but tilt with some resistance. For spherical-roller bearings, use feeler gauges to check the reduction of radial clearance.

This mounting method is not recommended for precision applications such as, for instance, machine-tool spindles.

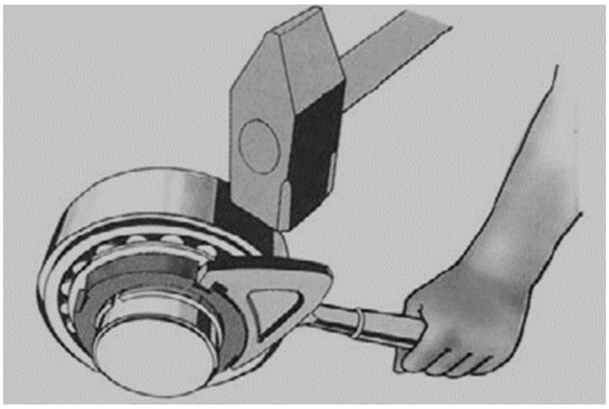
3.4 Using terminal nut and mounting spanner

If the shaft is threaded, small bearings can be fitted on the shaft using a terminal nut and a mounting spanner. Terminal nuts are designed to transmit mounting force. After assembly, check radial clearance.

Medium sized bearings can be mounted using a terminal nut, but you need a solid spanner and a heavy mallet. Lubricate the sliding surfaces and use firm, but not heavy strokes.



Bearing assembly using terminal nut and mounting spanner



Assembly of larger sized bearings using terminal nut, mounting spanner, and hammer

3.5 Hydraulic nut and pressure oil method

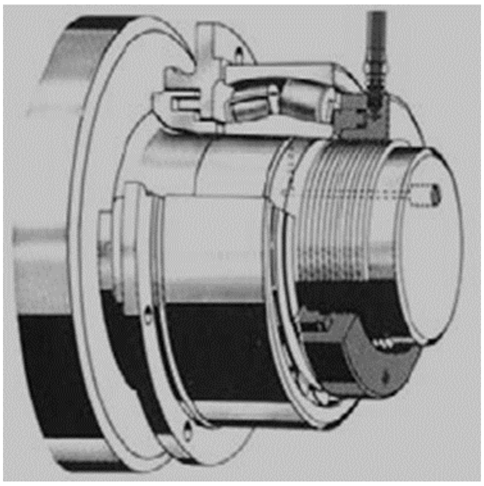
A hydraulic nut and the pressure oil method can make assembly considerably easier. For small and medium-sized removable tapered-sleeve adapters, use the hydraulic nut only. Large adapters require considerable mounting forces and for this reason, have feed channels and distribution grooves for pressure oil. Oil is pressed in between the adapter and the shaft by one channel, and between the adapter and the bearing by another channel. For large adapters, use the pressure oil method in combination with the hydraulic nut, or terminal nut and mounting spanner. Use oil with viscosity of about 300 mm^2/s at the temperature of 20 ^{0}C.

Bearings with bore diameter larger than 50 mm can be easily mounted using a hydraulic nut. The hydraulic nut can be used for mounting bearings of diameter up to 1000 mm. Easy disassembly can be done by the pressure oil method. When using the pressure oil method for the disassembly, grooves and channels for pressure oil must be made in the shaft.

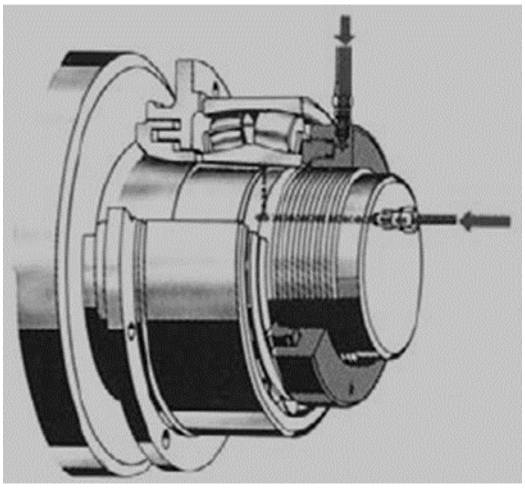
Place the nut with the piston towards the bearing face, tighten it manually, and feed oil into it, until the bearing is in the required position on the shaft – see Table 7. Then replace the hydraulic nut with the terminal nut, secure, and check the residual radial clearance after assembly. The pressure oil method allows to release and then shift the bearing, and increase the radial clearance.

The pressure oil method can be applied to bearing assembly and disassembly on tapered journal. A combination of the pressure oil method and the hydraulic nut method further facilitates assembly of large bearings. The method also simplifies disassembly, since after feeding in the pressure oil, the bearing becomes loose without assistance.

The pressure oil method is designed for medium-sized bearings. By feeding pressure oil in between the bearing and the journal, the contact surfaces separate, the friction is reduced nearly to zero, and the result is small force required for assembly. In this way, bearings can be mounted with certain radial clearance, which should be checked continuously. The final checking of the residual radial clearance should be done about 15 min after releasing the pressure.



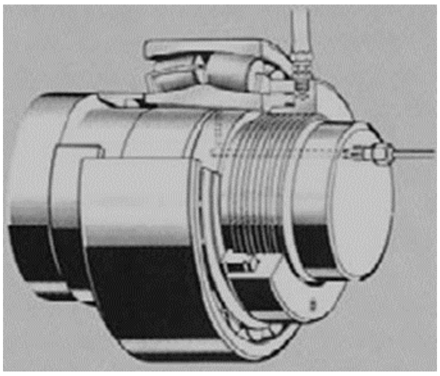
Bearing assembly using hydraulic nut. For disassembly, use pressure oil.



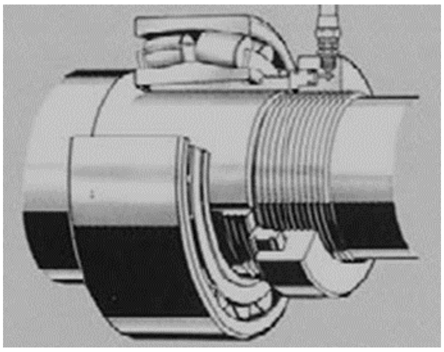
Bearing assembly using a combination of hydraulic nut and pressure oil.

For cylindrical surfaces, the pressure oil method can only be applied to disassembly. Use of oil with viscosity of about 1 000 mm2/s at 20 C ensures slower oil run-off, which is important for preventing metal-to-metal contact between the bearing and the shaft after withdrawing the bearing beyod the distribution groove, and therefore stopping feeding oil between the surfaces.

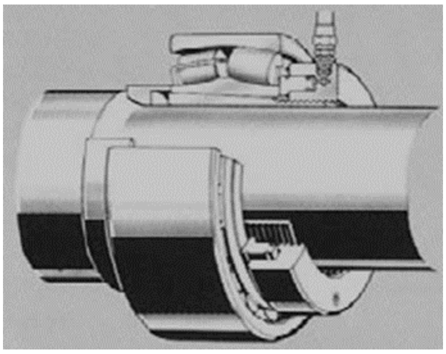
The hydraulic nut saves time and effort during bearing assembly and disassembly. It consists of the ring body with an internal thread and an annular groove in one of the faces, and the ring piston seated in this groove. The seal consists of two O-rings. When oil is fed into the groove space, the piston is pushed out with a force required for bearing assembly and disassembly. For ease of coupling, hydraulic nuts are provided with a connector for the quick coupler of the oil pump hose. The nuts are designed to bear the pressure normally required for assembly and disassembly. After finishing working with the hydraulic nut, open the pump check valve and tighten the nut so as to push the piston back into the initial position and return the oil into the pump.



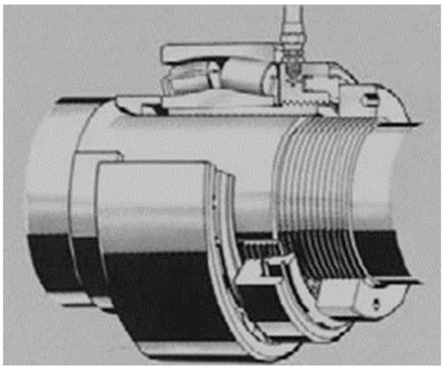
Hydraulic nut used for mounting bearings on a ball journal together with the pressure oil method



Hydraulic nut used for mounting bearings on a tapered sleeve



Hydraulic nut used for pressing in the removable tapered-sleeve adapter



Hydraulic nut used with a shaft nut for pressing in in the removable tapered-sleeve adapter

3.6 The effect of bearing clearance size on bearing life and precision of operation

Under stable service conditions, the size of the radial clearance of a radial bearing has an effect on the bearing life and reliability of operation as well as running precision of the rotating shaft (spindle).

A very large radial clearance causes the external load to spread on a smaller number rollers, increasing the load on each of them, and reducing the precision of the shaft run. The operating clearance of a thrust bearing depends on its clearance size in the disassembled state, on the size of the inner and outer ring overlap, and on the temperature gradient between the bearing rings. Although larger clearance during the bearing operation may not destroy the bearing rapidly, it will have an effect on reducing its load-bearing capacity and durability.

The operating clearance cannot be measured during the bearing operation, so that negative clearance may occur, i.e. prestress, causing premature destruction of the bearing.

4. DISMOUNTING PREPARATION

4.1 Workplace for the bearing dismounting

During unprofessional performed bearing dismounting, internal damage may occur or contamination may enter the bearing. We can definitely recommend avoiding the dismantling of undamaged bearing. If the bearing still requires dismantling, it is necessary to proceed with great care.

The workplace for dismantling must be sufficiently large and clean. It is simpler to protect the bearings from contamination then clean it.

Undamaged bearings should be assembled during re-mounting in the same position on the same location on the shaft. Considering the orientation the bearing should pre-marked.

4.2 Work procedure

Prior to the beginning of each dismounting, it is necessary to specify work procedure based on the mounting documentation, to be used for individual work tasks.

The location with the roller bearings should be resolved considering simple dismantling. During the dismantling of roller bearings, it is necessary to make sure the required forces are applied over the rolling components, and prevent the pressure marks on the bearing parts' rotating routes.

During the dismantling of solid placed bearing ring, it is necessary to apply higher force than during mounting. Some locations must include both bearing rings fixed. In such cases it is not possible to perform the dismantling without loading the rolling units. Balanced applied pressure from the press or the screw is less hazardous than the strokes.

If the bearing mounting requires special provisions, different to the common practise, the assembler must have available a derailed mounting manual including common work procedure plus required tool common devices for the mounting, e.g. transport tools, special mounting agents, measuring tools, heating tools, special tools, type and amount of greasing agents, etc.

Identically to mounting, the dismounting process includes four various methods: Mechanical, hydraulic, pressure oil method, and heat method which are then used according to the corresponding stock and bearing size. Smaller bearings commonly require the use of mechanical tools, larger bearing are dismantled by means of pressure oil method.

The dismantling processed depend significantly on the bearing position on the shaft and the in the body. The ring is usually placed with overlapping, and rotates due to load independently on the load type. It mostly includes the inner or external ring, however there are cases when both rings are overlapping.

Appropriate selection of tools is the most important factor for dismantling. The most suitable tools for appropriate assembly is recommended in the manual.

The selection of appropriate dismounting method is facilitated in the table below.

<table>
<tr><th rowspan="2">LOCATION</th><th rowspan="2">Ød of the bearing (mm)</th><th colspan="4">Mounting tools</th></tr>
<tr><th>Mechanical</th><th>Hydraulic</th><th>Pressurized oil</th><th>Heating agents</th></tr>
<tr><td rowspan="4">Cylindrical journal</td><td><80</td><td>recommended</td><td>unsuitable</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>80-200</td><td>recommended</td><td rowspan="3">recommended</td><td rowspan="3">recommended</td><td>unsuitable</td></tr>
<tr><td>>200</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>Roller bearings of all sizes</td><td>recommended</td><td>recommended</td></tr>
<tr><td rowspan="3">Conic journal</td><td><80</td><td>recommended</td><td>unsuitable</td><td rowspan="3">recommended</td><td>unsuitable</td></tr>
<tr><td>80-200</td><td>unsuitable</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>>200</td><td>unsuitable</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td rowspan="3">Clamping casing</td><td><80</td><td>recommended</td><td rowspan="2">recommended</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>80-200</td><td>recommended</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>>200</td><td>unsuitable</td><td>unsuitable</td><td>recommended</td><td>unsuitable</td></tr>
<tr><td rowspan="3">Fastening casing</td><td><80</td><td rowspan="2">recommended</td><td rowspan="3">recommended</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>80-200</td><td>unsuitable</td><td>unsuitable</td></tr>
<tr><td>>200</td><td>unsuitable</td><td>unsuitable</td><td>unsuitable</td></tr>
</table>

5. DISMOUNTING THE BEARINGS

5.1 Dismounting the cylindrical roller bearings

If the bearings and related parts are to be reused, it is necessary to apply great care during the dismounting.

Inseparable bearing is always dismounted by applying force on the ring placed with overlapping. Individual bearing rings in separable bearings are dismounted individually.

For dismounting smaller bearing, it is suitable to use mechanical clamps (see figure 20a) or hydraulic presses. If possible, apply the clamp on the bearing internal ring, and clamp the bearing with balanced force until the bearing bore does not leave the roller journal. The clamp must be centered ideally for the dismounting in order to prevent the journal damage. In order to limit the hazard, we can successfully use the self-centering clamps. Dismounting will be facilitated by the grooves on the shaft or in the body enabling to attach the clamp on the ring mounted with overlapping.

If the clamp is to catch the external ring, and the bearing is to be reused, external ring rotation is required during dismounting.

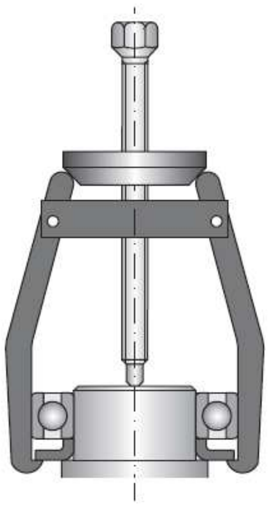


Fig. 20a

Never use hammer for direct strokes on the bearing rings. The best dismounting method of the bearing placed in the roller journal includes the use of a press. At first, make sure, only the ring placed with overlapping is supported. It is also suitable using the force out casing for dismounting.

Hydraulic clamp facilitates the disassembly of medium large bearings – see figure 20b.

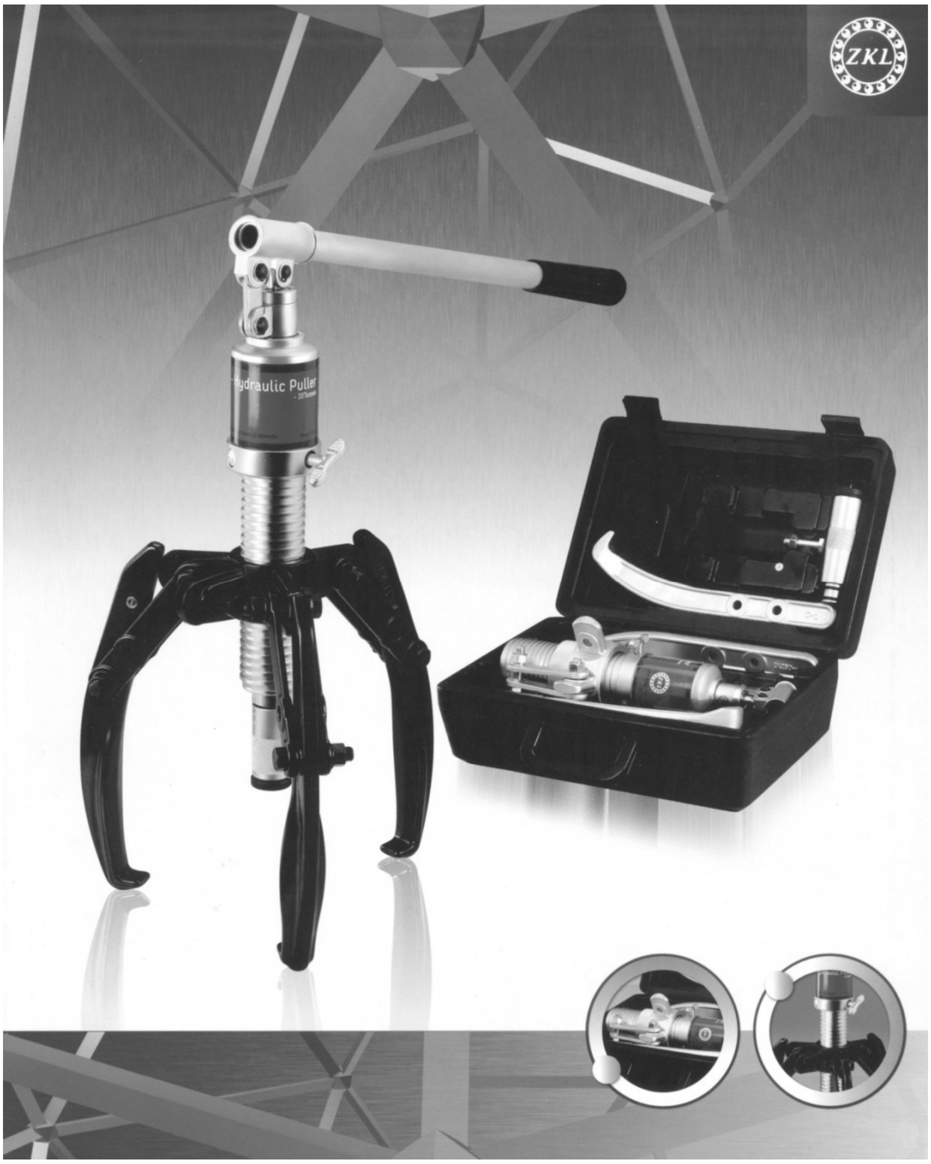


Fig. 20b

Pressure oil method is suitable for dismounting medium sized and large bearings fixed solid in the cylinder journal (see figure 21). This method simplifies the dismounting in cases great fastening forces were applied. The use of the method requires the location to be fitted with channel and distribution grooves for pressure oil inlet into the bearing inner ring location.

Oil viscosity should be about 1.000 mm^2/s at ambient temperature. Oil is introduced under high temperature between the bearing and shaft, until the surfaces are divided. As soon as oil separates the bearing surface, indicated by the oil leak, the bearing must be quickly and in one movement removed. Since the dismantling force is small, the clamp can be attached to the external ring. If the bearing after partial oil groove uncovering block on the shaft, it requires heating or removal with great force using hydraulic tools.

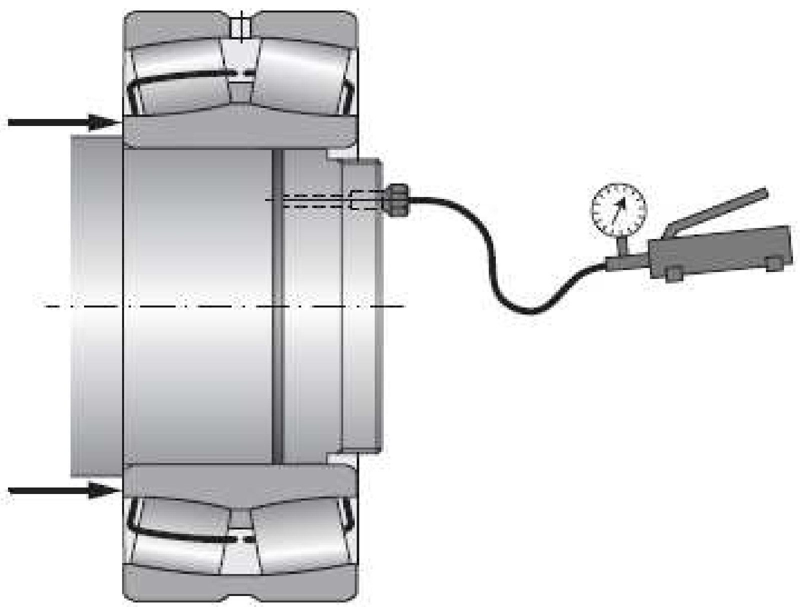


Fig. 21

The dismounting of internal roller bearing rings without the guiding flanges or with one guiding flange, which are hot mounted, can include the heating rings, i.e. thermo-rings (see figure 22). At first remove the external ring of the roller bearing with the cage and the rollers, and grease the rotation route of the internal ring with oxidizing preventing oil. The thermo-ring is heated on electrical heating hob to approx 280 – 300 ^{0}C, it is inserted on the internal bearing

ring and clamped with the holders. After removing the internal ring of the roller bearing from the journal, the ring should be immediately removed from the thermo-ring in order to prevent its overheating.

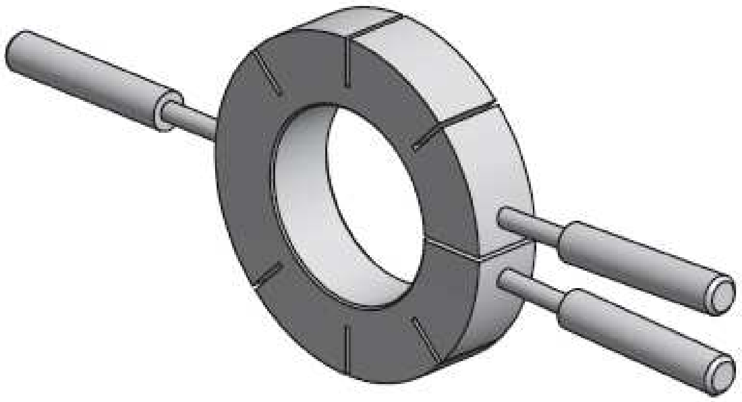


Fig. 22

The use of induction heating devices is more recommended for frequent dismounting of inner rings, which can be single purpose and adjustable for the rings of various diameters.

5.2 Dismounting the tapered roller bearings

If the bearings and related parts are to be reused, it is necessary to apply great care during the dismounting in order to ensure defect free dismounting. Correct dismounting method is crucial. The dismounting force should be applied only directly on the bearing ring mounted with the overlapping, and it commonly represents the internal ring.

The dismounting of small and medium bearings from the cylindrical journal is commonly performed by means of clamps attached on the bearing inner ring or the support part, i.e. labyrinth ring.

In order to prevent potential shaft damage, the clamp used must be centered. In order to prevent the hazard, self-centering clamps can be successfully used, and the dismounting process is then simpler and faster. If the clamp is to catch the external ring, and the bearing is to be reused, external ring rotation is required during dismounting in order to reduce the risk of bearing damage due to mounting force.

The use of press requires the fastening casing support, and the force application on the bearing inner ring (figure 23).

