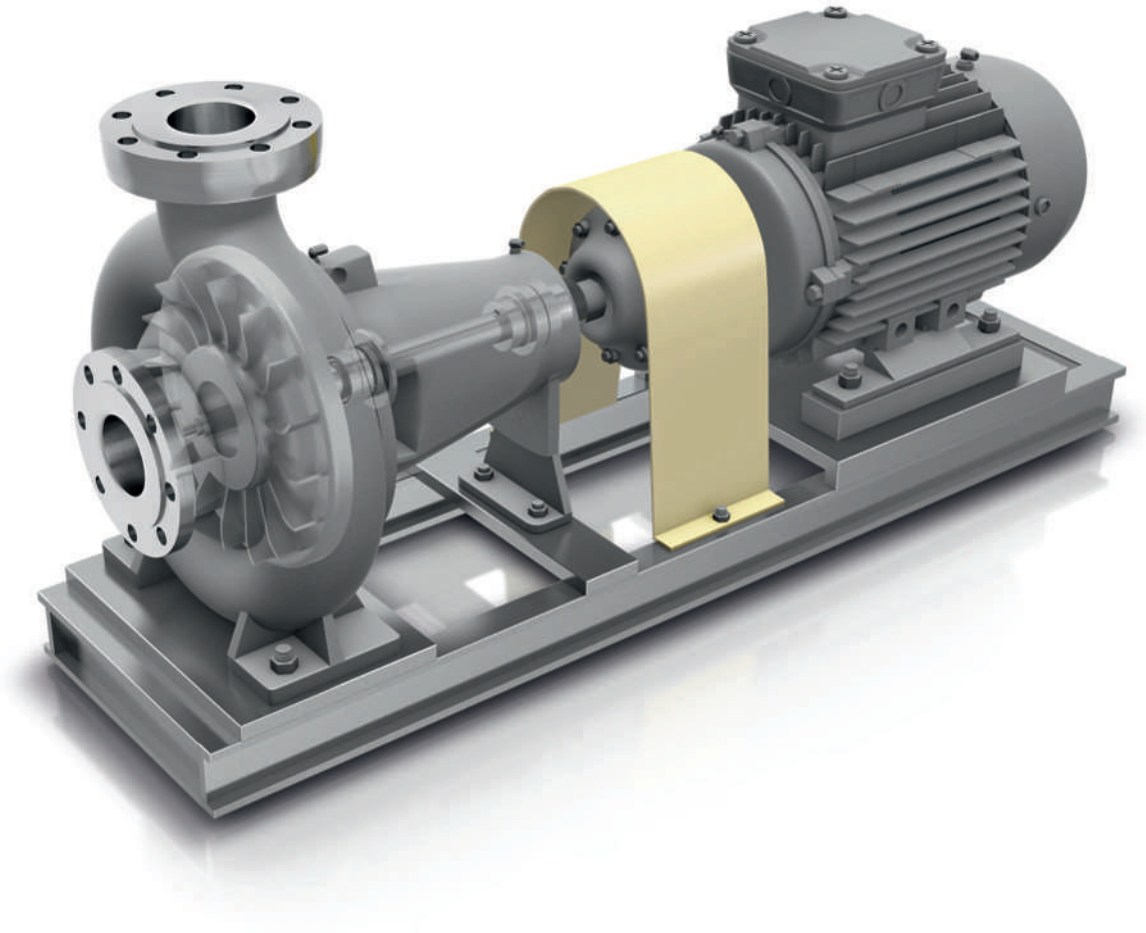
SCHAEFFLER



Schaeffler Solutions for Fluid Pumps

Design, maintenance and servicing

Technical Product Information

Foreword

Schaeffler is a leading worldwide supplier of rolling bearings, plain bearings, accessories specific to bearings and comprehensive maintenance products and services. Schaeffler offers solutions based on approximately 225000 products for more than 40000 customers and has an extremely wide portfolio that gives secure coverage of applications from more than 60 industrial market sectors.

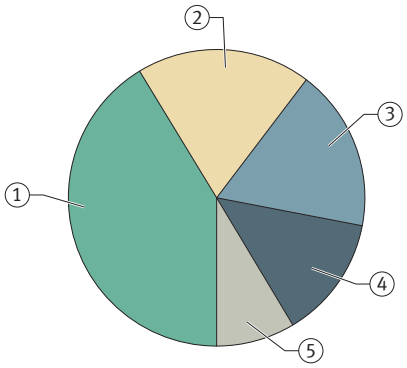
Economical solutions

Schaeffler products stand for cost effectiveness, energy efficiency and a long service life. Schaeffler offers both manufacturers and operators of fluid pumps an extensive range with high availability. In design, the focus is on product costs and unit costs. The topic of total cost of ownership (TCO) is of considerable interest to plant operators. As a result, precisely matched system solutions based on high-quality standard bearings are essential. Schaeffler's continuous further development of its product portfolio is also an advantage during operation.

Industry sectors

Pumps must work reliably and efficiently at all times – irrespective of their application. In this context, appropriate bearing support plays a key role. The rolling bearings are subject to special requirements arising from applicable standards according to their area of use, application and design. As a result, their selection and arrangement play a decisive role in supporting the forces acting in the pump in a reliable and continuous manner and with low friction.