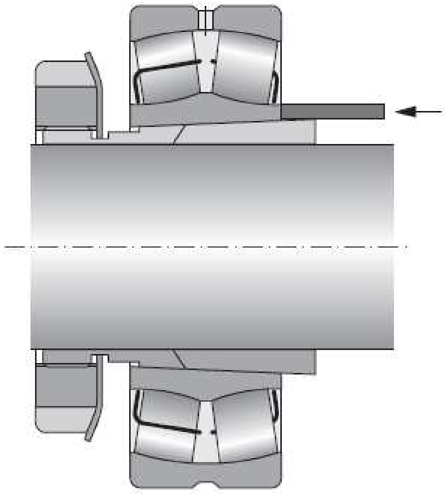


Fig. 23

Small and medium bearings mounted on the clamping casing can be dismounted from the clamping casings by means of the safety nut and the mounting or solid wrench (see figure 24). If the casing overlaps the shaft end, insert should be placed in the casing opening with corresponding diameter to the casing hole in order to prevent the casing deformation. The casing thread and the nut front attached to the bearing should be lubricated with substance for friction reduction (i.e. molybdenum-disulphate paste). Fasten the nut with the mounting or solid wrench until released.

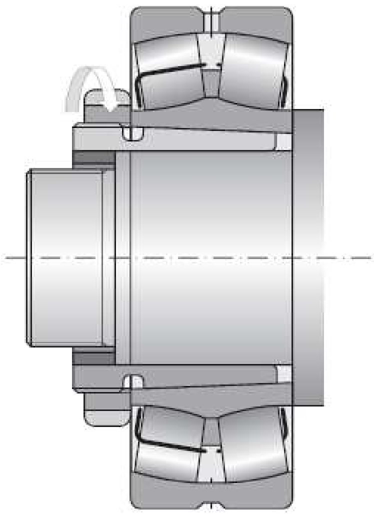


Fig. 24

During the dismounting of large bearings, it is suitable to use the forcing off screws controlled by a nut (figure 25). It is necessary to insert a mat between the bearing inner ring and the screws in order to prevent the bearing damage.

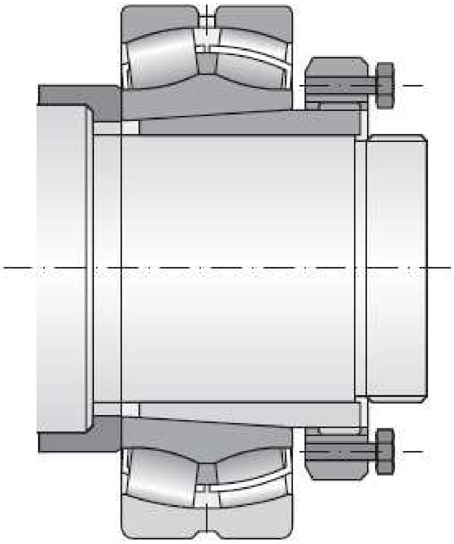


Fig. 25

Very fast, simple, and economical dismounting of the clamping casing is provided by the hydraulic nut If the bearing is on the journal end, we recommend secure the hydraulic nut prior to dismounting by means of agent attached e.g. to the shaft front (see figure 26).

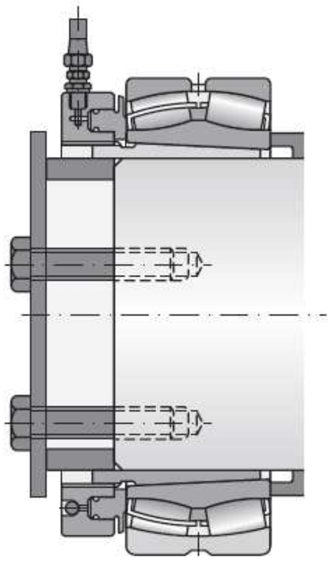


Fig. 26

Large clamping cases usually include channel grooves for pressure oil. Oil is introduced directly by the clamping nut between the shaft and casing, and between the casing and bearing (figure 27). The contact surfaces can mutually shift after pressurizing without the risk of damage. Required pressure is reached by oil injectors. The dismounting includes oil with viscosity 1000 mm^2 / s at 20^{0}C.

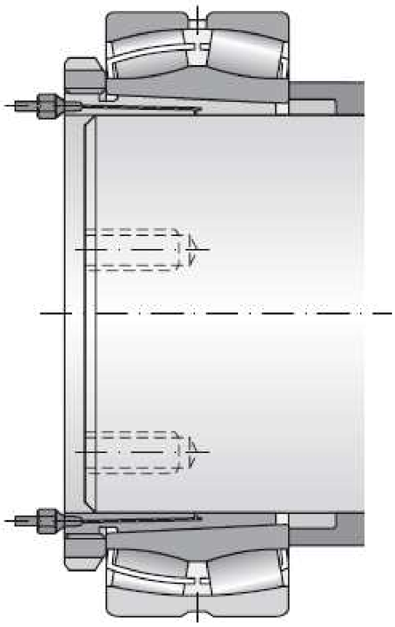
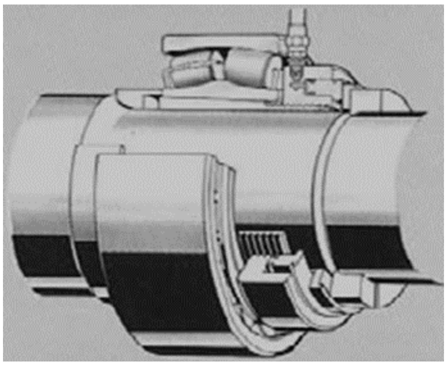
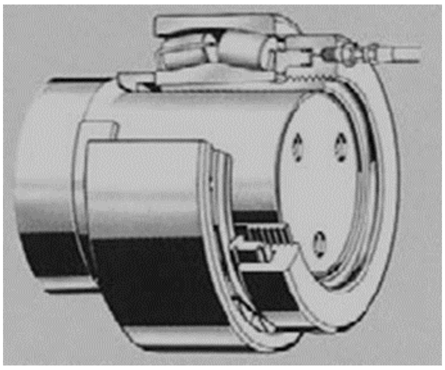


Fig. 27



Hydraulic nut used with a thrust collar for dismounting the tapered sleeve



Hydraulic nut used for dismounting the removable tapered-sleeve adapter

6. SHAFT AXIAL ALIGNMENT

Shaft axial misalignment often causes problems which lead to shut downs of rotating machines in up to 50 % of the cases. Therefore, professional alignment of shafts is a very effective method of preventive maintenance.

Shaft alignment leads to:

- Premature wear of bearings, seals, and shafts
- High bearing and coupling temperature
- Excessive vibrations
- Loosening of anchor bolts
- Higher consumption of energy

Shaft misalignment results in higher operating and maintenance costs and lower machine reliability.

Research done by one of the world´s leading repair shops of rotating machines showed that only 7 % out of 160 randomly chosen machines were aligned within acceptable tolerances.

Shaft misalignment can cause higher load on the bearings and, consequently, reduction of bearing life.

Shaft misalignment causes a reaction force in the bearings of the driving and driven unit.

A 20 % load increase caused by axial misalignment reduces the calculated durability by up to 50 %.

Furthermore, bearing misalignment can cause higher vibrations, greater noise, and higher energy consumption.

We distinguish two basic types of axial misalignment - parallel and angular misalignment. In practice, these two types are always combined.

One of the definitions of axial alignment reads:

"... if the machine is working under normal operating conditions, the axes of roation of both shafts should pass through the point where the power is transmitted from one shaft to the other". Similar to other definitions, there are exceptions to this one. Certain types of clutches such as jaw clutches, or cardan shafts require a certain defined amount of misalignment because of quality lubrication.

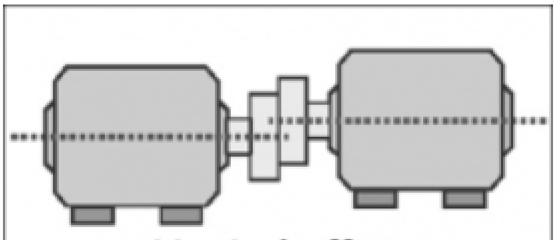
The mutual position of the machines, or their (mis)alignment, is defined by four parameters:

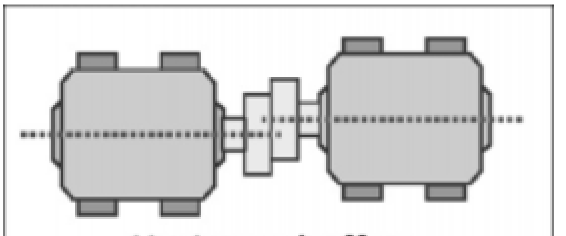
- vertical offset
- horizontal offfset
- vertical angularity
- horizontal angularity.

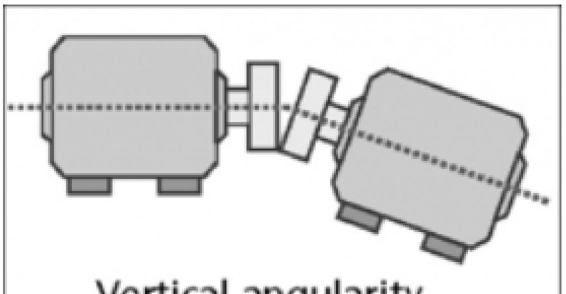
Offset means the distance between two axes of rotation at a given point, most often in the clutch plane.

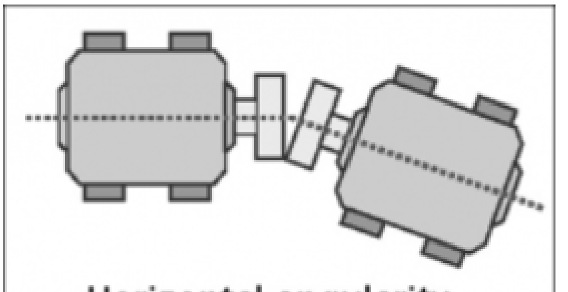
Angularity means the angle between the axes of rotation.

Both of these values, in the vertical and horizontal directions (i.e. 4 paramters altogether) define coaxial alignment.


Vertical offset


Horizontal offset


Vertical angularity


Horizontal angularity

By coaxial alignment we mean setting two machine units so that the shaft axes of the two machines are in a line.

If the machine is not supported on its base uniformly, we refer to this as a „loose foot". There is a basic rule: if the value exceeds 0.05 mm, the base must be levelled with supports, or by further finish.

The loose foot arises from an imperfect contact between the machine foot and the base. This may be caused by an uneven base, poorly finished machine foot, settling of the subsoil, temperature deformation of the foundations or frame, wrong wedging of the machine foots during machine alignment, twisted machine construction, as a result of impact for instance, etc.

There are two basic types of the loose foot – parallel loose foot and inclined loose foot. A parallel loose foot means that, with a loose anchor bolt, there is no contact between the machine and the machine base. By an inclined loose foot we mean a situation, where the machine foot, with a loose anchor bolt, is only in partial contact with the base. A loose foot causes a change in the machine position after tightening the anchor bolts, and therefore, a change in its alignment with respect to the other machine, often in a totally unpredictable way. This can also cause a deformation of the machine shell. A loose foot must be eliminated prior to the machine alignment, otherwise we are faced with the almost impossible task of aligning the unalignable. There are several ways of eliminating the loose foot:

- repairing the machine base
- new machining of the machine foots, or their other modification
- wedging the loose foot with support plates.

Wedging the loose foot with support plates is simpler for the parallel loose foot, where it suffices to use support plates of the right thickness; it is less simple for the inclined loose foot, where a suitable wedge must either be made from standard support plates, or a wedge is made to measure, e. g. using peel support plates.

All laser alignment devices feature as a standard equipment the loose foot inspection function, which allows fast and simple loose foot detection and elimination. Also important is to check the correct centering of the anchor bolts in the holes so that they allow horizontal movement during the alignment process. The distance between the halves of the clutch must be observed according to the manufacturer´s instructions.

Modern devices for checking and setting shaft alignment are based on the laser beam.

Since axial misalignment is responsible for about 50 % of all shut-downs of rotating machines, high precision axial alignment is essential.

The introduction of shaft alignment operations to key machines will produce cost savings, bearing life extension, and improve side effects such as reduction of vibrations, noise, and electric energy consumption.

7. BEARING LUBRICATION

From the design perspective, special attention must be paid to the bearing from the lubricating system and sealing points of view.

When using plastic lubricants, regular re-lubricating must be ensured. Oil should be used where plastic lubricant cannot be used because of the operating revolutions and temperatures, and also where bearings are fitted in a space where other parts such as gear wheels in a gearbox are lubricated with oil

Whether oil lubrication should be used (level, circulation-system, splash, oil-mist lubrication), depends on the running conditions and the lubricating system of the piece of machinery in question. The design solution must be such that the bearings have a sufficient amount of oil not only during normal operation, but also during the machine start. Excessive amount of oil increases its temperature.

7.1 Lubrication with plastic lubricants

Most stocks under common operating conditions use plastic lubricants. Approximately 90% of all bearings is lubricated with plastic lubricants. It represents the advantages to the oil lubrication. The plastic lubricants advantages are based on better lubrication position in the stock, in the sealing against the penetration of contamination and water, and in particular in simple bearing maintenance.

The primary task of the solid lubricant in the roller bearing is the division of all parts moving against each other by minimizing friction, preventing the wear and tear or its is maintained at the lowest level. Solid lubricants optimally designed for the specified operation can form fully bearing lubrication coating. If the surfaces are divided in such way, it is called "physical lubrication".

Three basic lubrication states are recognized:

- Limit lubrication,
- Partial lubrication,
- Full lubrication.

The limit lubrication – if the load is transferred by the surface contact, adverse lubrication may result in extreme wear and tear and premature bearing failure. It is prevented by using the plastic lubricants for high pressures and loads, with respective EP "extreme pressures" additives and the protection against wear and tear or also solid lubricants additives. The protective effects also result from the sandwich lubrication, i.e. the surface coating plus lubrication by means of the plastic lubricant.

Partial greasing – load between the surfaces is transformed partially by means of the created oil coating, and touching tops of the rough surfaces. The adequate additives are added in order to prevent increased abrasion.

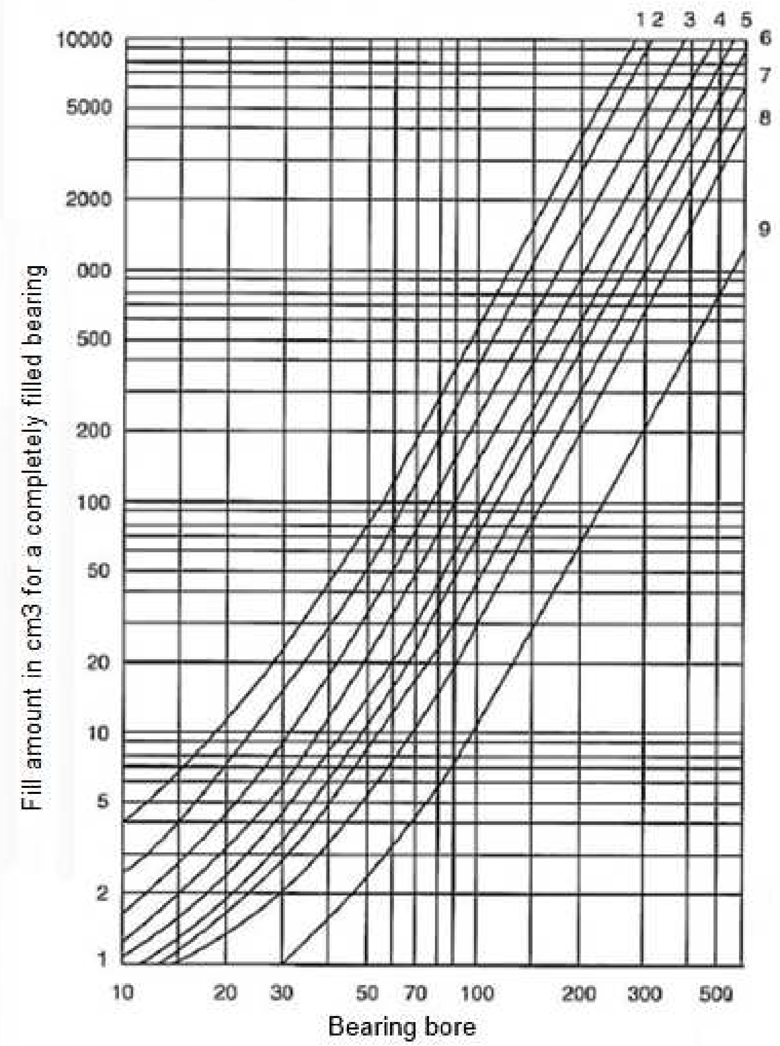
Full lubrication – full greasing is an ideal state when the surfaces are completely separated by the bearing lubrication coating. It is possible to reach extremely low friction depending on low inner lubricant friction.

The friction moment, i.e. the friction coefficient depends on the load, lubrication state, and the bearing revolutions.

During the first assembly, the inner bearing space should be filled with lubricant only to one half to two thirds, if the revolutions are lower than 50 % of the bearing critical revolutions, and to one third to one half, if the revolutions are higher than 50 % of the bearing critical revolutions. Where possible, we recommend lubricating bearings after assembly, in order to prevent contamination or other damage caused to the lubricant during assembly.

A graph for determining the free space in the bearing

Bearing type	Curve
Ball bearings	
618 klec T	8 - 9
618 klec M	9
160	7
60	6
62	4
63	2 - 3
64	1
Angular-contact ball bearings	
70	6
72B	4
73B	2 - 3
Tapered roller bearings	
302	3 - 4
303	2
313	2
320	6
322	3 - 4
323	1 - 2
329	7 - 8
330	5
331	4
332	4
Cylindrical roller bearings	
NU10	7
NU2	5
NU22	4
NU23	2
NU3	3
NU4	2
NN30K	5
NNU49	7
Spherical-roller bearings	
213	3
222	4
223	2
230	6
231	4
232	3 - 4
239	8
240	5
241	3



Orientation values for fill amounts (density approx. 0,95g/cm3)

For most thrust bearing applications, running-in is not necessary. The reason is that the required revolution factor is met anyway. Running-in is therefore required for high-precision bearings designed for high revolutions. By running- in a thrust bearing with plastic lubricant, the revolution factor can be substantially increased. During running-in, the hardener structure is adjusted so that oil separation, and therefore oil elimination, occurs ideally in the direction of the bearing raceways. In this way, there is only the necessary amount of lubricant in the contact zone. Then plastic lubricant as such is not captured by the rollers or cage.

The selection of appropriate plastic lubricant as regards large selection which is currently available is performed in few several steps and by means of the most important criteria. The more data available to more accurate the lubricant selection.

Criteria for selecting plastic lubricant (PM):

- Operating temperature,
- Specification of minimum required viscosity based on the base oil,
- Revolution factor,
- Load index C/P.

Plastic lubricant looses its greasing properties after some time. The main factors affecting the plastic lubricant service life:

- Lubricant quality
- Bearing size,
- Operating revolutions,
- Operating temperature,
- Operating environment.

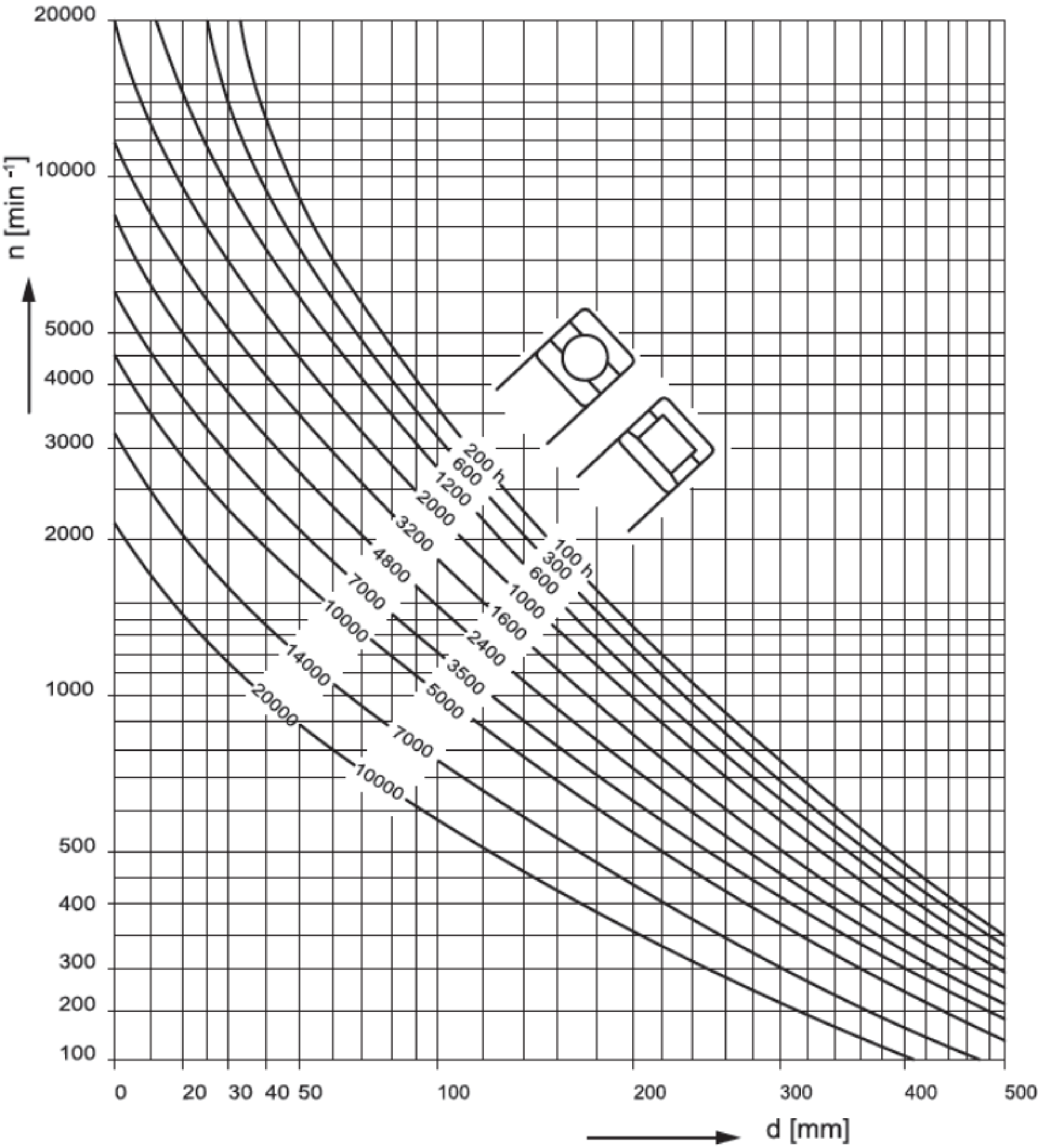
It is therefore necessary to regularly lubricate the bearings. The lubrication automatic period is a period when the plastic lubricant keeps the required properties. After the period passes, the bearing must be re-lubricate, and the old lubricant must be completely removed from the bearing area. The recommended duration of the lubrication automatic period t_f can be read from the scheme below, which specifies the value depending on the operating revolutions n, and on the bearing diameter d.

The scheme applies for the operation conditions:

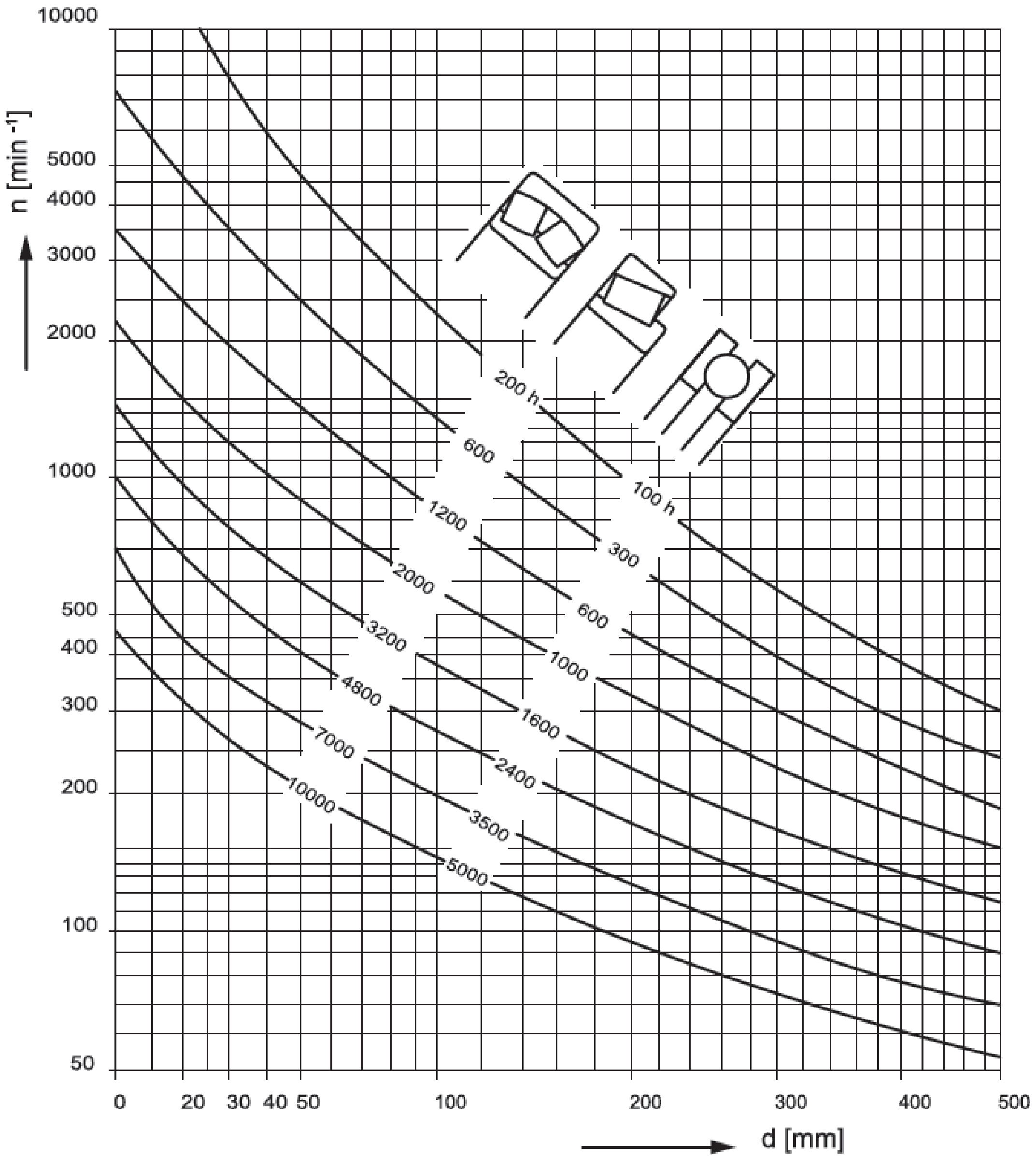
- The bearing load does not exceed 15% of basic dynamic load capacity,
- Plastic lubricant of common quality is used,
- External bearing ring operating temperature is max. 70 °C,
- The bearing is placed on horizontal shaft.

If the operating temperature exceeds 70 °C, the lubrication automatic period is reduced, for each 15 °C, by which temperature exceeds 70 °C, to one half. At temperature below 40 °C, it is possible to increase the automatic lubrication up to the double. We recommend reducing t_f for the bearings placed on the vertical shafts as per the scheme to one half.

Graph for automatic lubrication with plastic lubricants



Graph for automatic lubrication with plastic lubricants



For small, in particular single row ball bearings, the lubrication automatic periods are multiply linger than the bearing service life, the bearings therefore do not require lubrication.

The reason above indicate it is beneficial to use the bearings in design with the cover sheet metal or with sealing on both sides, filled by the manufacturer with plastic lubricant for the full service life. For some frequencies, the automatic lubrication period is outside the graph curves, which means the permitted limit for greasing with plastic lubricants is exceeded. In these cases, we recommend resolving the stock construction for oil lubrication.

Regenerating the plastic lubrication filling is recommended always with the automatic lubrication interval exceeding 6 months. The application of plastic lubricants for high performance can extend the automatic lubrication period. For further information, contact ZKL technical-consulting services.

The amount of Q lubricant for final bearing lubrication is specified according to the instructions of the device manufacturer where the bearing is assembled, or as per the formula

Q = 0,005 * D * B

where	Q	... Lubricant amount [g]
	D	... Bearing outer diameter [mm]
	B	... Bearing width [mm]

Plastic lubricant is supplied to the bearing ideally by the lubrication press. For bearing design W33 it is most suitable (if enabled by the construction) to introduce plastic lubricant through the holes in external ring. If the bearing operates at quite high revolutions, i.e. it requires frequent additional lubrication, there is a hazard of excessive lubricant accumulation in the bearing area. This lubricant must be removed after some period by means of the lubricant spray removal forming a part of the stock structure. New spherical-roller bearings operating at high revolutions using the lubricant spray removal must be sufficiently lubricated at the operation commencement. After one hour and then again after 24 hours from starting the new bearings, the triple amount of common lubricant should be added.

Factors reducing the final lubrication period: High vibrations, vertical shaft (automatic lubrication period must be reduced to one half, and it is necessary to use sealing and covers preventing the lubricant leak), lubricant contamination.

Important notice: Automatic lubrication uses the same type of plastic lubricant as used before. Never mix various plastic lubricants, unless you are sure they are mutually compatible.

Since in practise, the mixing of plastic lubricants cannot be completely avoided, it is possible to use the mixtures below, without significant consequences:

- Plastic lubricants with the same thickening agent
- Lithium/ calcite plastic lubricants,
- Calcite / bentonite plastic lubricants,

Unsuitable mixtures of plastic lubricants:

- Sodium / lithium,
- Sodium / calcite,
- Sodium / aluminium,
- Sodium / bentonite,
- Aluminium / bentonite,

During mixing of the above lubricants, the change of the structure may occur resulting in strong softening of the plastic lubricant. If different type of plastic lubricant should be used, it is necessary to perform the automatic lubrication with large amount of lubricant (rinsing with plastic greasing agent), if enabled by the stock construction. Potential further lubrication should be completed for shorter period. The review of plastic lubricants is available in table 8.

Table 8. Review of plastic lubricants

Grease characteristics for roller bearings				
Grease type		Characteristics		
Thickening agent	Base oil	Heat range of use [°C]	Water resistance	Application
Lithium soap	mineral	-20 to 130	resistant	multi-purpose lubricant
calcium soap	mineral	-20 to 50	highly resistant	good sealing effect against water
sodium soap	mineral	-20 to 100	non-resistant	emulsifies with water
aluminium soap	mineral	-20 to 70	resistant	good sealing effect against water
lithium complex soap	mineral	-20 to 150	resistant	multi-purpose lubricant
calcium complex soap	mineral	-30 to 130	highly resistant	multi-purpose high temperature, high-load lubricant
sodium complex soap	mineral	-20 to 130	resistant	suitable for high temperatures, high loads
aluminium complex soap	mineral	-20 to 150	resistant	suitable for high temperatures, high loads
barium complex soap	mineral	-30 to 140	resistant	suitable for high temperatures, high loads
bentonite	mineral	-20 to 150	resistant	suitable for high temperatures and low speeds
polycarbamide	mineral	-20 to 160	resistant	suitable for high temperatures and medium speeds
lithium soap	silicone	-40 to 170	highly resistant	suitable for wide temperature ranges and medium rotational speeds
barium complex soap	ester	-60 to 140	resistant	suitable for high temperatures and high speeds

7.2 Oil lubrication

The bearing oil lubrication is used in the cases below:

- Automatic lubrication intervals with plastic lubricants are too short:
- The operating temperature is so high, it is not suitable to use plastic lubricant,
- The whole device is oil lubricated (e.g. gearboxes).

The spherical roller bearings use the oil bath lubrication, and the oil level reaches usually up to the central height of the lowest rolling body in the bearing, and for oil circulation lubrication. The lubrication of roller bearings usually includes the use of mineral oil with good chemical stability. Suitable relative viscosity of mineral oil v_1, is specified in the graph depending on the bearing medium diameter:

$d_s = (D + d) / 2$

where d_s ... Bearing central diameter [mm]

D ... Bearing outer diameter [mm]

d ... Bore diameter [mm]

If the operating temperature t is known (or can be found), we can use the graph to specify the operating viscosity v at internationally standardized comparable temperature 40 °C which is required for the viscosity ratio calculation

$k = v / v_1$,

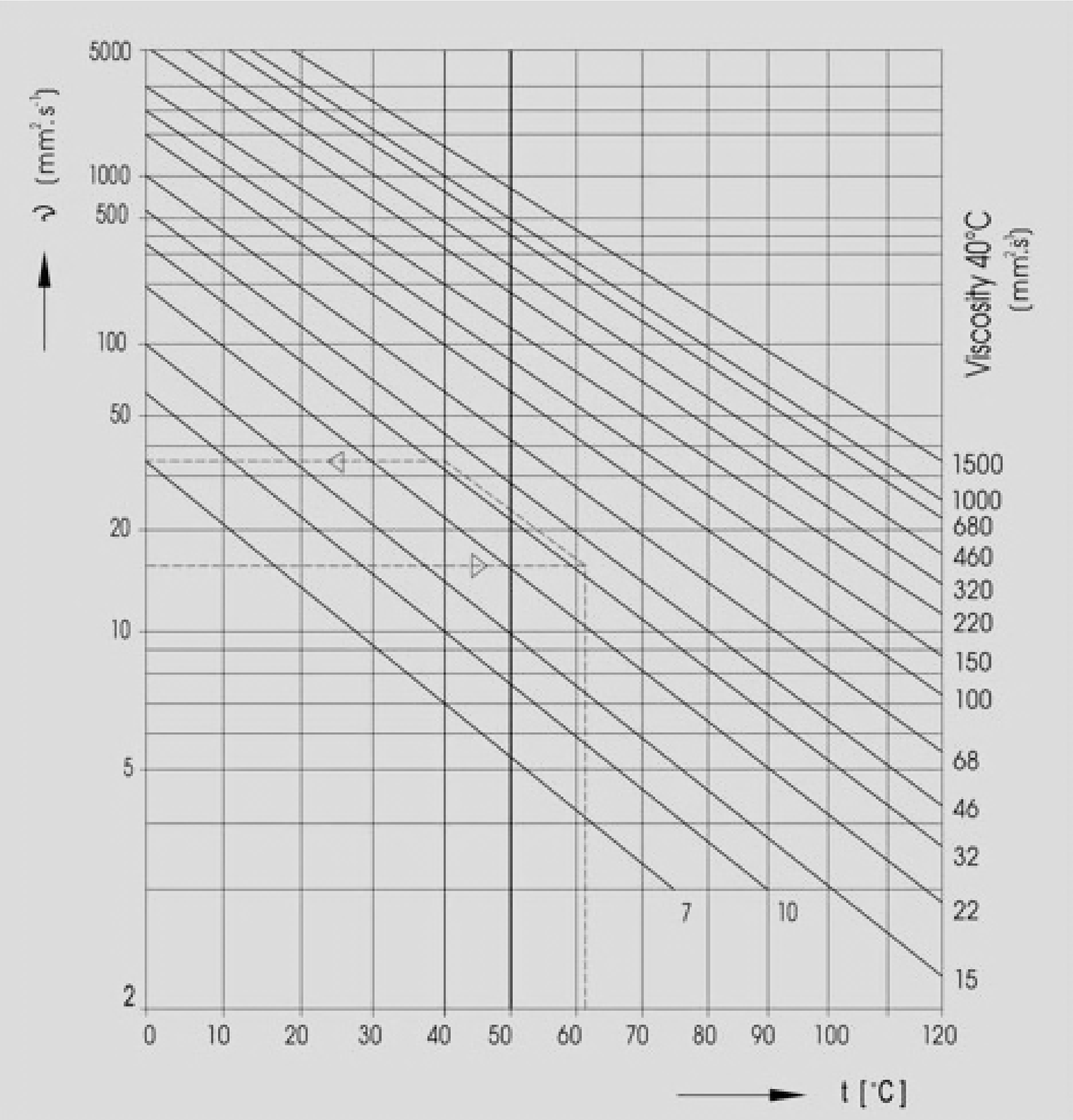
where to ... Viscosity ratio

v ... Operating viscosity [mm2s']

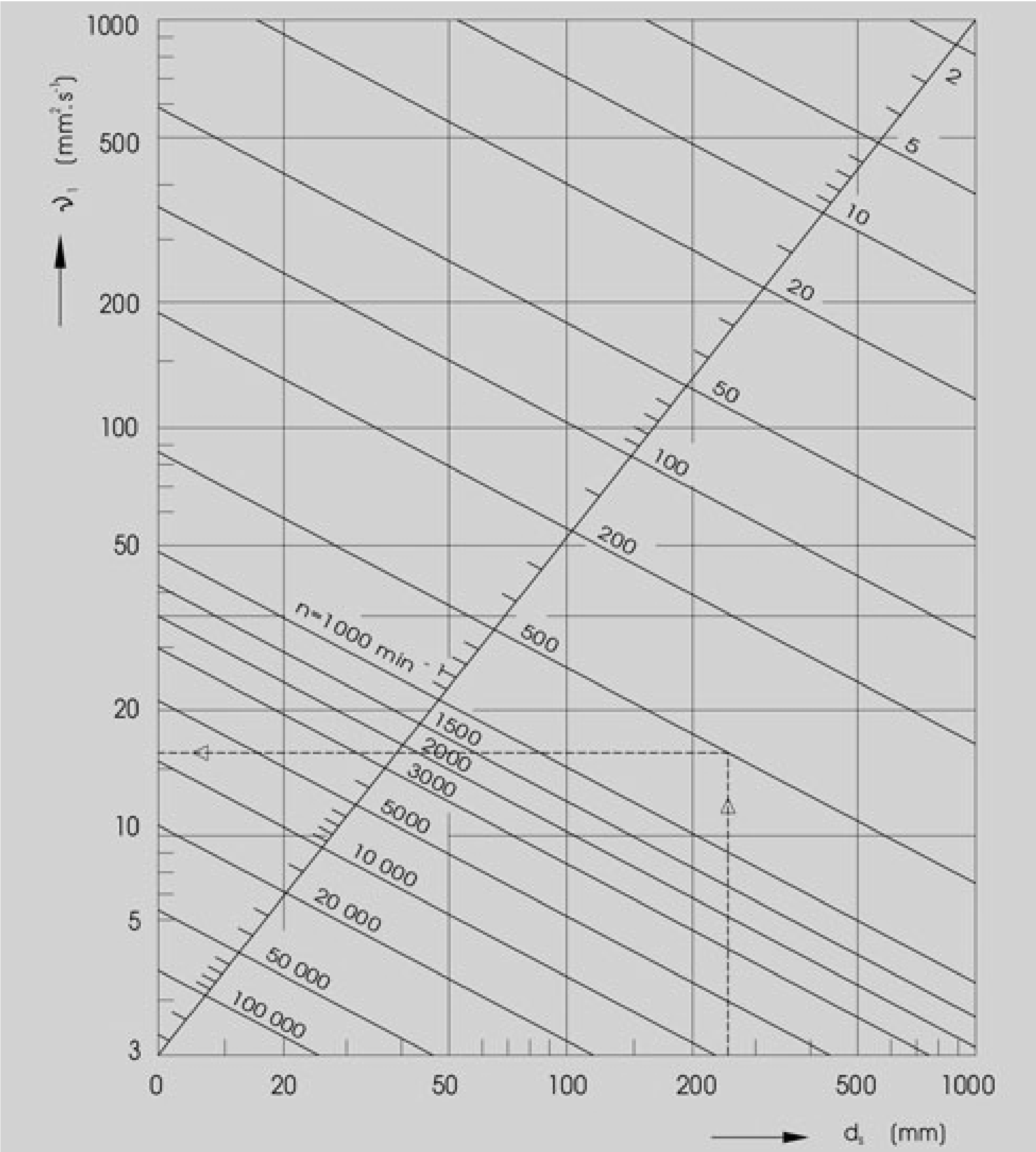
v_1 ... related viscosity [mm2s']

If k is lower than 1, it is recommended using oil with EP additives preventing the melting of metal parts in the contact location at local temperature increase. If k drops under value 0.4 the use of oil with EP additives is necessary.

Graph for selecting cinematic viscosity of the lubricant at 40 °C



Graph for specifying the operating viscosity of the lubricant



8. BEARING MAINTENANCE

Most correctly selected and mounted bearings require hardly any maintenance, except regular re-lubricating.

Monitoring the reliability of operation is limited to temperature control, occasional bearing tapping, and vibrodiagnostic monitoring, if it is available.

Some errors in the bearing operation become evident by an increase or fluctuation of vibrations, temperature, and noise values. In this case we recommend informing the manufacturer about these parameter values.

Bearings in a good operating condition give out a fine buzz. Unusual noise indicates that the bearing is in a poor operating condition.

A bearing which was found defective during operation must be dismounted so that the root cause may be discovered and eliminated. Further, steps must be taken to prevent premature damage to the spare bearing. This is especially important in the case of large bearings and key machines.

Monitoring the operating condition is becoming increasingly useful in preventive maintenance. Early detection of damage signs allows to replace the bearing during planned maintenance, which prevents unplanned shut-downs caused by bearing emergencies.

8.1 Machine maintenance

The role of maintenance is not to repair damaged machines but to prevent their damage but not just that. We want our machines to work efficiently, reliably and safely. The objectives of maintenance can be therefore expressed in three interconnected requirements:

1. achieve maximum productivity:
   - Ensure satisfactory and continuous operation of the machine throughout its designed service life, or even longer.
   - Achieve higher machine sustainability with minimum shutdowns for maintenance and repairs
   - Continuously improving the manufacturing process.
2. Optimise machine efficiency – Calmly, economically running machines cost less and produce products of higher quality.
3. Ensure safety of operation.

8.2 Types of maintenance

During technological development several types of maintenance had developed the application of which depends on a number of circumstances that need to be taken into account. Basic maintenance tasks are stated in the above paragraph. When evaluating these, apart from operational safety, one has to consider costs as well. Therefore, small and backed up plants still utilize the maintenance-free system – i.e. operation until failure. This type of maintenance is called reactive.

More expensive plants, operation of which is more expensive, have recently accustomed to a maintenance method consisting of periodical inspections, revision or repairs – i.e. preventive maintenance. An example of it can be cars with a service book according to which certain service actions are performed in certain time intervals, or by driven distance. The goal is to avoid machine failure. The time until repair is calculated according to the frequency of similar appliances (frequency of failures is expressed by the so-called mean time to failure). This is kind of a weakness of the method since it is difficult to estimate the time between the repairs - some appliances fail earlier, some are inspected or repaired “in vain” (they were OK). Mostly due to the effort to avoid unexpected failures, and also due to the effort to optimise maintenance costs which in a medium size enterprise represent about 1/3 of all costs, two additional aforementioned types of maintenance has been developing:

Predictive maintenance – Machine is not repaired in pre-defined intervals but only if the condition of it requires so. This certainly requires knowing this condition, and therefore it has to be watched during operation (monitoring and diagnostics). Such approach helps us prevent unplanned failures and shutdowns. The key idea is the right information at the right time. If you know which part of the plant requires replacement or repair, spare parts can be ordered in advance, staff can be provided for, etc., and shutdown can be performed when it is convenient. A planned shutdown is shorter and less expensive than a shutdown forced by an appliance failure, or even by an accident. Other advantages of predictive maintenance are longer life of the appliance, enhanced safety, less accidents with negative consequences for living environment, optimisation of spare parts management, etc.

Proactive maintenance - on top of the previously described management type includes also a solution of the root cause of deteriorated condition. Corrective actions are not focused on current failure symptoms (e.g. damaged bearing) but the key idea is to find out and remove the root cause of that failure (e.g. damage of bearing occurs as a result of improper machine positioning).

In predictive and proactive maintenance you thus need to examine the current condition of the machine. The maintenance process can be divided in five stages:

1. **finding out initial condition** – involves comprehensive measurement of the machine at the time when it is OK, and the so-called basic, reference values are stated for subsequent comparison.
2. **monitoring** – spots are defined on the machines where vibrations are measured in regular intervals, mostly total values of vibrations. This activity can be carried out by a trained worker without any knowledge of diagnostics.
3. **detection –** data obtained in monitoring are evaluated in a simple quantitative manner. Alarm limits are defined for every quantity measured. If a quantity exceeds the programmed alarm limit, it is a notification of a problem.
4. **analysis (own diagnostics)** – detection of a problem is followed by detailed measurement and analysis (trend evaluation, FFT analysis, phase analysis, etc.) which facilitates a clearer view to the problem and its root cause.
5. **recommendation** – once the root cause of the problem is found, economically acceptable corrective measures can be recommended and adopted.

8.3 Diagnostics

By diagnostics, we usually mean monitoring and evaluating the state of the machine during operation. In practice, however, other parameters must also be used for monitoring the state of the machine. Most procedures are described by international ISO standards. The different types of diagnostics by the type of parameters analyzed are as follows:

- **Operational diagnostics**

Attention is paid primarily to bearings, because they represent an essential part of all machines with rotating parts.