1 Industry sectors (source: Oxford Economics, Global Pump Market Forecast 2019)



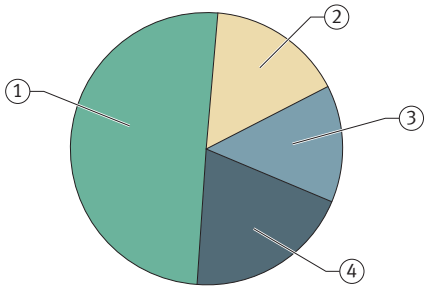
1	Water and waste water	2	General industry
3	Oil and gas	4	Chemical industry
5	Power plants		

Pump designs

Pumps essentially differ in terms of their functional principle. The energy generated by the electric motor is transferred to the fluids in the form of pressure and volume flow.

The corresponding pump designs are derived from the application-specific requirements. **Centrifugal pumps** account for the largest share.

2 Pump designs (source: Oxford Economics, Global Pump Market Forecast 2019)



1	Centrifugal pumps	2	Reciprocating piston pumps
3	Circulating displacement pumps	4	Others

Bearing selection and design

The basis for designing the bearing arrangement is the operating data, primarily the effective bearing forces, speeds and lubrication conditions, from which the required bearing design, bearing arrangement and basic load rating are then derived. Using the free online calculation programs, you can perform rating life calculations for individual bearings or shaft models to select the optimal design. This publication focuses on the rolling bearings in **centrifugal pumps** and on the electric motors that are partly integrated into the pump. Detailed information on rolling bearings in electric motors can be found in our separate publication TPI 274, Rolling Bearings in Electric Motors.

Development partners

The application engineering and field service engineers at Schaeffler are available worldwide as development partners to help electric motors operate more effectively, reliably and economically.

This publication gives an overview of various rolling bearings that can be fitted in centrifugal pumps in an application-oriented manner. Fluid pumps themselves are subjected to widely varying operating conditions in their different areas of application. In addition to the pump design and operating conditions, many other factors are of particular importance for the optimal selection of bearings.

Maintenance and service

The services and maintenance products provided by Schaeffler ensure all-round support during operation:

- premium lubricants that are optimally matched to the machine
- intelligent lubricators that supply all rolling bearings installed in the machines with lubricant as required
- condition monitoring devices that identify faults long before they can be detected through changes in sound or through an increase in temperature

Product information

In medias and in Catalogue HR 1, Rolling Bearings, all rolling bearings according to DIN ISO, the specific bearing accessories, as well as further rolling bearing types and design variants are described.

They show which products can be considered for a bearing arrangement, the factors that must be taken into consideration in the design, the tolerances required for the adjacent construction and how the bearing arrangement is sealed.

They also provide detailed information on the calculation of bearing rating life, on temperatures and loads, on suitable lubricants and, last but not least, on how the products are correctly fitted and maintained.

Further information

HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

medias | Product catalogue |
medias.schaeffler.com

medias | Stromisolierende Wälzlager
https://www.schaeffler.de/std/2024

medias | Flüssigkeitspumpen
https://www.schaeffler.de/std/2025

Contents

1 Bearing selection and bearing design

1.1 Principles and requirements

1.1.1 Basic principles

A distinction is made between radial centrifugal pumps, axial centrifugal pumps and mixed-flow centrifugal pumps based on the design of the impeller. The design has a significant influence on the direction and magnitude of the acting forces. The operating data, such as the effective bearing forces, speeds and lubrication conditions, form the basis for the mathematical design of the bearing. In order to determine the bearing forces, the forces acting on the pump impeller from axial thrust and radial thrust of the pump must be determined as part of the pump design process. Axial thrust and radial thrust consist of hydraulic forces, drive forces, and gravitational and inertial forces.

Axial force

The hydraulic forces, particularly in axial centrifugal pumps and mixed-flow centrifugal pumps, predominantly act as axial forces on the impeller, whereby the influence of various components must be taken into account.

The difference in pressure between the suction side and pressure side induces an axial force on the rotor, which is composed of the following:

- The pressure on the suction side of the impeller, relative to the area of the impeller plate on the suction side, results in an axial force in the direction of the pressure side.
- The pressure on the pressure side of the pump, relative to the area of the cover plate on the pressure side, results in an opposing axial force.

Similarly, the pressure difference at the shaft seal is related to the area of the shaft cross section. The overall result is the axially acting hydrostatic force. The design of the impeller as an open, semi-open or closed impeller therefore has a major influence on the magnitude and direction of the acting axial force. The hydrostatic pressure force can be reduced by means of compensating holes in the impeller and a throttle gap at the cover plates. The load on the bearing arrangement can be relieved but with detrimental effects on pump efficiency and manufacturing costs.

In radial centrifugal pumps, the pumped medium enters the volute housing through the axially arranged suction nozzle, but exits in a tangential direction through the discharge nozzle. An impulse acts on the rotor in an axial direction. The impulse force is determined from the differences in the axial components of the flow velocity between the inlet and outlet and taking into account the flow and density of the pumped medium. The impulse force can be reduced by means of diffusers provided in the design.

During start-up, turbulence can occur in the impeller side chamber. The resulting axial forces can lead to axial load changes during start-up.

Radial force

The radial hydraulic force is created from an interaction between the impeller and the volute housing. Due to the tangential arrangement of the discharge nozzle, the centrifugal flow does not develop uniformly. Differences in flow velocities occur over the circumference of the housing, which fluctuate according

to the operating point of the pump. As a result, radial hydraulic forces act on the impeller. By providing a double volute housing with 2 spiral ducts offset by 180°, which merge into a single discharge nozzle, more uniform flows with lower hydraulic radial thrust can thus be achieved.