Bearings working in important parts of machinery or in demanding operating conditions should be frequently inspected. At present, a whole number of systems and devices for monitoring the bearing condition are available.

In practice, however, not all machines and their functionality can be monitored by sophisticated modern devices. In such cases, the machine operators, or maintenance workers must keep watching for any signs of problems in the bearing such as noise, rising temperature, or vibrations. This is mainly done by listening, touch, or vision.

By listening we usually find out whether the machine run is regular or irregular. An experienced worker is able not only to use a stethoscope to detect unusual sounds, but also to determine the corresponding part of the machine. Bearings in good operating condition give out a fine buzz. Sounds like grinding, screeching, or other unusual sounds usually indicate that the bearing is in a poor operating condition.

Screeching or whistling may be caused by insufficient lubrication. Small bearing clearance may manifest itself by a metal noise. Damage to the ring caused by impact during assembly, or by imprints and grooves in raceways cause a noise which varies with bearing revolutions. Intermittent noise may indicate damage to a rollerbody. The noise comes from rolling over a damages surface. Dirt in the bearing causes a grinding noise.

Although damage to the bearing can be detected by listening, it is usually so serious that the bearing must be replaced immediately. For this reason, it is better to use certain electronic devices for monitoring the bearing condition.

It has been proved that these modern devices provide a much safer and more accurate way of estimating the bearing condition than some of the procedures used formerly, such as pressing one end of a screwdriver against the bearing body and holding and ear to the other end.

Touching can be used to detect high temperatures, which often indicate an unusual bearing condition. These may have a negative effect on the lubricant in the bearing. Sometimes overheating can also be related to the lubricant present in the bearing. If the bearing works in temperatures higher than 125° C over a longer period of time, its durability may be reduced. The high temperature may be caused by insufficient, or on the contrary excessive amount of lubricant, contaminated lubricant, damage to the bearing, small clearance, clamping and excessive friction of the seals.

Therefore, it is necessary to frequently check the bearing temperature as well as the temperature of other important parts. Any change of temperature may be a sign of defect, if the running conditions have not changed.

The bearing temperature can be regularly and reliably checked by contact thermometer. Any change of temperature may be a sign of defect, if the running conditions have not changed. Some digital thermometers feature colour signalling indicating normal operation, increased temperatures, and critical temperature when the machine must be turned off. Such temperature sensors with the signalling should be applied to bearings in critical locations, where an emergency might cause the machine shut-down.

Let us emphasize that after lubricating or re-lubricating the temperature usually increases for a period of one or two days.

Visual inspection can be used for inspecting the bearing sealing so as to prevent hot or agressive liquids and gases from entering the bearing along the shaft. Maintain the pre-set rings and labyrinth packings filled with plastic lubricants to ensure maximum protection. Replace felt and rubber seals as soon as possible.

The seal not only prevents dirt from penetrating into the bearing, but also prevents lubricant from leaking. If lubricant leaks around the seal, check immediately if the seal is not worn-out, defective, or if the plugs are not loose. Lubricant leakage can also be caused by untightness of insufficiently clamped contact surfaces in the division plane of the bearing body or released oil leakage when plastic lubricant has been destroyed as a result of excessive mechanical stress, i.e. by over-lubrication.

The lubricant itself must also be carefully watched. Different or dark colour usually indicates that the lubricant is contaminated.

There are a whole number of ways of monitoring the bearing operating condition, which can help to find out whether the bearing is likely to break down, and avoid costly machine shut-downs.

Data provided by diagnostic devices can assist users in preventing unplanned shut-downs. The devices regularly provide instant reports on the operating condition of the bearing, and based on the evolution trend, the bearing can be replaced during planned shut-downs. This saves time, costs and makes it possible to purchase replacement bearings well in advance.

Monitoring the operating condition is an aggregate term denoting the monitoring of the machinery condition using devices.

Operational diagnostics utilizes all available measured service parameters that allow evaluation of the machine condition in run. For new appliances often online systems with big databases are used and potential software for their analysis. For less complicated machine units one periodically records parameters and may carry out tests in run, in order to verify correct function. The issue is dealt with in ISO 17359. Table 1 is taken over from the aforementioned standard and demonstrates how individual service parameters are associated with failures in the machine. Majority of failures in rotary machines usually manifest in change of size and spectral content of vibrations.

Table 1 Example of monitoring service parameters according to ISO 17359

Machine type: Pump	Symptom or parameter change									
Failure	Leak of liquid	Measurement of lengths	Power output	Pressure or vacuum	Revolutions	Vibrations	Temperature	Stop time	Oil contamination	Oil leak
Damaged impeller		•	•	•	•	•	•	•	•	
Damaged plugs	•	•		•	•	•				
Eccentric impeller			•	•	•	•	•	•		
Damaged bearing		•	•		•	•	•	•	•	•
Worn bearing		•				•	•	•	•	
Improper assembly						•				
Imbalance						•				
Misalignment		•				•				
* If a failure occurs, indicated symptom or parameter change may occur.										

➢ Tribodiagnostics

Fulfils three basic tasks:

- Monitoring the state of lubricant – The state of lubricant may deteriorate for various reasons (oxidation, penetration of water or other substances, etc.).
- Analysis of impurities and abrasion particles (ferrography) – Based on material and shape of particles that occur in lubricant a place is determined where the machine usually gets damaged.

Tribodiagnostics (TD), as a part of maintenance, is based on regularly sampling lubricants, essentially lubricating oils only, used in the monitored machines, and analyzing these samples. This analysis can be used to determine the state of the oil itself and also the state of the monitored machine. Lubricating oil serves in this case as a medium carrying along particles originating from the wear of the lubricated parts of the monitored machine. Analysis of these parts yields important information on the processes happening in the machine. It is important to monitor the machine continuously in this way, and obtain trends of the volume of the particles present in the oil, because these give a sufficiently reliable information on changes occurring in the wear regime. The second part of TD is the oil analysis which detects changes in the chemical and physical qualities of the oil on the one hand, and contamination by foreign substances such as water, mechanical contamination, chemical compounds, on the other hand. Successful TD is based on a correctly taken oil sample. The sample must be truly representative, i.e. contain all substances in the proportion in which they occur in the lubricating system of the monitored machine. The best point for taking the sample is the run-back pipe which takes the oil from the lubricated points to the oil reservoir. However, since it is frequently not possible to take the sample at this point, the samples are often taken from the oil reservoir. The sampling must be carried out during the machine run if possible, or immediately after its stopping. The sample container must be clean and dry. An important aspect of any diagnostic method, and therefore TD, is the rapidity of the response and accuracy of results. Regularly taken samples are analyzed as rapidly as possible, and diagnosis is made on the basis of the results.

Monitoring the machine condition

In this case, lubricating oil is utilized as a medium carrying, during the wear process, metal particles produced by this wear process. Regular monitoring of specified metal concentrations allows to foresee impending failures. For determination of metals, or elements in lubricating oils, various methods of instrumental analysis are used. All these methods serve for determining the monitored element concentration. For monitoring the machine condition, one must know the materials from which the machines are made. Increased occurence of a certain element means increased wear of a certain machine part. E.g. occurrence of copper usually signals bearing wear, occurrence of aluminium signals piston or bearing wear etc.

Monitoring the oil condition

When monitoring the properties of lubricating oils, the values of a large number of indices are determined, and it is not the purpose of the present manual to enumerate them all. Nowadays, practically all lubricant types contain additives which improve some of their properties. During operation, there is loss of additives, and when a certain minimum level is exceeded, the lubricant loses its utility properties. Very important for the determination of additive content is infrared spectrometry, presently probably the most useful methodology for analyzing lubricants. Computer controlled devices with Fourier transform enable a very fast and sensitive analysis of important groups of organic compounds present in lubricants. Infrared spectrometry can also be used for determining the products of oil aging, especially oil oxidation and oil nitration products. By comparing the spectra of used and clean oil, oil contamination can be determined. Presence of water and glycol, presence of fuel in the oil are some of the other possible applications of this almost universal methodology.

Oil analysis evaluation

After analyzing a given lubricating oil sample, we obtain a set of values. This set can be evaluated by comparing each of the specified indices with their critical values, if they are known. In this way, we get fairly easily the answer to the question, whether the tested oil can be further used, or whether the machine is wearing out excessively. This procedure is satisfactory for determining the oil condition, and the general evaluation of the analysis can be considered as reliable. The critical values for each of the indices are in most cases known. For monitoring the machine wear, the situation is different. Monitoring the trends in the content of each element is very useful here. The diagnostic signal is then represented not by exceeding the critical value, but by a sudden change in the trend of the monitored content. Critical values of element content can be reliably determined on the basis of long-term tests organized by the machine manufacturer.

Effectiveness and usefulness of tribodiagnostics

Any lubricating oil analysis costs money. When discussing the usefulness of TD, the price of the analysis is compared with the price of the oil fill. This is understandable, because these two values are easily determined. However, a correctly performed TD cannot be limited to saving oil only. As indicated above, savings can be made not only on oil, but also on machine idle time, spare parts, (because a signal which is received in time allows to prevent an extensive failure which requires extensive repair), and on maintenance work. Due to increased attention being paid to environmental protection, the fact that a smaller number of oil changes and oil manipulations reduces the danger of oil and contamination leaking into the environment, is not negligible. An important and little emphasized advantage of TD is that it detects failures at their very beginning. If oil samples are regularly analyzed for metal content, the first deviation from normal is usually captured (and if required, confirmed by a check sample) early enough for effective steps to be taken well in advance.

- **Thermodiagnostics**

Thermodiagnostics (temperature measurement, thermovision measurement) – By means of local or flat measurement of surface temperature places with different temperature can be detected, and thus the cause of that increased temperature evaluated (excessive friction, high electrical resistance, etc.). Figure 1 shows an example of themovision diagnostics application in order to find out misalignment in clutch (if the clutch is out of line, transmitted power is inhibited to a greater extent; the power converts to heat that heats the clutch and neighbour bearings). The shot from thermovision camera is supplemented by a regular photograph to make clear what appliance it is about.

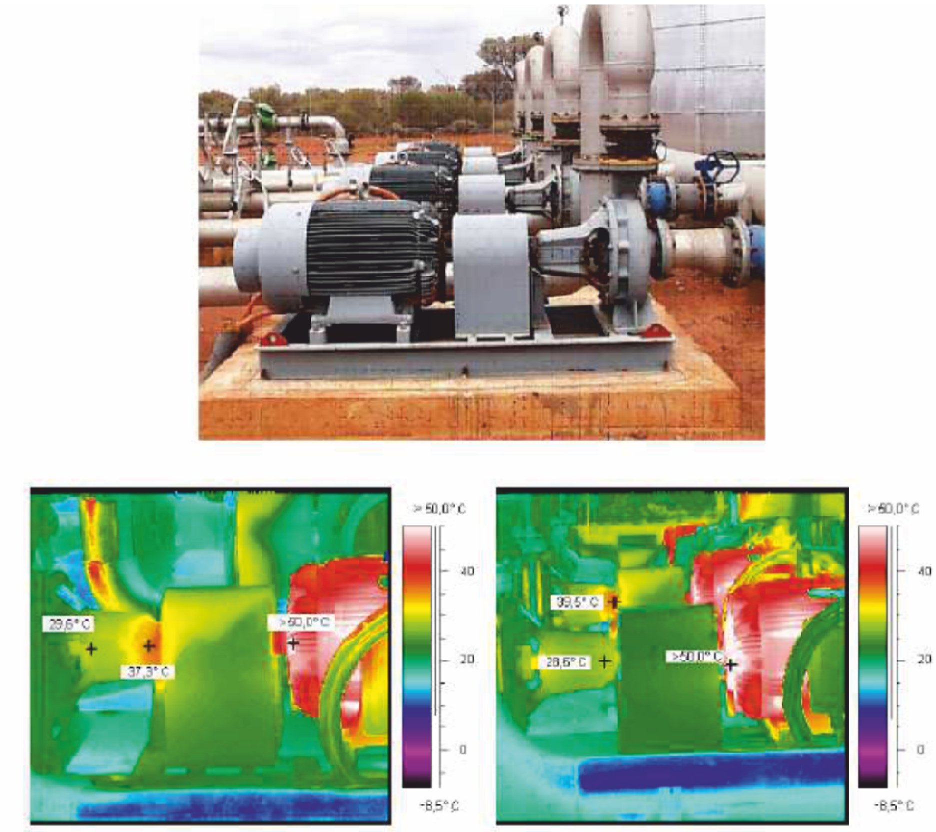


Figure: Example of thermovision measurement

The bearing temperature can be checked, for instance, by touch, but continuous regular checking by permanent temperature sensors is the best. High temperature usually indicates an unusual bearing condition. The life of bearings working at temperatures higher than 125° C over a longer period of time can be seriously reduced. The cause of the high temperature may consist in too little or too much lubricant, bearing damage, bearing overload, eliminated cleareance in the bearing etc.

Vibration diagnostics

Vibrodiagnostics is the basis of predictive and proactive maintenance and enables effective machine operation. It also represents a principal no-disassembly diagnostic method for rolling bearings, where it is very successful in defect detection.

During monitoring vibrations using converters, it converts mechanical movement to electric signal. The signal from the vibrations carries information on the cause of the vibrations, and by analyzing the signal with various methods, the defect can be detected in its beginning or development.

Low-frequency vibrations (0-2 kHz) are caused by the frame vibrations or by wrong assembly such as coaxial misalignment, imbalance, loose parts, and by rollers rolling over damaged areas.

High frequency vibrations (2 – 50 kHz) arise each time a roller rolles over a damage spot. This give rise to small impulses, which transmit their energy to the bearing body, which responds by oscillating at its proper frequency and gradual damping of the oscillations in the mechanical construction. By comparing the frequency spectra recorded during a definite time interval, an increase in amplitude can be detected during a proper frequency peak, which may be related to bearing damage. Very high frequencies are in the accoustic emission range, i. e. over 50 kHz, and are caused by the rollers rolling over damaged areas and by metal-to-metal contact. These signals can be detected by very sensitive devices such as sensors.

Another way of detecting bearing defects on the basis of vibrations is based on determining the typical frequencies of bearing defects. Each rolling of the rollers over the damaged area causes a peak in the signal. Repetition of peaks depends on the position of the damaged area in the bearing (in the inner or outer ring, roller etc.), on the bearing geometry and revolutions.

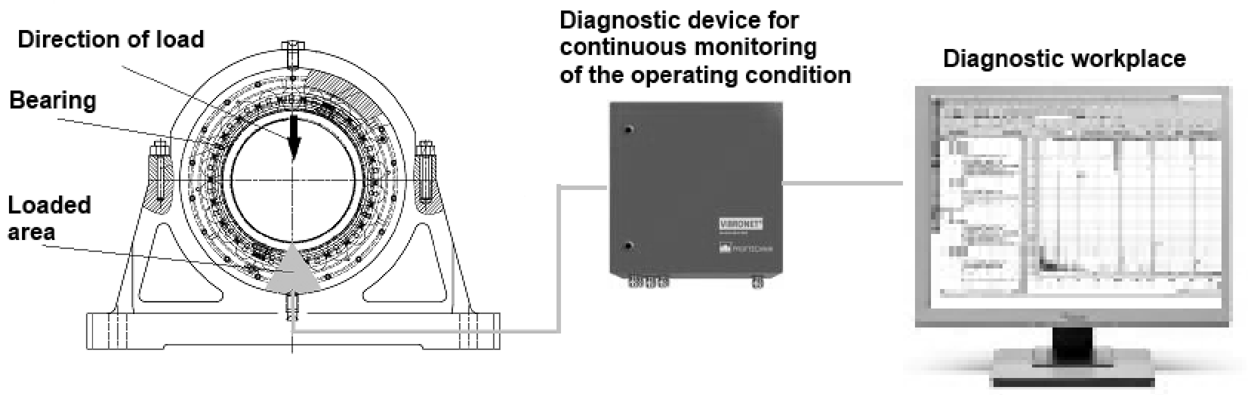
Envelope analysis is a method that uses both very high frequencies, and signal repetition caused by bearing defects in the low-frequency range. During envelope analysis, the signal is first carried into the filter, which lets through only high frequencies and eliminates most of the noise caused by construction vibrations, coaxial misalignment etc. The energy decreases, but the impulses are repeated at the same intervals, because the frequency of repeating the signal caused by the bearing defect is not changed by filtering.

The envelope analysis can be applied to all frequencies, but is generally used in the low-frequency range.

Monitoring the operating condition represents an effective way of predicting a failure of the machine or it part, which means that sudden emergencies, which cause costly repairs and uplanned interruptions of production, can be prevented. Methods and devices adequate to the machine type should be selected.

The operating condition can be regularly recorded using portable devices, and the information sooner or later evaluated.

Machines working continuously, such as paper machines, are best protected by a device for continuously monitoring the operating condition, supplemented with automatic alarm which signals the attainment of a pre-set state. More important machines, such as winding machines in head frames, can be equipped with a device for continuous monitoring of the operating condition, which stops the machine as soon as a certain vibration level is attained.



Monitoring the operating condition in continuous regime

9. OTPP

9.1 Offered services

The respective department focuses on resolving the customer related problems:

The application engineers can:

- Analyze the stock – find the problem (cooperation with the IT department)
- Propose a solution - cooperation with the construction
- Cooperation during assembly
- Provide consulting with lubrication
- Perform standard, potentially individual training for the customers

10. FAILURES OF ROLLER BEARINGS

10.1 Causes of bearing emergency

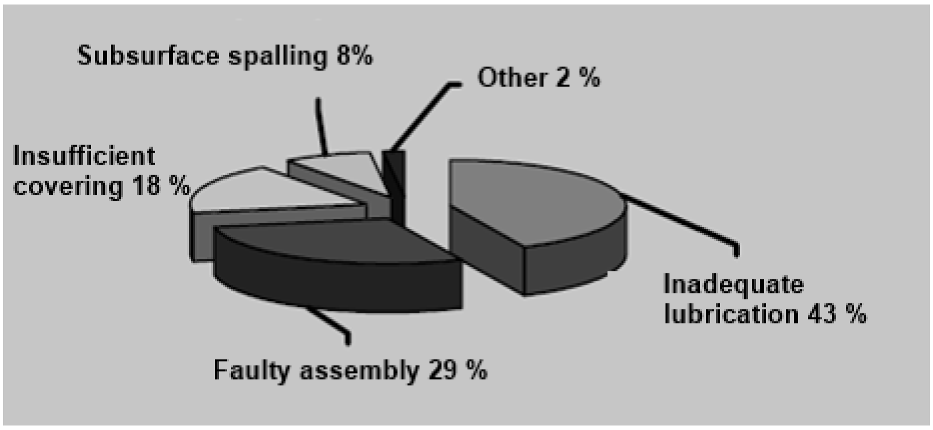
Only in a small proportion of all operated bearings an emergency occurs during operation. Most bearings have a longer life than the machines or apparatus in which they are mounted.

A bearing emergency can have a number of causes:

- Unprofessional assembly – e. g. assembly with a large overlap, causing bearing damage,
- Higher load than anticipated,
- Inefficient seal – penetration of dirt
- Faulty lubrication – for instance, a poorly designed lubricating system, insufficient thickness of lubricating film

Based on the bearing inspection and the characteristic signs of damage, the cause of the damage and emergency can in most cases be determined and eliminated.

Only in 10 % of all bearing emergencies, the fatigue damage of the bearing functional surfaces results from long-term operation, 43 % of the bearings had an emergency because of insufficient lubrication, and in nearly one half of all bearings, the bearing emergency was caused by faulty assembly or penetration of foreign matter or dirt into the bearing.



Occurrence of bearing failures

10.2 Course of bearing damage

The rapidity of development and course of bearing damage (pitting) in raceways depends on bearing load, revolutions, radial clearance, and quality of lubrication.

Fatigue damage develops as a result of shear stress, which occurs close under the loaded surface and after some time causes small cracks which gradually spread towards the surface. As a result of the rolling bodies rolling over the cracks, particles of material peel off and the damaged area (pitting) keeps growing (see fig. 28 and 29). Thus the bearing ceases to be functional, which may lead to an emergency. This is a case of material fatigue ocurring right under the loaded raceway surface. The course of this type of damage is comparatively long, with increasing vibration and noise. Early detection of these symptoms usually allows to gain enough time for replacing the damaged bearing and preventing an emergency.

Another type of damage consists in cracks developing in the raceway surface and spreading deeper into the material. Subsurface damage is most frequent when two microscopic peaks on two functional surfaces positioned against one another get in contact. The probability of this type of damage developing can be considerably reduced by using a suitable lubricant. Nevertheless, material fatigue usually becomes evident after some time, especially in heavily loaded bearings.

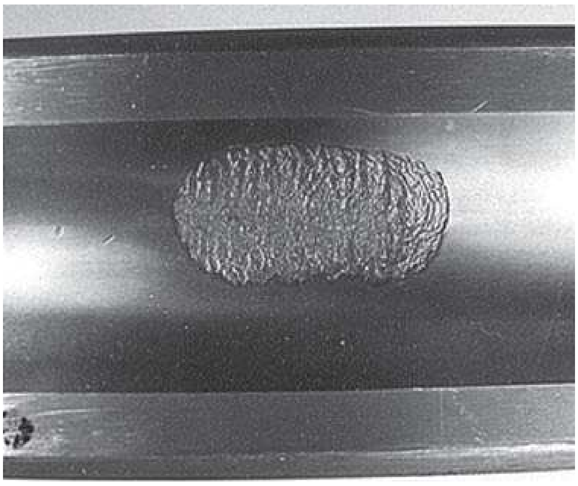


Fig. 28

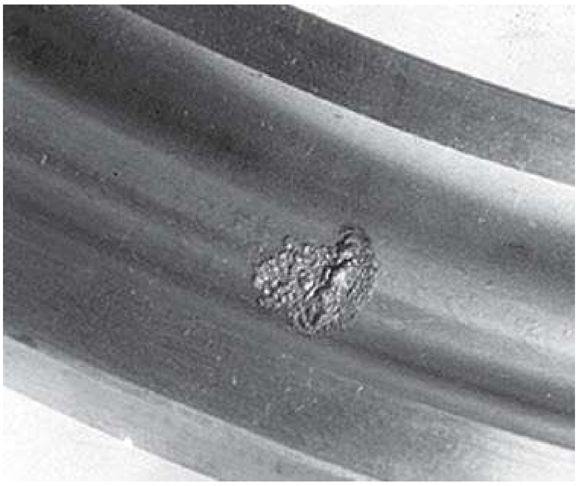


Fig. 29

Raceway damage caused by insensitive assembly (fig. 30) and shallow hollows in the raceway resulting from hard dirt rolled in during the bearing operation (fig. 31). Both of the types of damage shown are of inadmissible extent and can be the cause fatigue damage - pitting. Raceway damage caused by faulty mounting procedure is easily recognizable, because the distance corresponds to the roller spacing.

Bruises caused by overload in a stationary state or by machine vibrations during long-distance transportation, such as ship transportation, can also be dangerous.

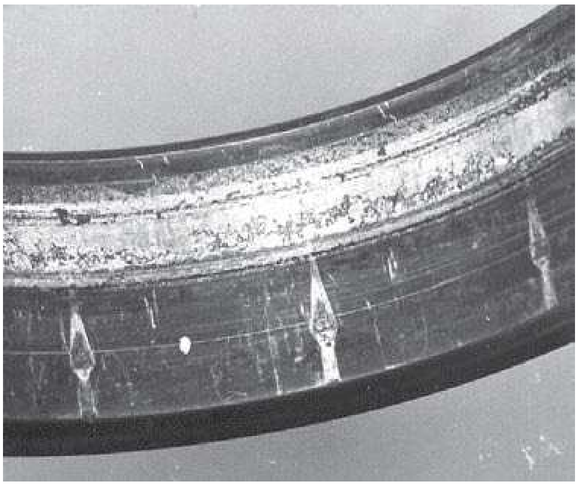


Fig. 30

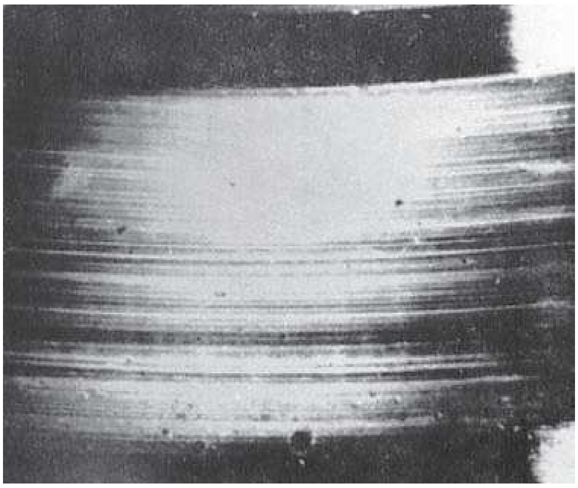


Fig. 31

Polished ball surface as a result of overload and lubrication failure (fig. 32) and rubbed-off ring seat surface caused by turning over in the seat (fig. 33). In both cases, this is inadmissible damage.

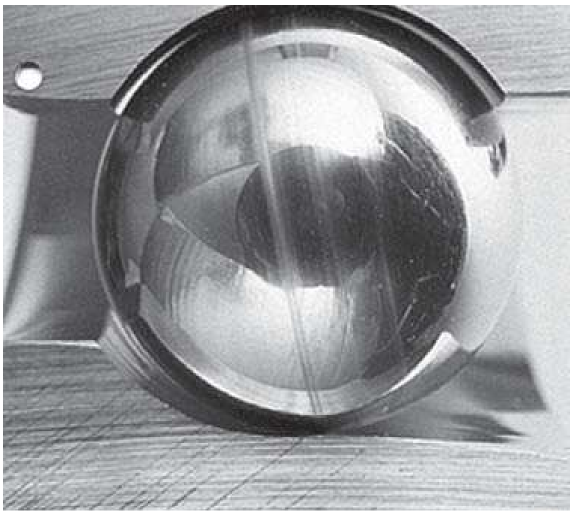


Fig. 32

Fig. 33

Ball (fig. 34) and raceway (fig. 35) damage caused by passage of electrical current through the rolling contact.

This damage is inadmissible. It results from sparking through a thin layer of lubricant. Burnt-out craters develop in these areas, causing vibrations and increased bearing noise. The development of this type of damage in electric motor bearings and other roller bearings of rail vehicles with electrical traction can be prevented for instance by using bearings with an insulating layer on one of the rings or by using hybrid bearings with ceramic balls.

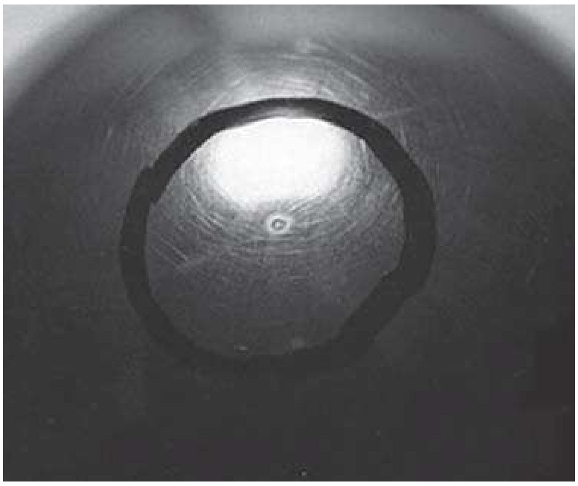


Fig. 34

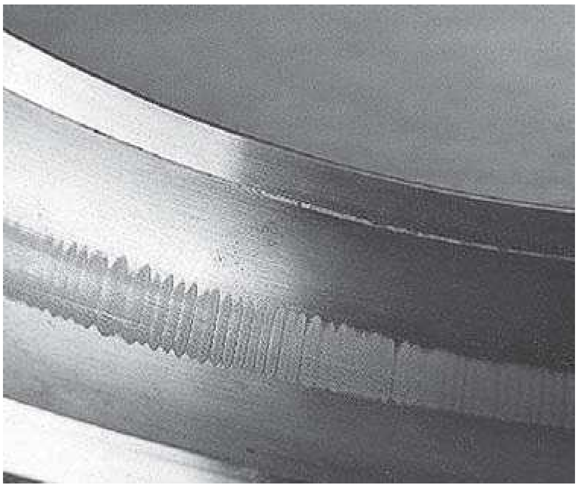


Fig. 35

The wear on the rolling surfaces of tapered rollers (fig. 11.11) and ring raceways (fig. 11.12) caused by a lubrication failure without material tear-out. Such damage may occur in areas with poorer conditions for maintaining the lubricating film such as on bearing ring collars or tapered-roller faces. Undesirable wear can also result from the rollers slipping with respect to the bearing rings.

The wear is characterized by traces of rubbing in and slipping, often accompanied by brownish places in the raceway. This wear is inadmissible.

Fig. 36

Fig. 37

The first photo (fig. 11.13) shows traces of contact corrosion of admissible extent in the raceway, and the second (fig. 11.14), corrosion of the inner ring. Corrosion resulting from insufficient protection against humidity or use of inappropriate lubricant is always inadmissible. Rust-attacked areas may be the source of peeling in the functional surfaces, which may cause a deterioration of the bearing run precision and reduction of the bearing durability. Corrosion arises from condensation of air humidity which may be caused by inadequate storage conditions. Contact corrosion is caused by very weak oscillations or vibrations of parts fitted with clearance which may lead to serious bearing damage and prevent its further use.

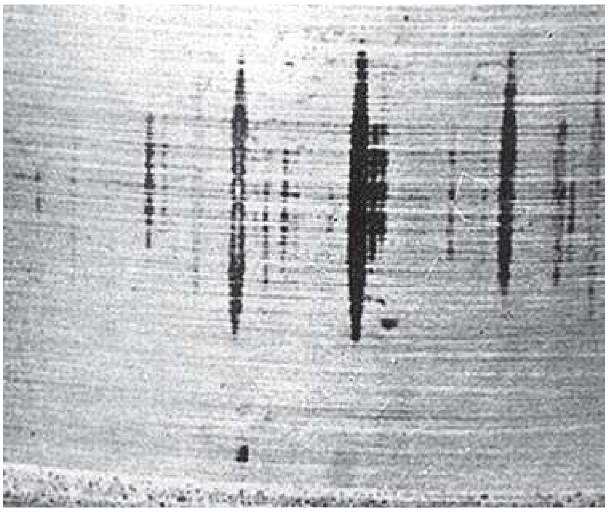


Fig. 38

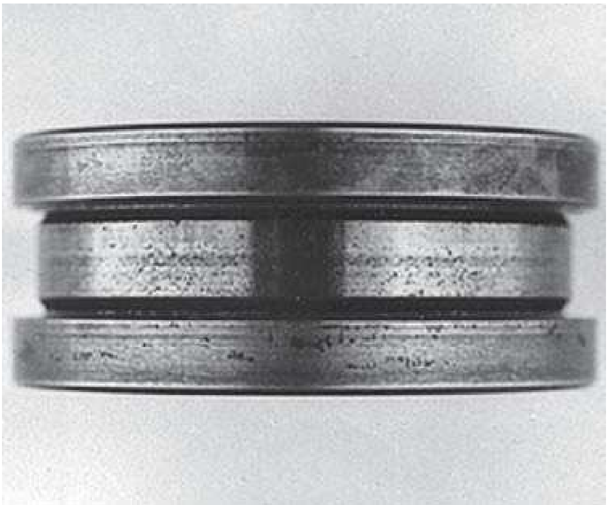


Fig. 39

11. TROUBLESHOOTING

Incorrectly functioning bearings usually show clearly identifiable signs. Depending on the degree of bearing damage, a whole number of other misleading signs may occur, which are usually the result of consequent damage. To eliminate the defect, it is necessary to analyze the signs which appeared first.

The most frequent signs of a bearing defect are:

A – bearing overheating

B – bearing noise

C – unexpected and too frequent bearing replacements

D - vibrations

E – the machine or device is not working properly

F – the bearing is loose on the shaft

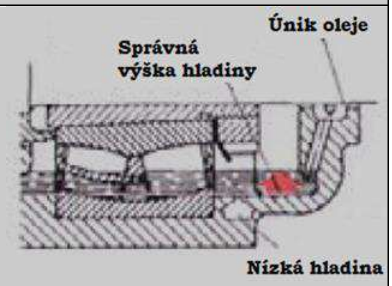
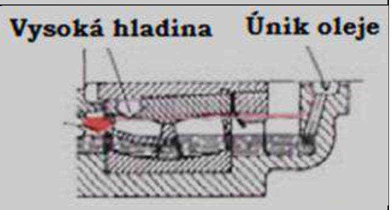
G – the shaft is revolving with difficulty

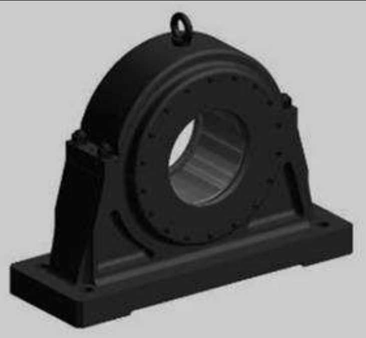
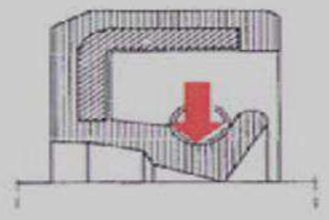
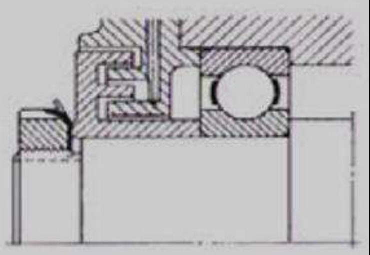
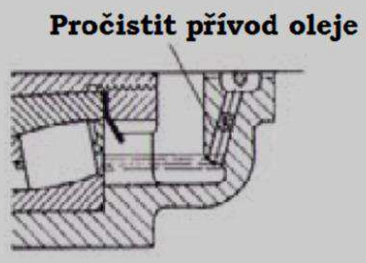
Sign code	Sign	Practical solution
A	Bearing overheating	p. 111 – 115
B	Bearing noise	p. 116 – 122
C	Unexpected and too frequent bearing replacements	p. 123 – 128
D	Vibrations	p. 129 – 131
E	The machine or device is not working properly	p. 132 – 136
F	The bearing is loose on the shaft	p. 137
G	The shaft is revolving with difficulty	p. 137 – 141

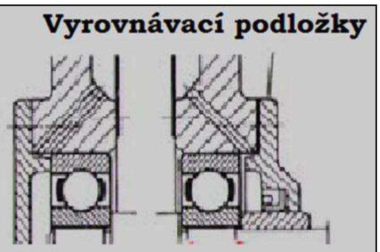
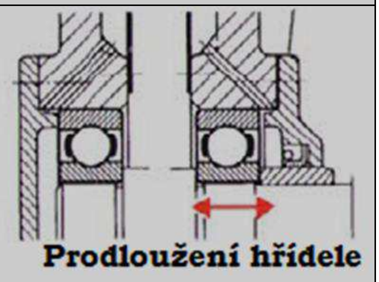
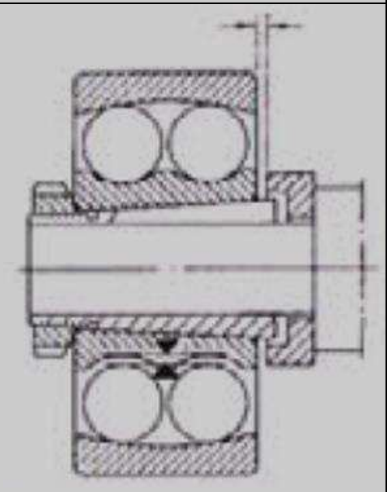
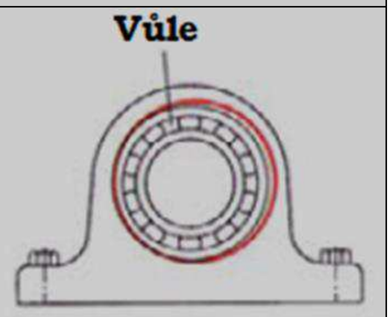
SIGNS							Typical running conditions	Kód řešení
A	B	C	D	E	F	G		
x	x	x				x	Inappropiate lubrication (wrong type of oil or plastic lubricant)	1
x	x	x				x	Insufficient lubrication (too little oil – leakage of lubricant through seal)	2
x						x	Too much lubricant (too much oil or plastic lubricant in the body)	3
x	x	x		x		x	Insufficient bearing clearance (wrong selection of ring fit)	4
	x	x	x	x		x	Foreign matter acting as an abrasive (sand, carbonized matter)	5
	x	x	x	x		x	Aggressive foreign substances (water, acid, varnish)	6
x	x	x	x	x		x	Bearing is clamped in the bore (non-circular bore)	7
x	x	x	x	x		x	Bearing is clamped in the bore (deformed bore)	8
x	x	x	x	x		x	Body is not well levelled by shim blocks (deformed body – possible cracks in the bottom part)	9
	x	x	x	x		x	Foreign matter in the bearing body (chips, burr, or contaminants left in the body)	10
		x					High air speed around the fit causing pressure differences (oil leakage)	11
x						x	The seal causes too much pressure on the neighbouring part (deformed seals)	12
x	x					x	Axially misaligned seals (contact with stationary parts)	13
x							Runback (inlet) holes, during oil bath lubrication, are clogged (oil leakage)	14
x	x	x		x		x	Pre-stressed bearings (symmetrical fit)	15
x	x	x				x	Prestressed bearings (two axial guide bearings on the shaft)	16
	x	x	x	x	x		Bearing is loose on the shaft (shaft diameter is two small)	17
	x	x	x	x	x		Bearing is loose on the shaft (tapered sleeve is insufficiently firm)	18
x	x	x		x		x	Bearing clearance is too small (tapered sleeve is excessively	19
		x					Split (standing) bearing body has uneven contact surfaces (oil leakage)	20
x	x	x	x	x			Outer ring is turning over in the body (bearing is affected by misalignement)	21
	x		x	x			Bearing is noisy (flat on roller surface caused by slippage)	22
		x	x	x			Journal taper (load concentration in the bearing)	23
		x	x	x			Body bore taper (load concentration in the body)	24
	x	x	x	x		x	Shoulder on the shaft is too small (insufficient bearing area – shaft deflection)	25
X	x	x				x	Shoulder on the shaft is too large (contact with bearing seal)	26
	x	x	x	x		x	Shoulder in the bearing bore is too small (insufficient support)	27
		x				x	Shoulder in the body bore is too large (damaged bearing seals)	28
		x	x	x	x	x	Transition in the shaft is too large (shaft deflection, bearing is not sufficiently supported)	29
		x	x	x	x	x	Transition in the body is too large (insufficient support)	30

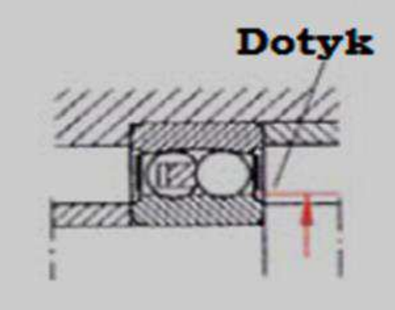
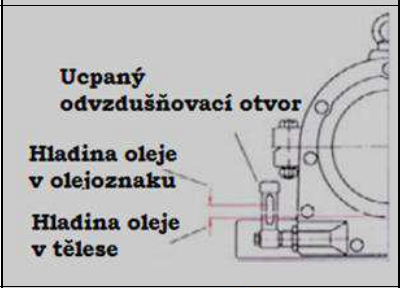
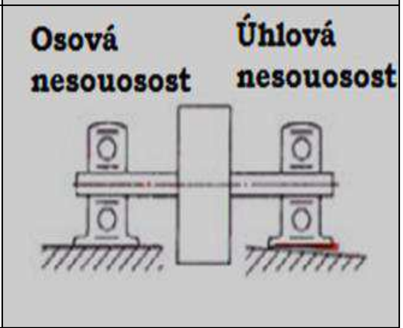
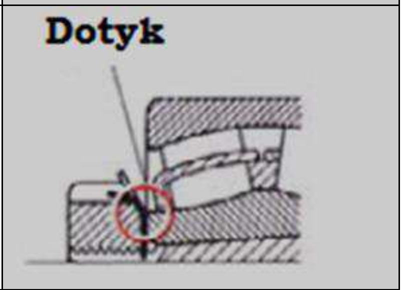
X	X	X				X	Insufficient clearance in labyrinth packing (contact)	31
X		X					Deaeration hole of the oil level indicator is clogged (shows wrong values)	32
X		X	X	X		X	Shaft axial misalignment	33
X		X	X	X		X	Shaft angular misalignment	34
X		X					Constant oil level cups (wrong oil level)	35
X		X					Constant oil level cups (wrong position)	36
X	X			X		X	Bent lock washer tabs (contact with bearing)	37
X	X	X				X	Wrong position of oil throw rings (contact with caps)	38
X	X	X	X	X		X	Uneven support area (deformed body causes excessive clamping of the bearing)	39
	X	X	X	X			Damaged roller (caused by impact on the bearing)	40
	X						Noisy fit (caused by other parts)	41
X	X	X					Lubricant leakage and penetration of dirt particles into the bearing (worn-out seal)	42
	X		X	X			Vibration (excessive clearance in the bearing)	43
	X		X	X			Vibration (imbalance)	44
		X		X		X	Shaft is turning with difficulty (shoulder on the shaft and in the body bore are not	45
	X						Bearing colouring (burner was used in disassembly)	46
X	X	X		X		X	Shaft diameter is too large (bearing is overheating)	47
X	X	X		X		X	Body bore is too small (bearing is overheating)	48
X	X	X	X	X			Body bore is too large (outer ring is turning over, bearing is overheating)	49
X	X	X	X	X			Enlarged body bore (knockout of body bore – body from non-ferrous material)	50
	X			X			Bearing is noisy (grooves in raceways)	51

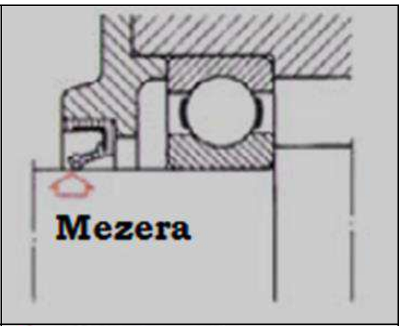
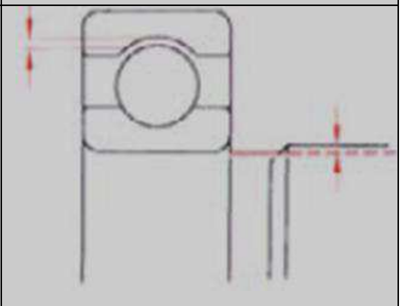
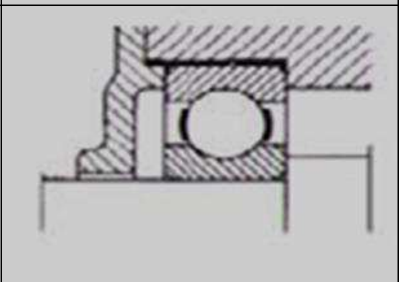
Bearing overheating – sign A

Solution code	Cause of operating condition	Practical solution	
1	Plastic lubricant or oil is loosing its lubricating qualities, because an inappropriate type of lubricant was chosen for the given running conditions	Consult the lubricant manufacturer about his recommendations regarding a suitable type of lubricant. When changing from one type of plastic or oil lubricant to another, check mixing ability.	
2	Low oil level. Lubricant is leaking around the seal. Insufficient amount of plastic lubricant in the body.	Oil level should reach just to the center of the lowest roller in the bearing. Fill the body to 1/3 – 1/2 of its volume with plastic lubricant.	
3	The body is completely filled with plastic lubricant, or the oil level is too high. This causes excessive mechanical stress to the lubricant, high operating temperatures, or lubricant leakage.	Withdraw plastic lubricant, until the body is filled only to one half. If your are using oil lubricant, reduce the oil level so that it reaches just to the center of the lowest roller in the bearing.	
4	The bearing has insufficient clearance due to to the running conditions, where heat from an external source is conducted by the shaft. This causes excessive expansion of the inner bearing ring.	Check, if clearance in the bearing corresponds to original technical requirements (technical documentation). If so, use a bearing with a larger radial clearance, i. e. C3 instead of normal, or C4 instead of C3. If not, order a new bearing according to technical documentation. If the bearing designation is unreadeable, consult the manufacturer.	 
7	Non-circular bore in the	Check the body bore and remove burr	

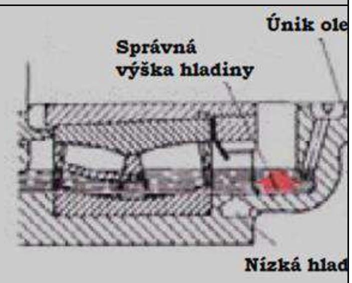
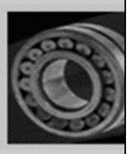
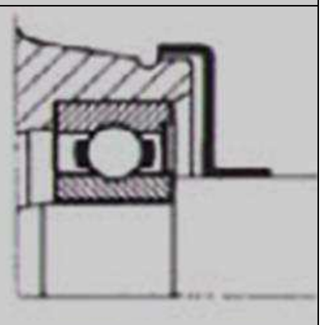
8 9 39 48	body. Body is deformed. Support area is uneven. Body bore is too small.	so that the bearing is not excessively clamped. If necessary, re-turn the bore to the correct dimension. Make sure that the base area is even and check, if the body is supported by shim blocks over the entire area. The body bore is too small, if the roller bearing is replaced by a ball bearing on the free axial side.	
12	Contact (friction) seal is dry, or there is excessive pressure from the spring.	Replace friction (contact) seals by new ones, with a spring providing the correct pressure. Lubricate the seals.	
13 31 38	Rotating parts of the seal or oil throw rings are touching the stationary parts.	Check operating clearance of the moving parts of the seals or oil throw rings. Eliminate misalignment.	
14	Oil backrun holes are clogged. Pumping effect of the seal causes oil leakage.	Clean the holes. Discharge used oil and refill new oil to the correct level.	