Imbalance forces generated by the rotor act in a radial direction at the centre of mass. Depending on the pump arrangement, the weight forces generated by the rotor act axially in the case of a vertical axis and radially in the case of a horizontal axis.

Other driving forces

Depending on the design of the drive train, various driving forces such as coupling forces, belt tension or magnetic pull must be taken into account. Based on the corresponding bearing arrangement, the effective bearing forces required for dimensioning the bearings can be calculated from the axial and radial thrust. There are also various other requirements that must be taken into account when selecting bearing arrangements.

1.1.2 Shaft seals

In addition to rolling bearings and their arrangement, shaft seals also have a major influence on the design of the pump and bearing arrangement as a result of being a central component. Shaft seals ensure that the pump housing is sealed against the egress of pumped medium and the ingress of air and contaminants. The bearing seal is often realised using separate seals in the bearing housing. The stuffing boxes, radial seals or mechanical seals used to seal against pressure can be technically complex and are a significant cost factor in the design. As wear parts, seals are often critical components and have a major impact on the maintenance strategy and dimensioning of bearings.

For low-wear operation of the seal, the bearing arrangement must ensure good shaft guidance with limited shaft deflection. With the Easy Pump module from Bearinx-online, shaft guidance can be verified as early as the design phase.

More complex mechanical seals require additional installation space and involve increased bearing distances from the impeller as well as additional moment loading of the bearings.

1.1.3 Requirements

Electric motors are used in preference as drive units in fluid pumps, and their bearing arrangements must take account of certain influencing factors.

Requirements for electric motor bearing arrangements:

- operating conditions such as load, speed, temperature
- rating life requirements
- shaft arrangement and design envelope
- vibration and noise behaviour
- friction-optimised design with optimum sealing
- lubrication (temperature, noise, grease operating life)
- current insulation, particularly in frequency converter-controlled electric motors

Requirements for pump bearing arrangements:

- support of radial and axial loads and of vibrations and shocks
- long operating life with low maintenance outlay
- use of cost-effective standard rolling bearings, also with regard to sealing and greasing
- type reduction and standardisation
- conformity with norms and standards
- low total cost of ownership (TCO)

Further application-specific requirements for rolling bearings:

- longer relubrication intervals, moving towards lifetime lubrication
- corrosion resistance
- energy-efficient rolling bearings and complete solutions
- suitability for higher temperature range
- media lubrication
- products and services for maintenance and mounting
- automatic relubrication systems, e.g. with Schaeffler CONCEPT
- cost-effective condition monitoring, e.g. with OPTIME or OPTIME Ecosystem

1 Requirements for rolling bearings in fluid pumps

Requirements for rolling bearings in fluid pumps	Deep groove ball bearings	Cylindrical roller bearings	Angular contact ball bearings	Double row angular contact ball bearings
	Generation C	X-life	X-life	X-life
Low noise	++	+	++	++
Low friction	++	+	++	++
High speed [1]	++	+	++	++
Current insulation by means of ceramic rolling elements HC	++ [2]	◊	◊	◊
Current insulation by means of coating, e.g. J20GA	++	++	+	+
Radial load	+	++	+	+
Unilateral axial load	+	+ [3]	++	+
Support of axial load in both directions	+	+ [4]	–	++
High temperatures T [5]	◊	◊	◊	◊
High sealing action	++	◊	++	++
For-life lubrication	++	◊	++	++
Long relubrication intervals, grease operating life	++	+	++	++

++ highly suitable
+ suitable
– not suitable

◊ not relevant

1) Speed parameter $n \cdot d_M > 500000$
2) especially for smaller diameter ranges D < 110 mm
3) NJ or NUP design only
4) NUP design only
5) T > +80 °C

2 Requirements for rolling bearings in fluid pumps

Requirements for rolling bearings in fluid pumps	Spherical roller bearings	Tapered roller bearings	Four point contact bearings	Needle roller bearings	Ceramic rolling elements
	X-life	X-life	X-life	X-life	X-life
Low noise	–	–	++	+	++
Low friction	–	–	++	+	++
High speed 6)	–	+	+	+	++
Current insulation by means of ceramic rolling elements HC	◊	◊	◊	◊	++
Current insulation by means of coating, e.g. J20GA	+	+	+	+	◊
Radial load	++	++	–	++	◊
Unilateral axial load	+	++	++	–	◊
Support of axial load in both directions	+	–	++	–	◊
High temperatures T 7)	◊	◊	◊	◊	++
High sealing action	◊	◊	◊	◊	◊
For-life lubrication	◊	◊	◊	◊	++
Long relubrication intervals, grease operating life	–	+	+	+	++

++ highly suitable
+ suitable
– not suitable
◊ not relevant

6) Speed parameter $n \cdot d_M > 500000$
7) T > +80 °C

3 Requirements for rolling bearings in fluid pumps

Requirements for rolling bearings in fluid pumps	Seal		Cage	
	Non-contact, e.g. 2Z	Contact, e.g. 2HRS	Metal	Plastic
Low noise	+	◊	+	++
Low friction	+	◊	+	++
High speed 8)	+	–	++	++
Current insulation by means of ceramic rolling elements HC	◊	◊	◊	◊
Current insulation by means of coating, e.g. J20GA	◊	◊	◊	◊
Radial load	◊	◊	◊	◊
Unilateral axial load	◊	◊	◊	◊
Support of axial load in both directions	◊	◊	◊	◊
High temperatures T 9)	+ 10)	+ 10)	◊	◊
High sealing action	+	++	◊	◊
For-life lubrication	++	++	+	++
Long relubrication intervals, grease operating life	–	–	+	++