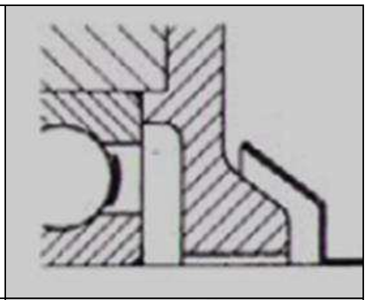
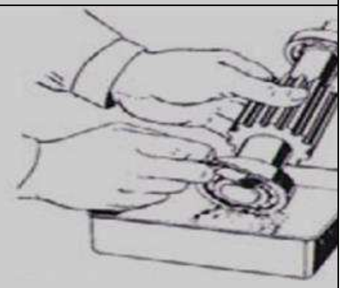
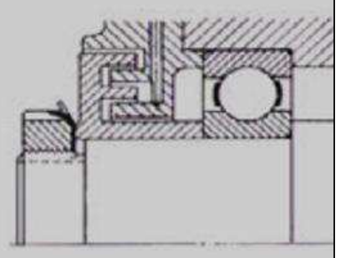
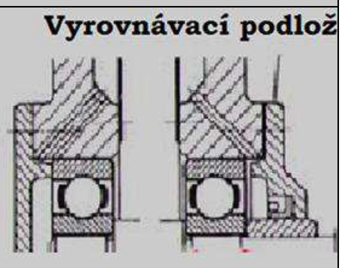
15	Symmetrical fit.	Insert a washer between the body and the bearing cap to release the bearing axial pre-stress.	
16	Two axial guide bearings on a single shaft. Insufficient clearance in the bearing is caused by excessive extension of the shaft.	Release the bearing cap on one side of the body. Use shim blocks to set the required clearance between the bearing cap and the outer ring. If possible, use a spring to axially pre-stress the outer ring and reduce the shaft axial movement.	
1 9	Tapered sleeve nut is too tight.	Loosen the terminal nut and release the sleeve. Re-tighten the nut to clamp the sleeve sufficiently on the shaft, but the bearing must turn freely.	
21 49	Imbalance. The bore in the body is two large.	Balance the machine. Use a body with the correct bore.	

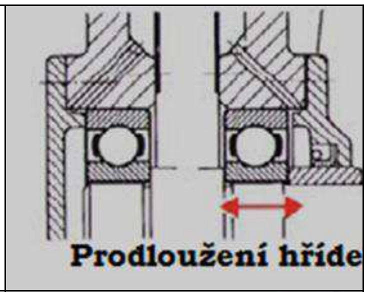
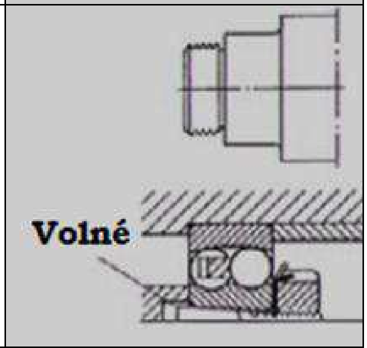
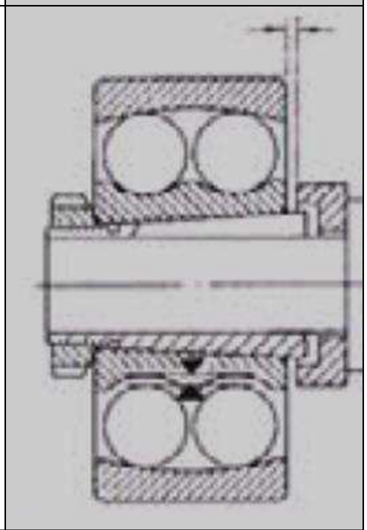
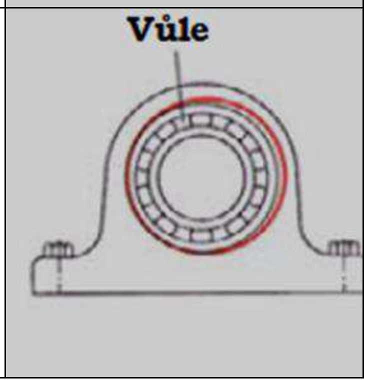
26	Shaft shoulder is touching the bearing seal.	Re-turn the shaft shoulder so that it does not touch the bearing seal. Check, if the connecting dimensions correspond to manufacturers recommendations.	
32	The bearing is not lubricated as a consequence of wrong oil level.	Clean the clogged deaeration hole of the oil level indicator.	
33 34	Wrong axial or angular alignment of two or more coupled shafts fitted on two or more bearings.	Correct the misalignment by inserting shim blocks under the body. Check, if the coupled shafts are well aligned, especially if the shaft is fitted on three or more bearings. Make sure the bodies are supported over the entire area.	
35 36	The constant oil level cup is positioned too high or too low. The cup is positioned in the opposite direction to of rotation of the bearing.	At rest, the oil level must not be higher than the center of the lowest roller. Replace the cup by oil level indicator. Position the cup in the direction of rotation of the bearing.	
37	The lock washer tab touches the bearing.	Dismount the lock washer. Put the tab straight or replace the washer.	

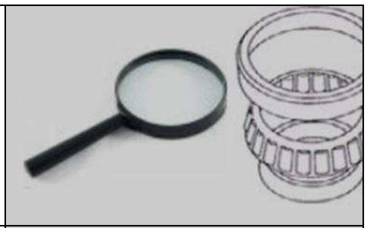
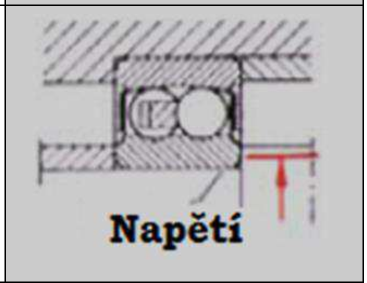
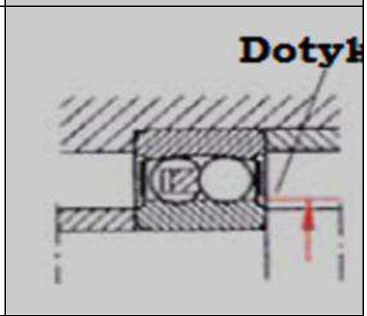
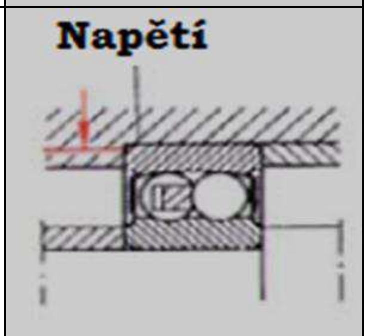
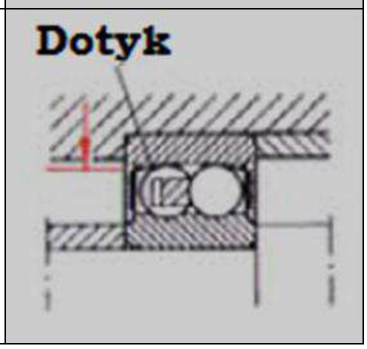
42	The friction seals are worn out, which causes lubricant leakage or penetration of dirt particles.	After thoroughly rinsing the bearing and refilling fresh lubricant, replace the seal.	
47	The journal diameter is too large, causing the inner ring to expand. This reduces the bearing clearance.	By regrinding the journal, make sure the bearing inner ring is correctly fitted on the shaft. If it is not possible to regrind the shaft, use a bearing with larger bearing clearance.	
50	Body bore "knockout", as a result of the body material being too soft. The bearing outer ring is turning over in the enlarged body bore.	Machine the body bore and press fit a steel sleeve into it. Machine the sleeve bore to the correct diameter.	

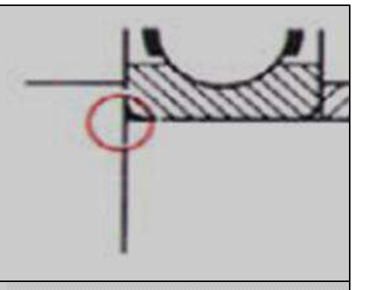
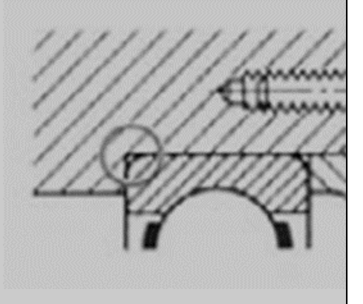
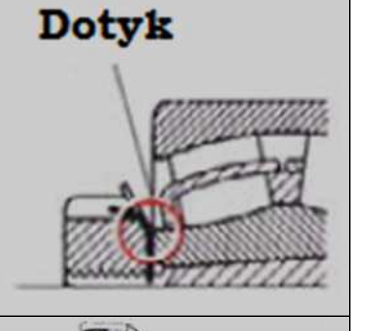
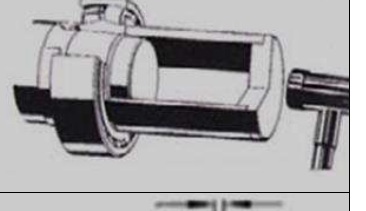
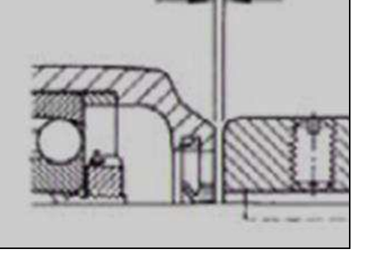
Bearing noise – sign B

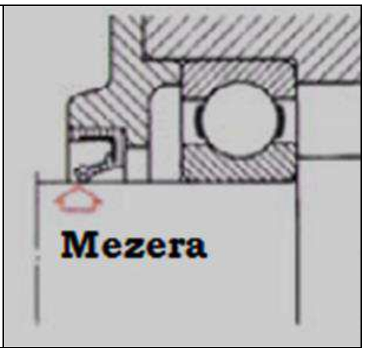
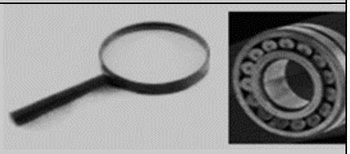
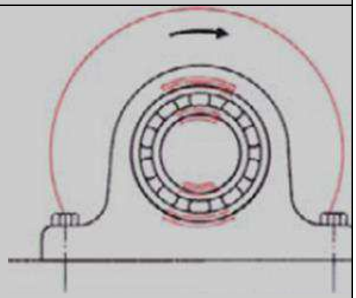
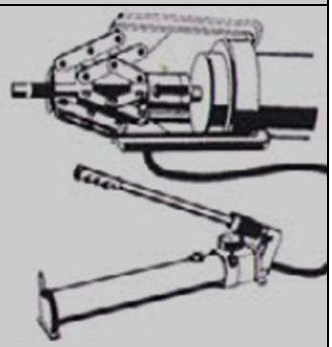
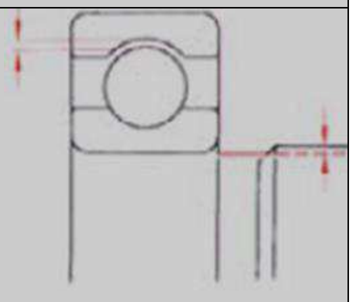
Solution code	Cause of operating condition	Practical solution	
1	Plastic lubricant is loosing its lubricating qualities, because an inappropriate type of lubricant was selected for the given running conditions.	Consult the lubricant manufacturer about his recommendations regarding a suitable type of lubricant. When changing from one type of lubricant to another, check mixing ability.	
2	Low oil level. Lubricant is leaking around the seal. Insufficient amount of plastic lubricant in the body.	The oil level should reach just to the center of the lowest roller in the bearing. Fill the body to 1/3 – ½ of its volume with plastic lubricant.	
4	The bearing has insufficient clearance due to the running conditions, where heat from an external source is conducted by the shaft. This results in excessive expansion of the bearing inner ring.	Check, if the bearing clearance meets the original design requirements (technical documentation). If so, use a bearing with a larger radial clearance, i. e. C3 instead of normal, or C4 instead of C3. If not, order a bearing according to the technical documentation. If the bearing designation is unreadable, consult the manufacturer.	 
5	Dirt, sand, carbonized matter, and other contamination has penetrated into the bearing body.	Clean the bearing body. Replace worn-out seals or choose a more suitable seal design to ensure appropriate bearing protection.	

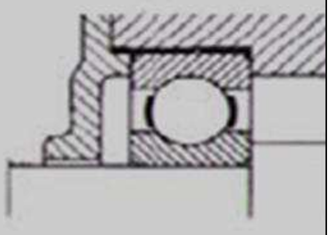
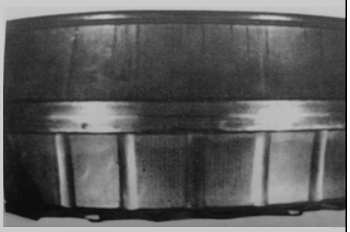
6	Water, acids, varnish, or other aggressive substances have penetrated into the bearing body.	Mount a pre-set protecting ring or oil throw ring to prevent penetration of contaminants. Improve the sealing.	
7 8 9 39 48	Non-circular bore in the body. Body is deformed. The support area is uneven. Body bore is too small.	Check the body bore and remove any burr so the bearing is not excessively clamped. If needed, re-turn the bore to the correct diameter. Make sure the base area is even and check, if the body is supported by shim blocks over the whole area. The body bore is too small if the roller bearing is replaced on the free axial side by a ball bearing.	
10	Burr, chips, and dirt particles had not been removed from the body prior to assembly.	Clean the body carefully and fill it with fresh lubricant.	
13 31 38	Rotating parts of the seal or oil throw rings touch the stationary parts.	Check the running clearance of the moving parts of the seal or oil throw rigns. Eliminate misalignment.	
15	Symmetrical fit.	Insert a washer between the body and the bearing cap to release the bearing axial prestress.	

16	Two axial guide bearings on a single shaft. Insufficient clearance in the bearing caused by excessive shaft extension.	Release the bearing cap on one side of the body. Use shim blocks to set the required clearance between the cap and the outer ring. If possible, axially prestress the outer ring using a spring to reduce axial movement of the shaft.	
17 18	Journal diameter is too small. Tapered sleeve is insufficiently clamped.	Repair the journal by adding material and regrinding to achieve the required fit. Tighten the sleeve nut until the sleeve firmly clamps the journal.	
19	Tapered sleeve nut is too tight.	Loosen the terminal nut and release the sleeve. Retighten the nut so the sleeve is sufficiently clamped on the shaft, while making sure the bearing is turning freely.	
21 49	Imbalance. The body in the body is too large.	Balance the machine. Use a body with the correct bore.	

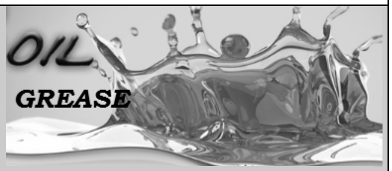
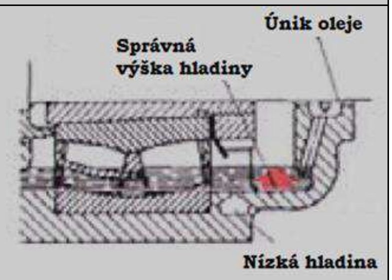
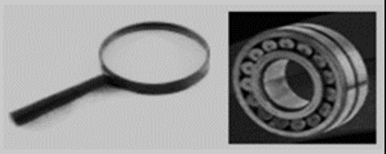
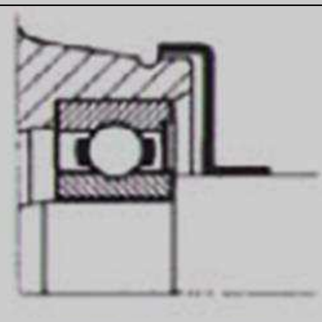
22	A flat on the surface of a bearing roller caused by slippage (during rapid machine starts)	Visually inspect the rollers. If there are any flats on them, replace the bearing. Make sure the bearing is under the minimum required load.	
25	Shaft deflection caused by wrong shoulder dimensions.	Re-turn the transition to prevent development of stress. Depending on the fit design, you may need to use a thrust collar. Check, if the coupling dimensions correspond to the manufacturer´s recommendations.	
26	The shaft shoulder touches the bearing seal.	Re-turn the shaft shoulder to make sure it does not touch the bearing seal. Check, if the coupling dimensions correspond to the manufacturer´s recommendations.	
27	Deformation of the outer ring caused by lack of support in the body.	Re-turn the shoulder transition in the body to prevent development of stress. Check, if the coupling dimensions correspond to the manufacturer´s recommendations. Depending on the fit design, you may need to use a thrust collar.	
28	Damaged bearing seals.	Re-turn the shoulder in the body, making sure the seal does not touch the shoulder.	

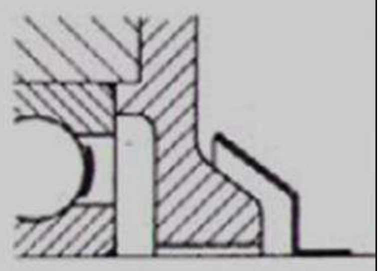
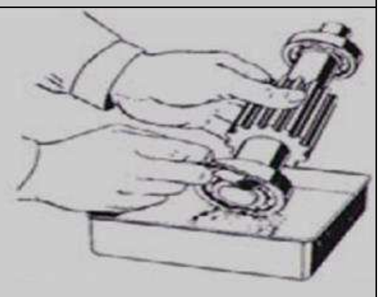
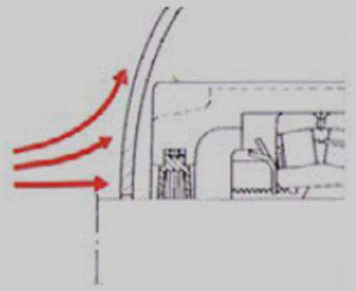
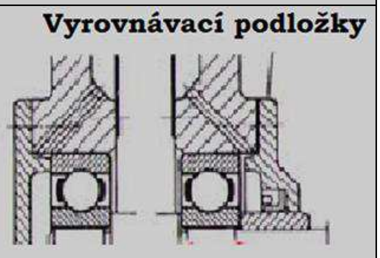
29	Shaft and inner ring are deformed.	Re-turn the shaft shoulder transition to ensure sufficient support.	
30	Body and outer ring are deformed.	Re-turn the shoulder transition in the body to ensure sufficient support.	
37	Lock washer tab touches the bearing.	Dismount the lock washer. Straighten the tab or replace the washer.	
40	Wrong assembly method. Hammer strokes on the bearing.	Replace the bearing. Never directly strike any part of the bearing with hammer. Always use a mounting sleeve.	
41	Moving parts of the machine are touching the bearing or housing.	Check all moving parts of the machine. Release the touching parts.	

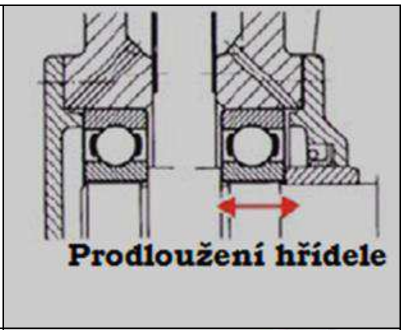
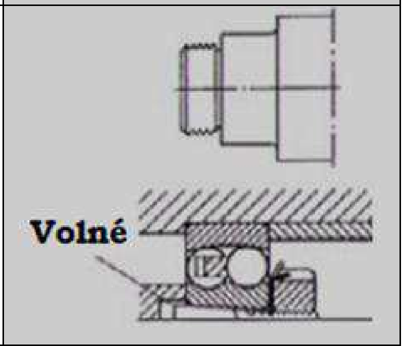
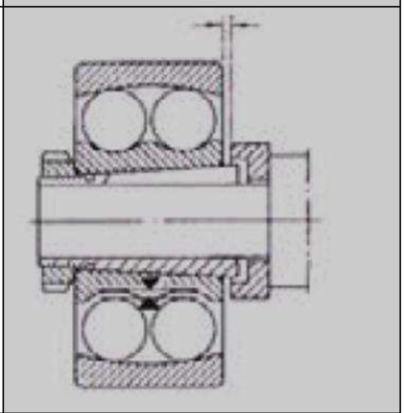
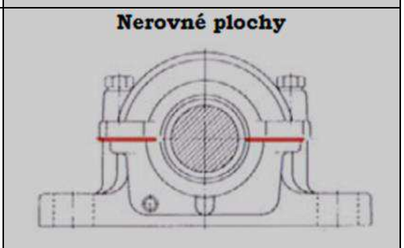
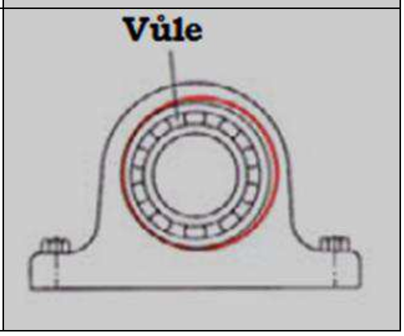
42	Friction seals are worn out, which causes lubricant leakage or penetration of contaminant particles.	After carefully rinsing the bearing and filling it with fresh lubricant, replace the seals.	
43	Excessive bearing clearance is causing vibrations.	Use a bearing with the recommended clearance. To eliminate axial and radial clearance, prestress the outer ring of an axially loose bearing using a spring.	
44	The whole machine is vibrating.	Check the balancing of the rotating parts. Rebalance the machine.	
46	Deformation of the shaft or other part of the fit caused probably by temperature.	When dismounting the bearing, use a burner only if necessary. Avoid local overheating which may cause deformation. Replace a coloured bearing.	
47	Large journal diameter causing excessive expansion of the inner ring. This reduces the bearing clearance.	By regrinding the journal, achieve correct fit of the bearing inner ring on the shaft. If it is not possible to regrind the shaft, use a bearing with larger bearing clearance.	