++ highly suitable
+ suitable

– not suitable
◊ not relevant

8) Speed parameter $n \cdot d_M > 500000$
9) T > +80 °C
10) observe material-specific temperature limits

4 Requirements for rolling bearings in fluid pumps

Requirements for rolling bearings in fluid pumps	Grease lubrication			Internal clearance
	Standard grease	Special grease	Relubrication with Arcanol	C3
Low noise	+	++	+	◊
Low friction	+	++	+	◊
High speed 11)	+	++	+	++
Current insulation by means of ceramic rolling elements HC	◊	◊	◊	◊
Current insulation by means of coating, e.g. J20GA	◊	◊	◊	◊
Radial load	+	+	+	◊
Unilateral axial load	+	+	+	◊
Support of axial load in both directions	+	+	+	◊
High temperatures T 12)	–	++	+	++
High sealing action	◊	◊	◊	◊
For-life lubrication	+	++	◊	◊
Long relubrication intervals, grease operating life	+	++	++	◊

++ highly suitable
+ suitable
– not suitable
◊ not relevant

11) Speed parameter $n \cdot d_M > 500000$
12) T > +80 °C

1.1.4 Further information

OPTIME | Ecosystem |
https://www.schaeffler.de/std/1FFF

MH 1 | Mounting Handbook |
https://www.schaeffler.de/std/1D53

TPI 165 | Deep groove ball bearings Generation C |
https://www.schaeffler.de/std/200C

TPI 176 | Lubrication of Rolling Bearings |
https://www.schaeffler.de/std/1F83

TPI 206 | Current-Insulated Bearings |
https://www.schaeffler.de/std/1FE8

medias | Engineering Apps
https://www.schaeffler.de/std/2032

Bearinx | Calculation modules |
https://www.schaeffler.de/std/1FEB

medias | Schaeffler Trainings
https://www.schaeffler.de/std/2033

1.2 conformity with norms and standards

Pump standards have been established for various bearing designs and applications, such as DIN 24255 for water standard pumps or ISO 2858 for chemical standard pumps. The primary aim of standardisation is to standardise mounting dimensions, components and performance data in order to simplify the planning, operation and maintenance of systems. This results in specific requirements for the design of pump bearing arrangements, as the standardised shaft diameters determine, for example, the bore number of the rolling bearings used.

Other standards, such as ISO 9905, ANSI B73.1 or API 610, also seek to establish a uniformly reliable quality standard and good operational reliability. The design and construction of pumps is also regulated by the design of the pump bearing arrangement. Detailed specifications are defined which relate to the requisite minimum life, design of the bearing seats, bearing support and seal, but also in part to the bearing arrangements, bearing designs, cage designs and relubrication intervals.

In addition, there are specifications that can be influenced by the appropriate design of the bearings, including permissible shaft deflection, radial run-out accuracies, vibrations and temperature ranges.

1.3 Selection of bearing arrangement

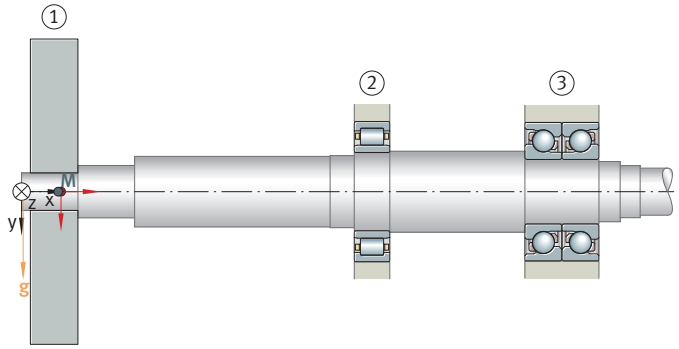
1.3.1 Common bearing arrangements for centrifugal pumps

In principle, the pump design of a centrifugal pump differs in terms of how the bearings are arranged relative to the impeller. In an overhung arrangement with an overhanging bearing pump, the impeller sits on the side of the locating bearing arrangement and non-locating bearing arrangement. In an “in-between bearing pump”, the impeller is arranged between the locating bearing and non-locating bearing.

Overhung impeller arrangement (“overhanging bearing pump”)

With only a few exceptions, centrifugal pumps are designed with an overhung impeller arrangement. In this arrangement, the impeller sits on the side of the locating bearing arrangement and the non-locating bearing arrangement. This design requires only one of the complex shaft seals for the pump housing, saving space and reducing the number of components. The radial forces acting on the impeller subject the overhung bearing arrangement to considerable tilting moments, while the axial forces present must be supported by the locating bearing. The resulting load distribution at the two bearing positions is uneven. The inner bearing on the output side supports most of the radial force, affecting the dimensioning of the bearing and the calculated rating life.

3 Overhung bearing arrangement



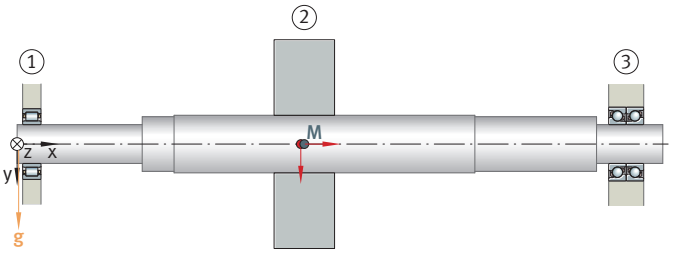
00193D05

1	Impeller	2	Non-locating bearing
3	Locating bearing		

The example shows a cylindrical roller bearing (non-locating bearing) for the exclusive support of radial loads acting on the pump side. The axial loads are supported by a matched pair of angular contact ball bearings of UB design in an O arrangement.

Impeller between the bearings (“in-between bearing pump”)

4 Bearing arrangement



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1	Non-locating bearing	2	Impeller
3	Locating bearing		

In contrast to the overhung bearing arrangement, the impeller in an “in-between bearing pump” arrangement is positioned between the locating bearing and the non-locating bearing.

1.3.2 Types of bearing arrangements

The guidance and support of a rotating shaft requires at least two bearings arranged at a certain distance from each other. Depending on the application, an adjusted bearing arrangement or a floating bearing arrangement is chosen, whereby a suitable locating/non-locating bearing arrangement must be ensured.

- adjusted bearing arrangement
- X arrangement and O arrangement
- elastic adjustment
- floating bearing arrangement
- locating/non-locating bearing arrangement

1.3.3 Adjusted bearing arrangement

The simplest bearing arrangement is an adjusted bearing arrangement. The bearing distance significantly determines the support width, rigidity and deflection of the pump shaft. An O arrangement of angular contact ball bearings or tapered roller bearings is preferred in order to achieve greater rigidity and thus reduced shaft deflection through an increased support distance of the bearing arrangement.

An adjusted bearing arrangement with deep groove ball bearings is axially spring-adjusted in order to reduce the shaft clearance. A larger operating contact angle for better support of axial loads can be set with internal clearance C3. For higher load carrying capacity requirements, the adjusted bearing arrangement can be designed with single row angular contact ball bearings. Angular contact ball bearings have a ball set with more rolling elements than comparable deep groove ball bearings and are characterised by a contact angle of 40°, offering a high axial load carrying capacity.

These bearing arrangements normally consist of two symmetrically arranged angular contact ball bearings or tapered roller bearings. During mounting, one bearing ring is displaced on its seat until the bearing arrangement achieves the required clearance or the necessary preload.

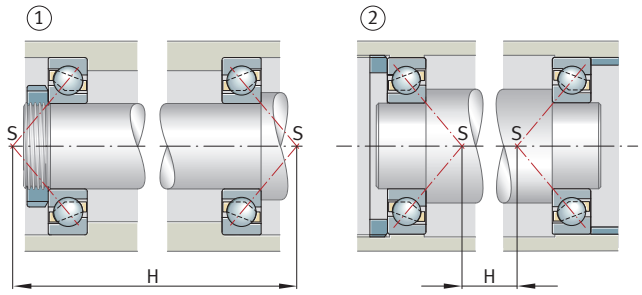
Due to this adjustment facility, the adjusted bearing arrangement is particularly suitable where close axial guidance is required.

1.3.4 X arrangement and O arrangement

A fundamental distinction is drawn between the O arrangement and the X arrangement of bearings. In the O arrangement, the apexes S of the cones formed by the contact lines point outwards; in the X arrangement, the apexes of the contact cones point inwards. The support distance H, in other words the distance between the apexes of the contact cones, is larger in the O arrangement than in the X arrangement. The O arrangement therefore gives the lower tilting clearance.

When setting the axial internal clearance, thermal expansion must be taken into consideration.

5 Adjusted angular contact ball bearing arrangement



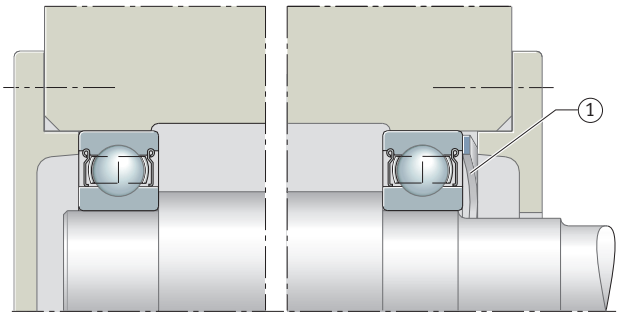
1	O arrangement	2	X arrangement
S	Apexes of the contact cones	H	Support distance

1.3.5 Elastic adjustment

Adjusted bearing arrangements can also be achieved by preloading using springs. This elastic adjustment method compensates for thermal expansion, for which a loose bearing fit on the outer ring is necessary. It can also be used where bearing arrangements are at risk of vibration while stationary or during operation.

This bearing arrangement is customary, for example, in electric motors. The spring preload not only permits the implementation of a minimum load to avoid slippage in the bearing, particularly in the case of deep groove ball bearings that are subjected to very low loads, but also has a noise-reducing effect.

6 Adjusted bearing arrangement (deep groove ball bearing, preloaded by spring washer)



1	Spring washer		

1.3.6 Floating bearing arrangement

The floating bearing arrangement is an economical solution where close axial guidance of the shaft is not required. Apart from the spring preload, its construction is similar to that of the adjusted bearing arrangement.