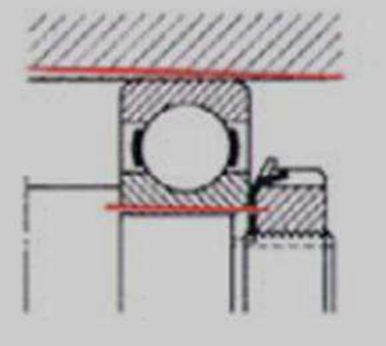
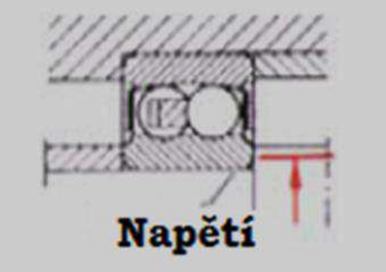
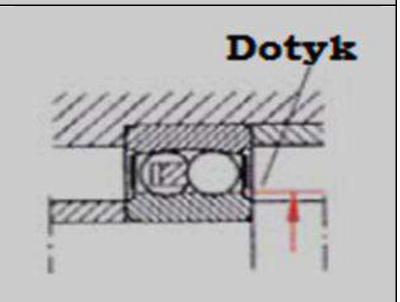
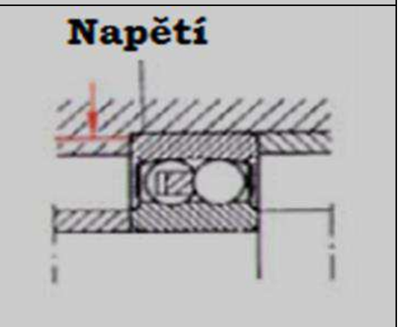
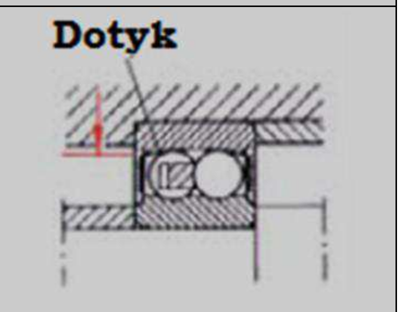
50	„Knockout“ of body hole as a result of the body material being too soft. The outer bearing ring is turning over in the enlarged body hole.	Remachine the body hole and press fit a steel sleeve into it. Machine the sleeve hole to the correct diameter.	
51	Bearing exposed to vibrations during machine rest.	Inspect the bearing carefully for the presence of any damage (grooves) in the raceways located within distances corresponding to roller spacing. For standby equipment, point-contact (ball) bearings are more suitable than line-contact (roller, etc.) bearings because of their resistance to vibrations.	

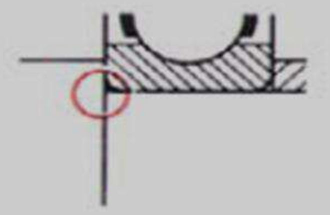
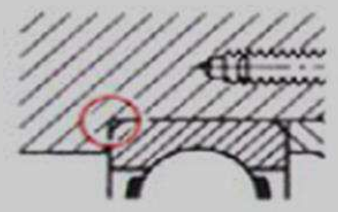
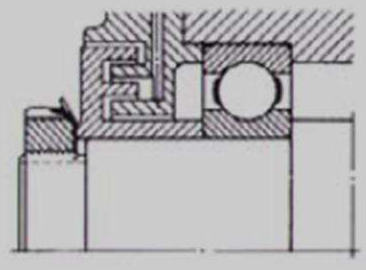
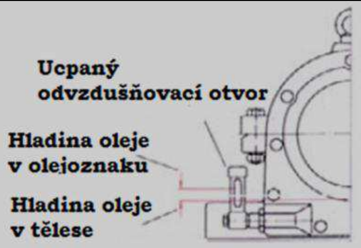
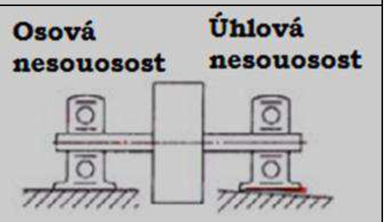
Unexpected and too frequent bearing replacements – sign C

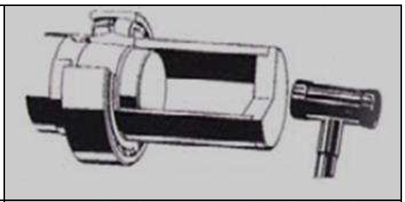
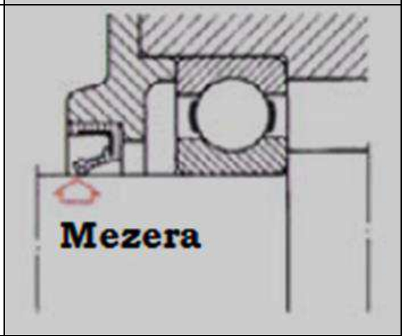
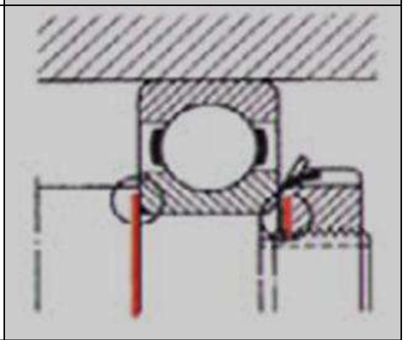
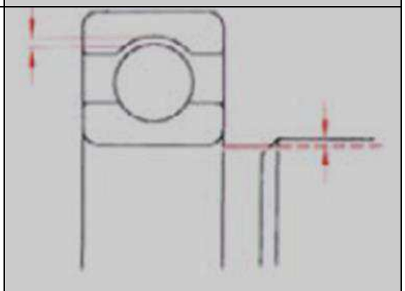
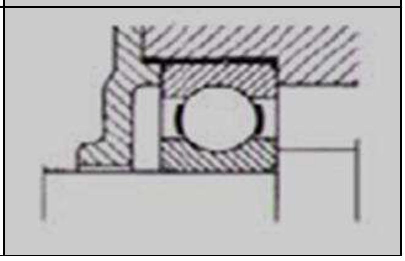
Solution code	Cause of operating condition	Practical solution	
1	Plastic lubricant or oil is loosing its lubricating qualities, because an inappropriate type of lubricant has been chosen for the given running conditions.	Consult the lubricant manufacturer about his recommendations regarding a suitable type of lubricant. When changing from one type of plastic lubricant or oil to another, check mixing ability.	
2	Low oil level. Lubricant is leaking around the seal. Lack of plastic lubricant in the body.	The oil level should reach just to the center of the lowest roller in the bearing. Fill the body to 1/3 – 1/2 of its volume with plastic lubricant.	
4	The bearing has insufficient clearance due to the given running conditions, where heat from an external source is conducted by the shaft. This causes the bearing inner ring to expand excessively.	Check, if clearance in the bearing meets the original design requirements (technical documentation). If so, use a bearing with larger radial clearance, i. e. C3 instead of normal, or C4 instead of C3. If not, order a bearing according to the technical documentation. If the bearing designation is undreadable, consult the manufacturer.	
5	Dirt, sand, carbonized matter, or other contaminants have penetrated into the bearing body.	Clean the bearing body. Replace worn-out seals or choose a more suitable sealing design to ensure appropriate bearing protection.	

6	Water, acid, varnish, or other aggressive substances have penetrated into the bearing body.	Mount a pre-set cover ring or oil throw ring to prevent penetration of contaminants. Improve the sealing.	
7 8 9 39 48	Non-circular hole in the body. Body is deformed. Support area is uneven. Body hole is too small.	Check the body hole and remove burr to make sure the bearing is not excessively clamped. If necessary, re-turn the hole to the correct dimension. Make sure the base area is even and check, if the body is supported by shim blocks over the whole area. The body hole is too small, if the roller bearing is replaced by a ball bearing on the axially free side.	
10	Burr, chips, contaminant particles, etc. had not been removed from the body prior to assembly.	Clean the body carefully and refill it with fresh lubricant.	
11	Air current around the bearing causes oil leakage (Example: An exhaust fan with inlet hole positioned above the bearing).	Mount cover metal sheets to change the direction of the air current. Make sure there is no pressure drop on the two sides of the bearing. If possible, use lubrication with plastic lubricant.	
15	Symmetrical fit.	Insert a washer between the body and the cap to release the bearing axial prestress.	

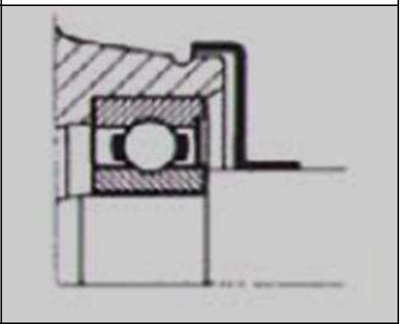
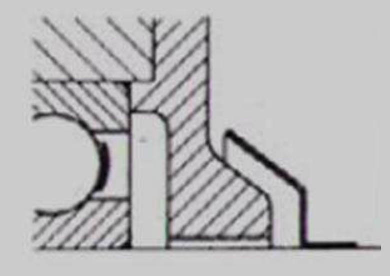
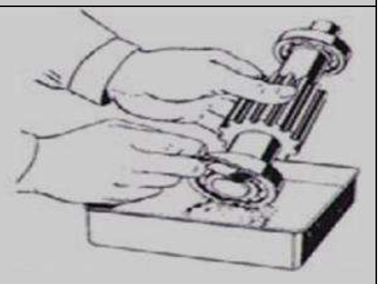
16	Two axial guide bearings on a single shaft. Insufficient clearance in the bearing is caused by excessive extension of the shaft.	Release the cap on one side of the body. Use shim blocks to set the required clearance between the cap and the outer ring. If possible, axially prestress the outer ring using a spring to reduce the shaft axial movement.	
17 18	Journal diameter is too small. Tapered sleeve is not sufficiently clamped.	Repair the journal by adding material and regrinding, to obtain the required fit. Tighten the sleeve nut so that the sleeve firmly clamps the journal.	
19	The tapered sleeve nut is too tight.	Loosen the terminal nut and release the sleeve. Retighten the nut, until the sleeve is sufficiently clamped on the shaft. However, the bearing must be turning freely.	
20	Oil is leaking in the dividing plane of the body. There is excessive leakage of lubricant.	A thin sealant film will eliminate minor leakiness. Do not use shim blocks. If necessary, replace the body.	
21 49	Imbalance. The hole in the body is too large.	Balance the machine. Use a bearing with the correct hole.	

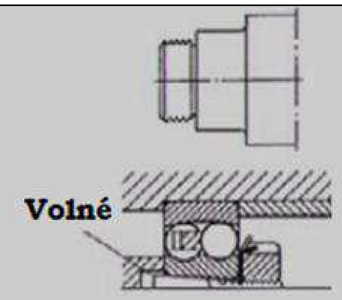
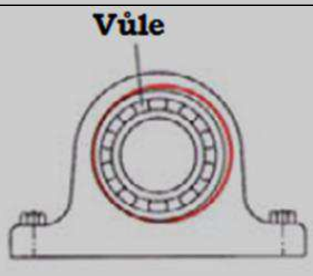
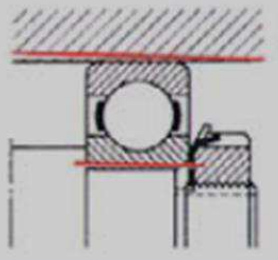
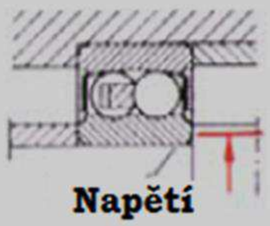
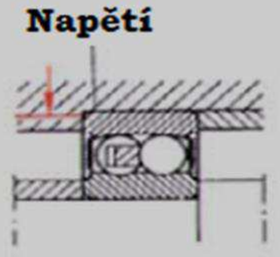
23 24	Wrong geometric shape of the journal or body hole causes uneven distribution of load on the bearing.	Re-turn the shaft, body, or both, to achieve the prescribed shape and tolerance of the fit.The fit design may require shaft or body replacement.	
25	Shaft deflection caused by wrong shoulder dimensions.	Re-turn the transition to prevent development of stress. Depending on the fit design, you may need to use a thrust collar. Check, if the coupling dimensions meet the manufacturer´s recommendations.	
26	The shaft shoulder is touching the bearing seal.	Re-turn the shaft shoulder so it does not touch the bearing seal. Check, if the coupling dimmensions meet the manufacturer´s recommendations.	
27	Deformation of the outer ring caused by lack of support in the body.	Re-turn the shoulder transition in the body to prevent development of stress. Check, if the coupling dimensions meet the manufacturer´s recommendations. Depending on the fit design, you may need to use a thrust collar.	
28	Damaged bearing seals.	Re-turn the shoulder in the body to prevent the shoulder from touching the seal.	

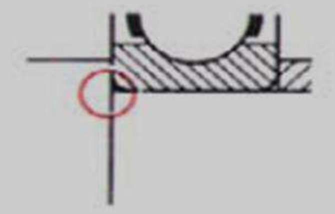
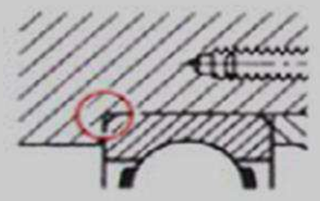
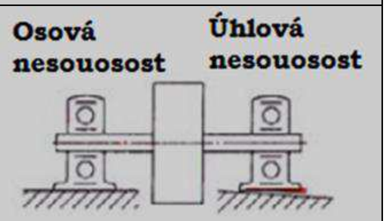
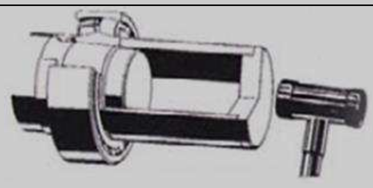
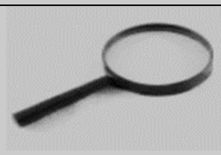
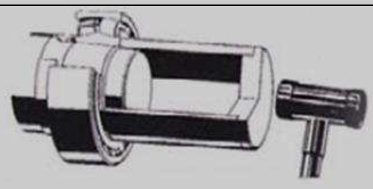
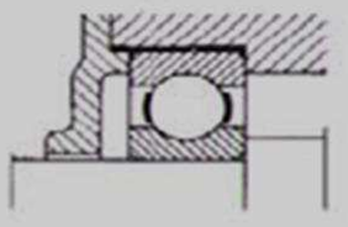
29	The shaft and inner ring are deformed.	Re-turn the shaft shoulder transition to ensure sufficient support.	
30	The body and outer ring are deformed.	Re-turn the shoulder transition in the body so as to ensure sufficient support.	
31 38	The rotating parts of the seal or oil throw rings are touching the stationary parts.	Check the running clearance of the moving parts of the seals or oil throw rings. Eliminate axial misalignment.	
32	The bearing is not lubricated as a result of wrong oil level.	Clean the clogged deaeration hole of the oil indicator.	
33 34	Axial or angular misalignment of two or more coupled shafts fitted on two or more bearings.	Correct the shaft misalignment by inserting shim blocks under the body. Check, if the coupled shafts are well aligned, especially if a shaft is fitted on three or more bearings. Make sure the bodies are supported over the entire area.	
35 36	Constant oil level cup is positioned too high or too low. The cup is positioned in opposite direction to the rotation of the bearing.	The oil level at rest must not reach higher than the center of the lowest roller in the bearing. Replace the cup by the oil indicator. Position the cup in the direction of rotation of the bearing.	

40	Wrong assembly method. Hammer strokes on the bearing.	Replace the bearing. No bearing part should be directly struck with hammer. Always use a mounting sleeve.	
42	Friction seals are worn out, causing lubricant leakage or penetration of contaminant particles.	After thoroughly rinsing the bearing and filling it with fresh lubricant, replace the seals.	
45	Shoulder on the shaft or in the body, or the terminal nut face does not form a right angle with the journal axis.	Re-turn the parts to ensure perpendicularity.	
47	Journal diameter is too large, causing the inner rign to expand. This reduces the bearing clearance.	By regrinding the journal, achieve the correct fit of the bearing inner ring on shaft. If it is not possible to regrind the shaft, use a bearing with larger bearing clearance.	
50	„Knockout“ of the body hole, caused by the body material being too soft.	Remachine the body hole and press fit a steel sleeve into it. Machine the sleeve hole to the correct diameter.	

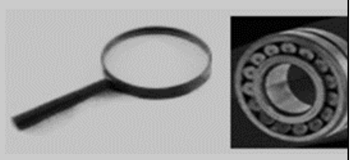
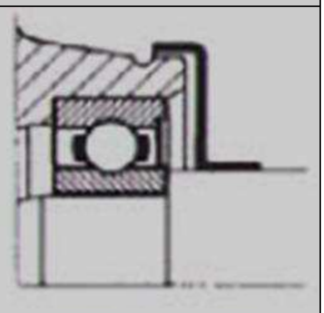
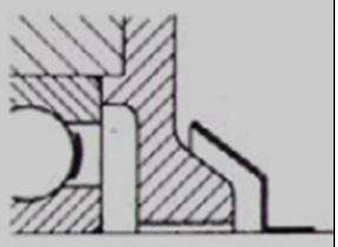
Vibrations – sign D

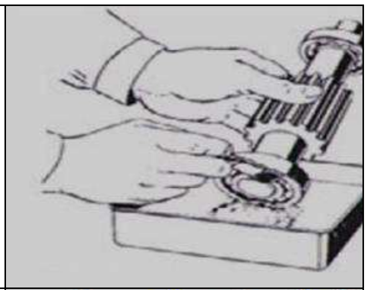
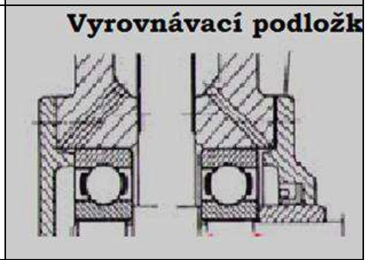
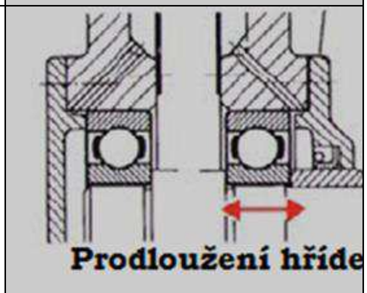
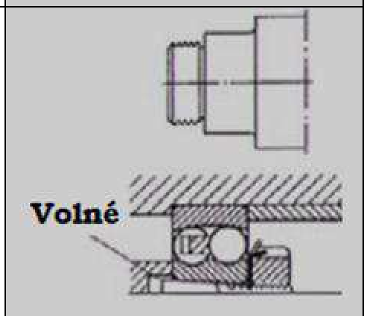
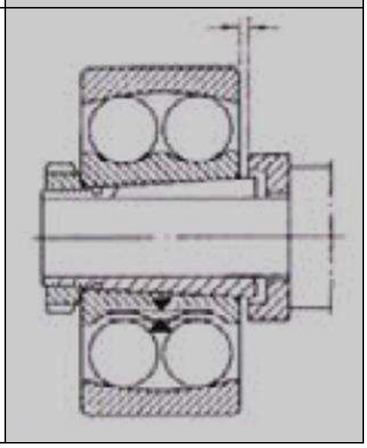
Solution code	Cause of operating condition	Practical solution	
5	Dirt, sand, carbonized matter, or other contaminants have penetrated into the bearing body.	Clean the bearing body. Replace worn-out seals or choose a more suitable seal design to ensure appropriate bearing protection.	
6	Water, acid, varnish, or other aggressive substances have penetrated into the bearing body.	Mount a pre-set cover or oil throw ring to prevent penetration of contaminants into the bearing body. Improve the sealing.	
7 8 9 39 48	Non-circular hole in the body. Body is deformed. Support area is uneven. Body hole is too small.	Inspect the body hole and remove burr so the bearing is not excessively clamped. If needed, re-turn the hole to the correct dimension. Make sure the base area is even and check, if the body is supported by shim blocks over the whole area. The body hole is too small if the roller bearing is replaced by a ball ring on the axially free side.	
10	Burr, chips, dirt particles, etc. had not been removed from the body prior to assembly.	Clean the body carefully and fill in fresh lubricant.	

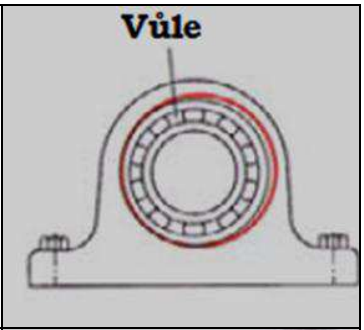
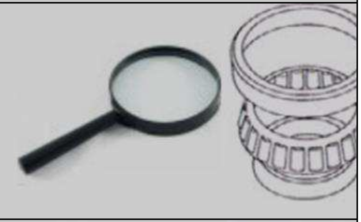
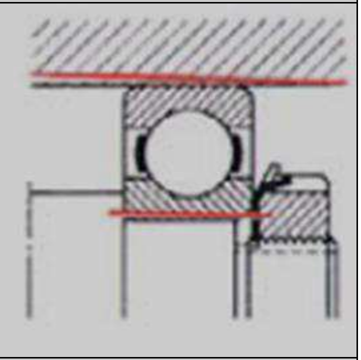
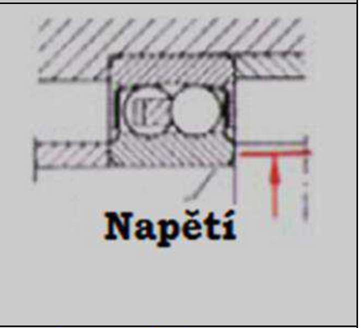
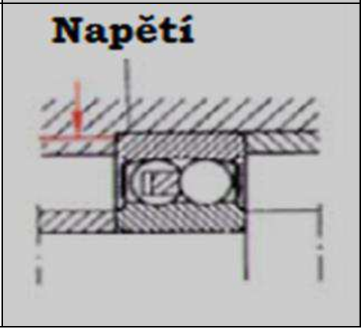
17 18	Journal diameter is too small. The tapered sleeve is not sufficienatly clamped.	Repair the journal by adding material a regrinding to achieve the required fit. Tighten the sleeve nut until the sleeve firmly clamps the journal.	
21 49	Imbalance. Hole in the body is too large.	Balance the machine. Use a body with the correct hole.	
22	A flat on the surface of a bearing roller caused by slippage (during rapid machine startups).	Visually inspect the rollers. If there are any flats, replace the bearing. Find out if the bearing has been under the minimum required load.	
23 24	Wrong geometric shape of the journal or body hole is causing uneven distribution of the bearing load.	Re-turn the shaft, body, or both to meet the prescribed shape and tolerance of the fit. The fit design may require shaft or body replacement.	
25	Shaft deflection caused by wrong shoulder dimensions.	Re-turn the shoulder transition to prevent development of stress. Depending on the fit design, you may need to use a thrust collar. Check, if the coupling dimensions correspond to the manufacturer´s recommendations.	
27	Outer ring deformation caused by lack of support in the body.	Re-turn the shoulder transition in the body to prevent development of stress. Check, if the coupling dimensions correspond to the manufacturer´s recommendations. Depending on the fit design, you may need to use a thrust collar.	