In the floating bearing arrangement, the shaft can be displaced in relation to the housing to the extent of the axial clearance s. The value s is defined as a function of the required guidance accuracy such that the bearings are not axially stressed even under unfavourable thermal conditions.

Suitable bearings

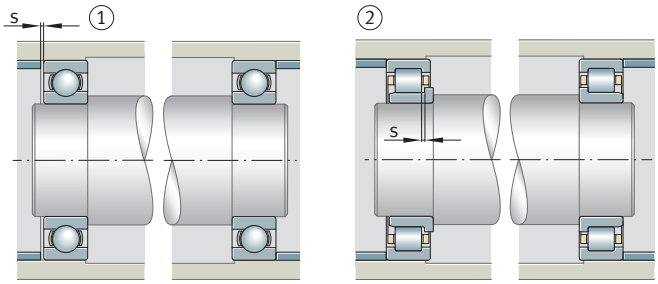
Suitable bearing types for the floating bearing arrangement include deep groove ball bearings or even spherical roller bearings.

In order to ensure length compensation which is free from axial forces, one ring each, usually an outer ring, has a fit that allows displacement.

In floating bearings arrangements with cylindrical roller bearings, such as in the NJ type shown, length compensation takes place within the bearings. The inner ring and outer ring can have tight fits.

Tapered roller bearings and angular contact ball bearings are not suitable for a floating bearing arrangement, since they must be adjusted in order to run correctly.

7 Floating bearing arrangements



0001AB9E

1	2 deep groove ball bearings	2	2 cylindrical roller bearings NJ
s	Axial clearance		

1.3.7 Locating/non-locating bearing arrangement

On a shaft supported by two radial bearings, the distances between the bearing seats on the shaft and in the housing frequently do not coincide as a result of manufacturing tolerances. The distances may also change as a result of temperature increases during operation. These differences in distance are compensated in the non-locating bearing.

Non-locating bearings

The non-locating bearing supports radial load only and enables axial displacement of the shaft to compensate for expansion. In an overhung arrangement, the bearing position on the impeller side is preferably designed as a non-locating bearing. As a result, the axial load support is shifted to the bearing position on the drive side, which is subjected to less radial load. The optimum non-locating bearing function can be achieved with cylindrical roller bearings, such as designs N or NU with cage. In these bearings, the roller and cage assembly is displaced with low friction on the raceway of the bearing ring without ribs. Cylindrical roller bearings have higher basic load ratings than ball bearings and are therefore suitable for high radial loads.

However, it should be noted that this bearing type is prone to slippage if the specified minimum load is not reached. After just a short period of load-free operation, slippage damage to the raceways can occur in the form of wear, which, when combined with suboptimal lubrication, can lead to an extreme reduction in operating life. The minimum load (C_0/P) > 60 must be ensured in all load cases.

All other bearing types, for example deep groove ball bearings or spherical roller bearings, can only act as non-locating bearings if one bearing ring has a fit that allows displacement. The bearing ring subjected to point load therefore has a loose fit; this is normally the outer ring.

Locating bearing

The locating bearing guides the shaft in an axial direction and is thus mainly subjected to axial load. The type of bearing selected as a locating bearing depends on the magnitude of the axial forces and the accuracy with which the shafts must be axially and radially guided. For higher demands on basic load rating and rigidity, double row angular contact ball bearings or a pair of single row angular contact ball bearings in universal design are commonly used.

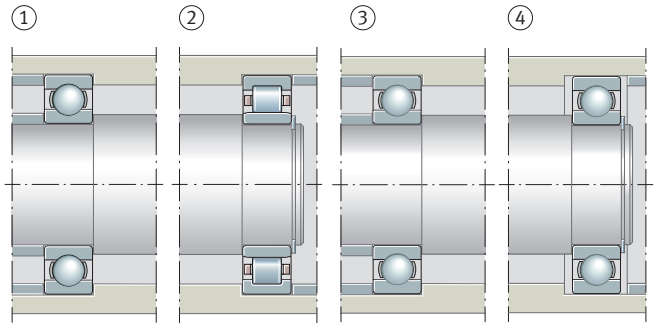
Single row angular contact ball bearings in an O arrangement with an optimised support width are particularly suitable for higher requirements. Compared with double row angular contact ball bearings, a pair of bearings offers advantages in terms of basic load ratings due to the ball set with a higher number of rolling elements and is also better suited to supporting axial loads due to the larger contact angle of 40°.

The bearings can be mounted in pairs in any O or X arrangement without shims. Angular contact ball bearings of the universal design are matched so that, in an X or O arrangement, they have a defined axial internal clearance. Common designs include UO (without clearance), UB (low axial internal clearance) or UA (slightly higher axial internal clearance).

An alternative for lower requirements is available in the form of four point contact bearings. Four point contact bearings QJ must not be subjected to radial or combined radial/axial loads. For this reason, they are generally used as locating bearings where separate radial bearings are already required in the design, such as in vertical immersion pumps with radial plain bushes.

Examples of locating/non-locating bearing arrangements

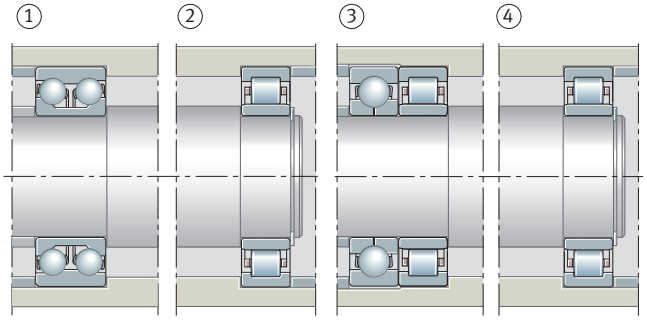
8 Locating/non-locating bearing arrangements



0001AB9A

1	Deep groove ball bearing, locating bearing	2	Cylindrical roller bearing NU, non-locating bearing
3	Deep groove ball bearing, locating bearing	4	Deep groove ball bearing, non-locating bearing

9 Locating/non-locating bearing arrangements



0000C142

1	Double row angular contact ball bearing, locating bearing	2	Cylindrical roller bearing NU, non-locating bearing
3	Four point contact bearing and cylindrical roller bearing, locating bearing	4	Cylindrical roller bearing NU, non-locating bearing

1.3.8 Axial location of bearings

Axial location of the bearing rings is matched to the specific bearing arrangement (locating bearings, non-locating bearings, bearings in adjusted and floating arrangements).

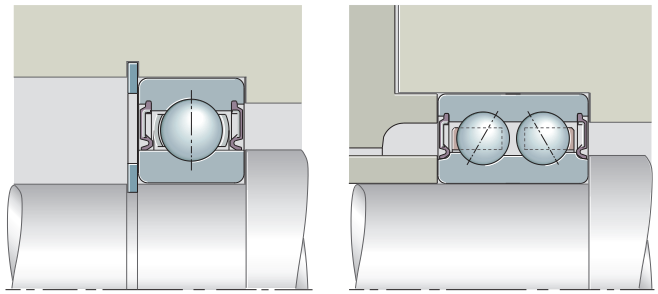
Design guidelines

The following aspects must be considered when designing the bearing arrangement:

- The shoulders on the mating parts must be large enough to provide a sufficiently wide contact surface even with the largest chamfer dimension of the bearing (DIN 5418).
- The bearing rings must be located by force contact or form contact in order to prevent lateral creep. The bearing rings must only be in contact with the shaft shoulder or housing shoulder, but not with the fillet.
- Locating bearings support axial forces. The retaining element must be matched to these axial forces. Shoulders on the shaft and housing, snap rings, housing covers, shaft covers, nuts and spacer rings are suitable.
- In non-separable bearings, one bearing ring must have a tight fit, while the other ring is retained by the rolling elements.
- Since bearings in adjusted and floating arrangements support axial forces in one direction only, the bearing rings only need to be supported on one side. Counter-guidance is performed by a second, symmetrically arranged bearing. Shaft nuts, ring nuts, covers or spacer washers are suitable as adjustment elements.
- In floating bearing arrangements, lateral movement of the rings is prevented by shaft or housing shoulders, covers and snap rings.

Examples of retaining elements

10 Locating bearings (axial location by form fit on the inner ring and outer ring)



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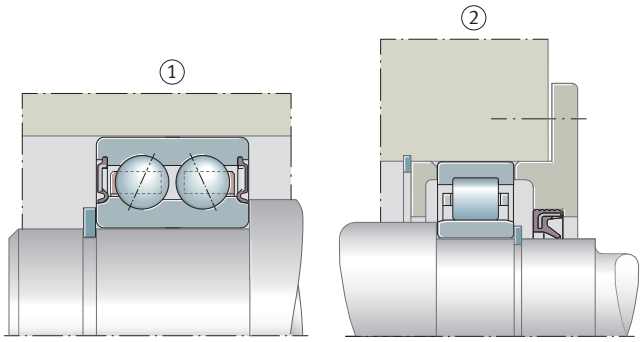
11 Non-locating bearings



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1	Axial location by form fit on the inner ring	2	Axial location by form fit on the inner and outer ring

1.3.9 Shaft tolerances

The following recommendations can be given for shaft tolerancing under normal mounting and operating conditions based on the conditions of rotation.

The ring subjected to circumferential load – usually the rotating inner ring in pumps – must be mounted with a tight fit. A transition fit in the housing allows for easy mounting of the bearing plate without damaging the bearing outer ring.

Deviations are possible if particular requirements apply, for example in relation to running accuracy, smooth running or operating temperature. Increased running accuracies thus require closer tolerances such as tolerance grade 5 instead of 6. If the inner ring is warmer than the shaft during operation, the seating may loosen to an impermissible extent. A tighter fit must then be selected, e.g. m6 instead of k6.

In some installation cases, the question of fits can only be resolved through a compromise. The individual requirements must be weighed against each other and those selected that give the best overall solution.