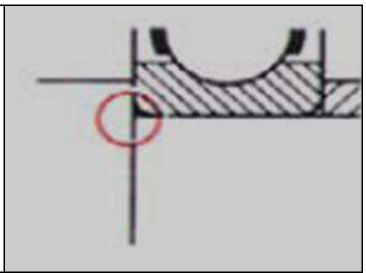
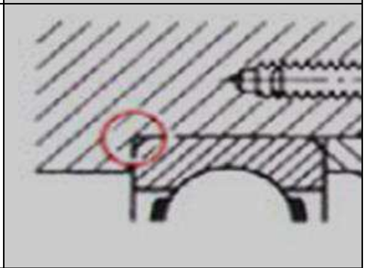
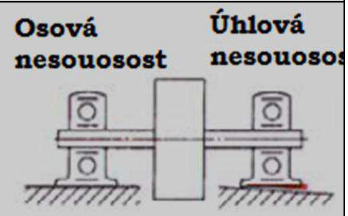
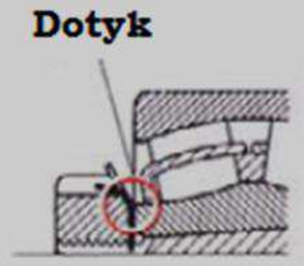
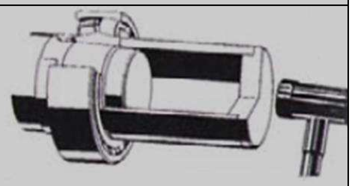
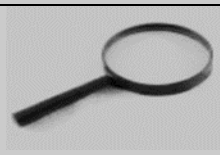
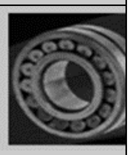
29	The shaft and inner ring are deformed.	Re-turn the shaft shoulder transition to ensure sufficient support.	
30	Body and outer ring are deformed.	Re-turn the shoulder transition in the body to ensure sufficient support.	
33 34	Axial or angular misalingment of two or more coupled shafts fitted on two or more bearings.	Correct the misalignment by inserting shim blocks under the body. Check, if the coupled shafts are well aligned, especially if the shaft is fitted on three or more bearings. Ensure that the bearing bodies are supported over the whole area.	
40	Wrong assembly method. Hammer strokes on the bearing.	Replace the bearing. Never strike any bearing part directly with hammer. Always use a mounting sleeve.	
43	Excessive bearing clearance is causing vibrations.	Use a bearing with recommended clearance. To eliminate axial and radial clearance, prestress the outer ring of the axially loose bearing using a spring.	 
44	The whole machine is vibrating.	Check the balancing of all rotating parts. Rebalance the machine.	
50	„Knockout“ of the body hole, caused by the body material being too soft. The outer ring is turning over in the enlarged body hole.	Remachine the body hole and press fit a steel sleeve into it. Machine the sleeve hole to the correct dimension.	

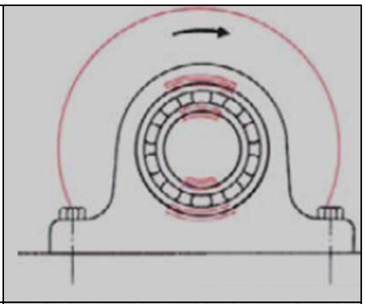
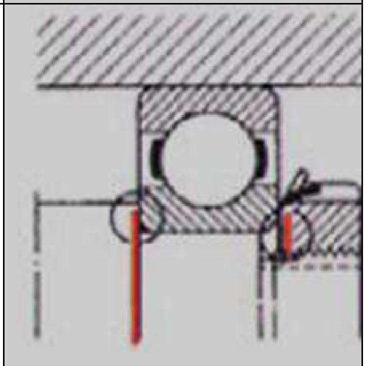
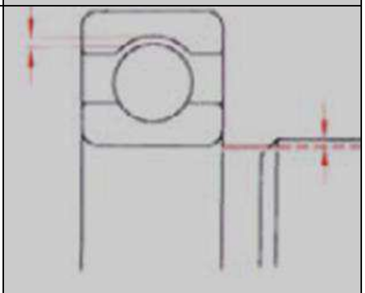
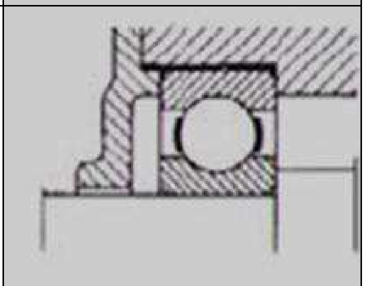
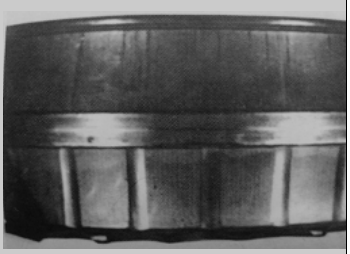
The machine is not working properly – sign E

Solution code	Cause of operating condition	Practical solution	
4	The bearing has insufficient clearance due to the running conditions, where heat from an external source is conducted by the shaft. This causes excessive expansion of the bearing inner ring.	Check, if the clearance in the bearing corresponds to the original design requirements (technical documentation). If so, use a bearing with a larger radial clearance, i. e. C3 instead of normal, or C4 instead of C3. If not, order a new bearing according to the technical documentation. If the bearing designation is illegible, consult the manufacturer.	
5	Dirt, sand, carbonized matter, or other contaminant particles have penetrated into the bearing body.	Clean the bearing body. Replace worn-out seals or choose a more suitable sealing design to ensure appropriate bearing protection.	
6	Dirt, sand, carbonized matter, or other contaminant particles have penetrated into the bearing body.	Mount a pre-set cover ring or oil throw ring to prevent penetration of contaminants into the body. Improve the sealing.	
7 8 9 39 48	Non-circular hole in the body. Body is deformed. Support surface is uneven. Body hole is too small.	Check the body hole and remove any burr to make sure the bearing is not clamped excessively. If necessary, re-turn the hole to the correct dimension. Make sure the base area is even and check, if the body is supported by shim blocks over the whole area. The body hole is too small, if the roller bearing is replaced by a ball bearing on the axially free side.	

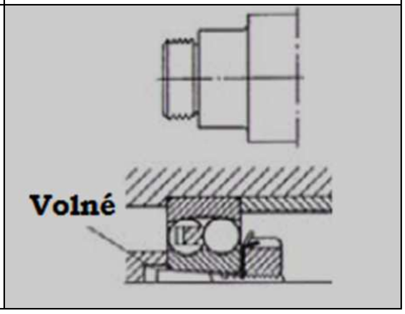
10	Burr, chips, contaminant particles, etc. had not been removed from the body prior to assembly.	Clean the body carefully and fill it with fresh lubricant.	
15	Symmetrical fit.	Insert a washer between the body and the cap to release the bearing axial prestress.	
16	Two axial guide bearings on a single shaft. Insufficient clearance in the bearing is caused by excessive extension of the shaft.	Release the cap on one side of the body. Use shim blocks to set the correct clearance between the cap and the outer ring. If possible, axially prestress the outer ring using a spring to reduce axial movement of the shaft.	
17 18	Journal diameter is too small. Tapered sleeve is not sufficiently clamped.	Repair the journal by adding material and regrinding to achieve the required fit. Tighten the sleeve nut until the sleeve clamps the journal firmly.	
19	The tapered sleeve nut is too tight.	Loosen the terminal nut and release the sleeve. Retighten the nut so the sleeve is sufficiently clamped on the shaft, but the bearing must be turning freely.	

21 49	Imbalance. The hole in the body is too large.	Balance the machine. Use a body with the correct hole.	
22	A flat on the surface of a bearing roller, caused by slippage (during rapid machine startups).	Visually inspect the bearing rollers. If there are any flats, replace the bearing. Make sure the bearing is under the minimum required load.	
23 24	Wrong geometric shape of the journal or body hole is causing uneven distribution of the bearing load.	Re-turn the shaft, body or both to meet the prescribed shape and tolerance of the fit. The fit design may require replacement of the shaft or body.	
25	Shaft deflection caused by wrong shoulder dimensions.	Re-turn the shoulder transition to prevent development of stress. Depending on the fit design, you may need to use a thrust collar. Check if the coupling dimensions correspond to the manufacturer´s recommendations.	
27	Deformation of the outer ring caused by lack of support in the body.	Re-turn the shoulder transition in the body to prevent development of stress. Check, if the coupling dimensions correspond to the manufacturer´s recommendations. Depending on the fit design, you may need to use a thrust collar.	

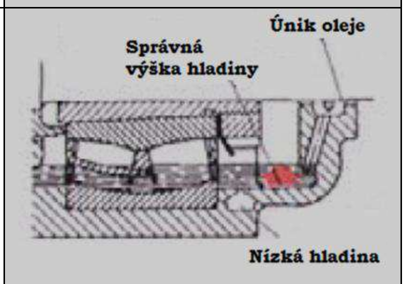
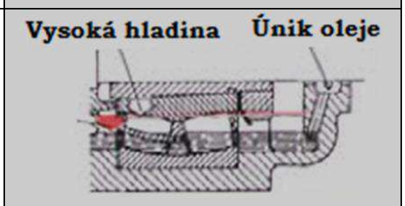
29	The shaft and outer ring are deformed.	Re-turn the shaft shoulder transition to ensure sufficient support.	
30	The body and the outer ring are deformed.	Re-turn the shoulder transition to ensure sufficient support.	
33 34	Axial or angular misalignment of two or more coupled shafts fitted on two or more bearings.	Correct the misalignment by inserting shim blocks under the body. Check, if the coupled shafts well aligned, especially if a shaft is fitted on three or more bearings. Make sure the bodies are supported over the whole area.	
37	The lock washer tab is touching the bearing.	Dismount the lock washer. Straighten the tab or replace the washer.	
40	Wrong assembly method. Hammer strokes on the bearing.	Replace the bearing. Never strike any part of the bearing directly struck with hammer. Always use a mounting sleeve.	
43	Excessive bearing clearance is causing vibrations.	Use a bearing with the recommended clearance. To eliminate axial and radial clearance, axially prestress the outer ring of the axially free bearing using a spring.	 

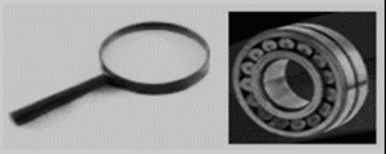
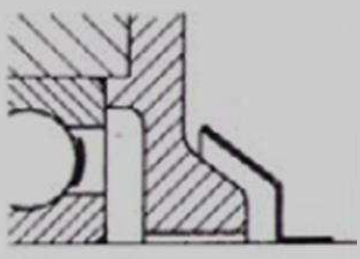
44	The whole machine is vibrating.	Check the balancing of the rotating parts. Rebalance the machine.	
45	The shoulder on the shaft or in the body, or the terminal nut face do not form a right angle with the journal axis.	Re-turn the parts to ensure perpendicularity.	
47	The journal diameter is too large, causing the inner ring to expand excessively.	By regrinding the journal, achieve the correct fit of the bearing inner ring on the shaft. If it is not possible to regrind the shaft, use a bearing with a larger bearing clearance.	
50	„Knockout“ of the body hole caused by the body material being too soft. The bearing outer ring is turning over in the enlarged body hole.	Remachine the body hole and press fit a steel sleeve into it. Machine the sleeve hole to the correct dimension.	
51	The bearing is exposed to vibrations when the machine is at rest.	Carefully inspect the bearing to see if there is any damage (grooves) in the raceways within distances corresponding to roller spacing. Because of their resistance to vibrations, point-contact (ball) bearings are more suitable for standby machines than line-contact (roller) bearings.	

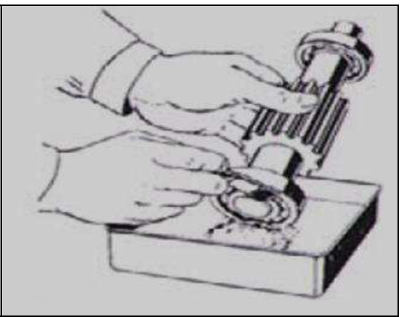
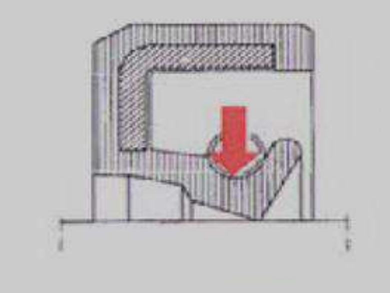
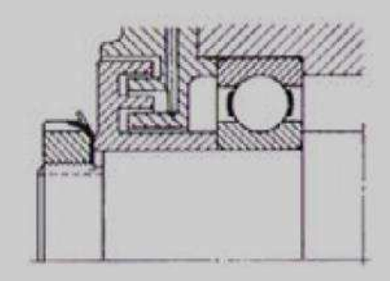
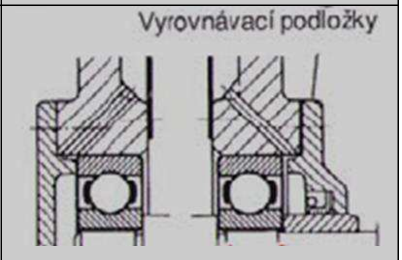
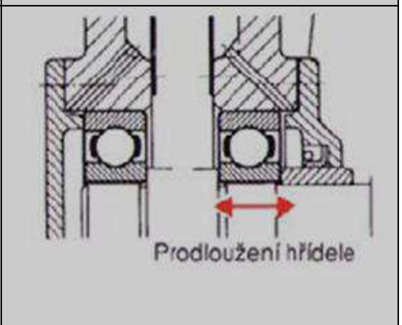
The bearing is loose on the shaft – sign F

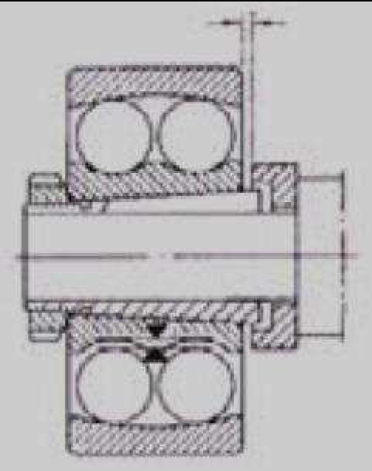
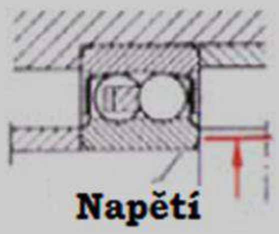
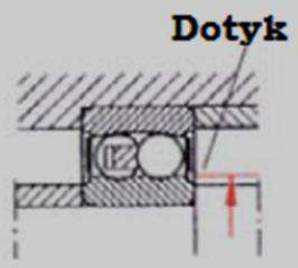
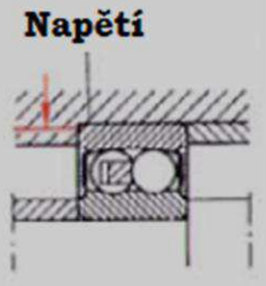
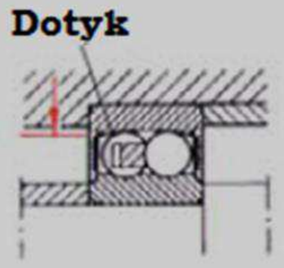
Solution code	Cause of operating condition	Practical solution	
17 18	The journal diameter is too small. The tapered sleeve is not sufficiently clamped.	Repair the journal by adding material and regrinding to achieve the required fit. Tighten the sleeve nut until the sleeve firmly clamps the journal.	

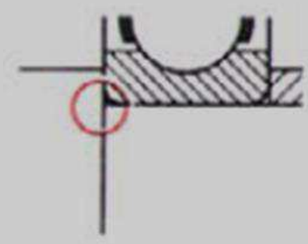
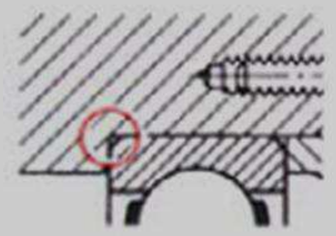
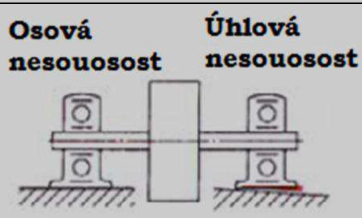
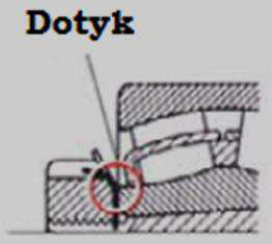
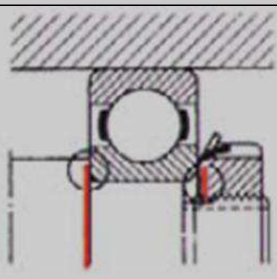
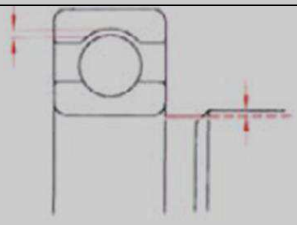
The shaft is turning with difficulty – sign G

Solution code	Cause of the operating condition	Practical solution	
1	Plastic or oil lubricant is loosing its lubricating qualities, because an inadequate type of lubricant has been chosen for the given running conditions.	Consult the lubricant manufacturer about his recommendations regarding a suitable type of lubricant. When changing from one type of plastic or oil lubricant to another, check mixing ability.	
2	The oil level is too low. Lubricant is leaking around the seal. Lack of plastic lubricant in the body.	The oil level should reach just to the center of the lowest roller in the bearing. Fill the body to 1/3 – ½ of its volume with plastic lubricant.	
3	The body is completely filled with plastic lubricant, or the oil level is too high. This is causing excessive mechanical stress to the lubricant, high operating temperatures, or lubricant leakage.	Take off plastic lubricant until the body is filled only to one half of its volume. In case of oil lubrication, reduce the oil level so that it reaches just to the center of the lowest roller in the bearing.	

4	The body has insufficient clearance due to the running conditions where heat from an external source is conducted by the shaft. This causes the bearing inner ring to expand excessively.	Check, if the clearance in the bearing corresponds to the original design requirements (technical documentation). If so, use a bearing with a larger radial clearance, i. e. C3 instead of normal, or C4 instead of C3. If not, order a bearing according to technical documentation. If the bearing designation is illegible, consult the manufacturer.	
5	Dirt, sand, carbonized matter, and other contaminant particles have penetrated into the bearing body.	Clean the body bearing. Replace worn-out seals or choose a more suitable bearing design to ensure appropriate bearing protection.	
6	Dirt, sand, carbonized matter, or other contaminant particles have penetrated into the bearing body.	Mount a pre-set cover ring or oil throw ring to prevent penetration of contaminants. Improve the sealing.	
7 8 9 39 48	Non-circular hole in the body. The body is deformed. The support area is uneven. The body hole is too small.	Check the body hole and remove any burr to ensure the bearing is not excessively clamped. If necessary, re-turn the hole to the correct diameter. Make sure the base area is even and check, if the body is supported by shim blocks over the entire area. The body hole is too small if the roller bearing is replaced by a ball bearing on the axially free side.	

10	Burr, chips, contaminant particles, etc. had not been removed from the body prior to assembly.	Clean the body carefully and fill it with fresh lubricant.	
12	Contact (friction) seal is too dry or there is too much pressure from the seal spring.	Replace the contact (friction) seals by seals giving the correct pressure from the seal spring. Lubricate the seals.	
13 31 38	The rotating parts of the seals or oil throw rings are touching the stationary parts.	Check the running clearance of the moving parts of the seals or oil throw rings. Eliminate axial misalignment.	
15	Symmetrical fit.	Insert a washer between the body and the cap to release the bearing axial prestress.	
16	Two axial guide bearings on a single shaft. Insufficient clearance in the bearing is caused by excessive extension of the shaft.	Release the cap on one side of the body. Use shim blocks to set the required clearance between the cap and the outer ring. If possible, axially prestress the outer ring using a spring, to reduce the axial movement of the shaft.	

19	The tapered sleeve nut is too tight.	Loosen the terminal nut and release the sleeve. Retighten the nut so the sleeve is sufficiently clamped, ensuring at the same time that the bearing is turning freely.	
25	Shaft deflection caused by wrong shoulder dimensions.	Re-turn the transition to prevent development of stress. Depending on the fit design, you may need to use a thrust collar. Check, if the coupling dimensions correspond to the manufacturer´s recommendations.	
26	The shaft shoulder is touching the bearing seals.	Re-turn the shaft shoulder so it does not touch the bearing seal. Check, if the coupling dimensions correspond to the manufacturer´s recommendations.	
27	Deformation of the outer ring caused by insufficient support in the body.	Re-turn the shoulder transition in the body to prevent development of stress. Check, if the coupling dimensions correspond to the manufacturer´s recommendations. Depending on the fit design, you may need to use a thrust collar.	
28	Damaged bearing seals.	Re-turn the shoulder in the body to prevent the seals from touching the shoulder.	

29	The shaft and inner ring are deformed.	Re-turn the shaft shoulder transition to ensure sufficient support.	
30	The body and outer ring are deformed.	Re-turn the shoulder transition in the body to ensure sufficient support.	
33 34	Axial or angular misalignment of two or more coupled shafts fitted on two or more bearings.	Correct the misalignment by inserting shim blocks under the body. Check if the coupled shafts are correctly aligned, especially if the shaft is fitted on three or more bearings. Ensure that the bodies are supported by the blocks over the entire area.	
37	The lock washer tab is touching the bearing.	Dismount the lock washer. Straighten the tab or replace the washer.	
45	The shoulder on the shaft or in the body, or the terminal nut face does not form a right angle with the journal axis.	Re-turn the parts to ensure perpendicularity.	
47	The journal diameter is too large which causes excessive expansion of the inner ring. That reduces the bearing clearance.	By regrinding the journal, achieve the correct fit of the bearing inner ring on the shaft. If it is not possible to regrind the shat, use a bearing with a larger bearing clearance.	

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