5 Shaft tolerances for ball bearings

Ball bearing		
Shaft diameter	**Tolerance**	
mm	**Shaft**	**Steel housing**
≤ 17	j5	H6
18 ... 100	k5	H6
101 ... 140	m5	H6
141 ... 200	m6	H6

6 Shaft tolerances for cylindrical roller bearings

Cylindrical roller bearing		
Shaft diameter	**Tolerance**	
mm	**Shaft**	**Steel housing**
≤ 30	k6	H6
31 ... 50	m5	H6
51 ... 65	n5	H6
66 ... 100	n6	H6
101 ... 200	p6	H6

7 Shaft tolerances for tapered roller bearings

Tapered roller bearing		
Shaft diameter	**Tolerance**	
mm	**Shaft**	**Steel housing**
≤ 40	k6	H6
41 ... 65	m6	H6
66 ... 200	n6	H6

8 Shaft tolerances for spherical roller bearings

Spherical roller bearing		
Shaft diameter	**Tolerance**	
mm	**Shaft**	**Steel housing**
≤ 40	m5	H6
41 ... 60	n5	H6
61 ... 100	n6	H6
101 ... 200	p6	H6

1.3.10 Radial and axial internal clearance

The radial internal clearance is determined on the dismounted bearing. It refers to the amount by which the inner ring can be moved in a radial direction relative to the outer ring from one extreme position to the other. The axial internal clearance s_a is defined as the amount by which one bearing ring can be moved relative to the other, without load, along the bearing axis.

1.3.11 Operating clearance

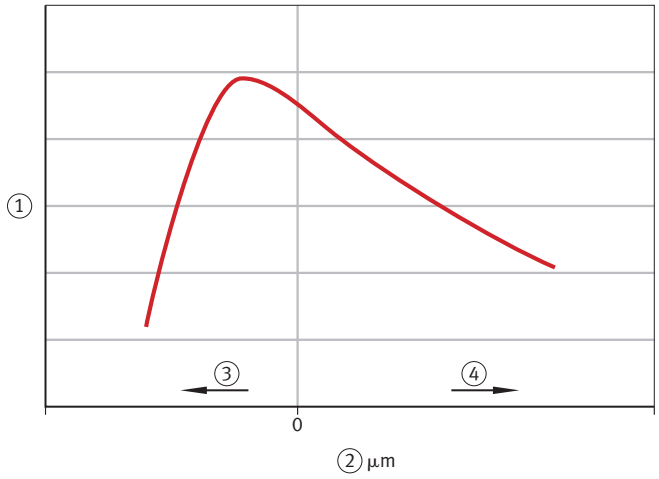
In contrast to a slight preload, an excessively large operating clearance can lead to sliding effects, unfavourable load distribution and unsatisfactory running behaviour.

The operating clearance is determined on a mounted bearing still warm from operation. It refers to the amount by which the shaft can be moved in a radial direction from one extreme position to the other. It is derived from the radial internal clearance and the change in the radial internal clearance as a result of interference fit and thermal influences in the fitted condition. This is therefore

largely defined by the operating and installation conditions of the bearing, which must be taken into account when selecting the bearing: for radial bearings, for example, with radial internal clearance values C3 or for axial bearings by spring preload.

A lower preload has proven advantageous in relation to the rating life of ball bearings, particularly angular contact ball bearings, since the load is then distributed over several rolling elements and the rigidity of the bearing arrangement can be increased. However, this preload must not be increased above an optimum value, since a significant reduction in the rating life must be anticipated due to the higher contact stresses.

12 Operating clearance



1	Rating life	2	Operating clearance
3	Preload	4	Clearance

Preload during operation must be avoided with roller bearings.

1.4 Dynamic load carrying capacity and life

1.4.1 Dimensioning of rolling bearings

The required design and size of a rolling bearing is largely dependent on the following requirements:

- application
- adjacent construction and requirements from applicable standards
- required rating life of the rolling bearings and the system
- load carrying capacity
- operational reliability

1.4.2 Calculation of rating life

The dynamic load carrying capacity of the rolling bearing is determined by the fatigue behaviour of the material. The dynamic load carrying capacity is described in terms of the basic dynamic load rating, which is based on DIN ISO 281. This, in turn, has been broken down further and specified in ISO/TS 16281 and DIN 26281 (formerly DIN ISO 281, Beiblatt 4), in order to take account of the corresponding influences from operation and thus further improve the calculation results.

Basic rating life L_{10} and L_{10h}

Methods and variations in fatigue life calculation, particularly in relation to the relevant influences from operation, include:

- the basic rating life L_{10} and L_{10h} according to ISO 281
- the expanded rating life L_{nm} and L_{nmh} according to ISO 281

The basic rating life L_{10} and L_{10h} according to DIN ISO 281 takes into account:

- bearing type
- load
- speed

The rating life is determined by means of comparison with reference conditions, essentially based on the basic load rating and bearing design (ball or roller bearings).

The basic reference rating life L_{hr} according to ISO/TS 16281 or DIN 26281 (formerly DIN ISO 281 Supplement 4) also takes account of the following influences:

- exact internal load distribution
- the fatigue limit of the material
- spatial load and tilting of the bearing
- operating clearance

A number of influencing factors must be taken into account in the design and dimensioning of the bearing concept. Bearinx-online Easy Pump, a free calculation program from Schaeffler, is the ideal tool for carrying out an uncomplicated, yet detailed expanded rating life calculation.

The adjusted reference rating life L_{hmr} according to ISO/TS 16281 or DIN 26281 (formerly DIN ISO 281 Supplement 4) additionally takes account of the following influences:

- the extent to which the surfaces are separated by the lubricant
- the cleanliness in the lubrication gap
- the additive package in the lubricant

1.4.3 Operating life

The operating life is defined as the life actually achieved by the bearing. It may differ significantly from the calculated rating life. In practice, the operating life is often significantly longer than the calculated rating life, however, it may also be shorter.

This may be due to wear or fatigue caused by the following influences:

- deviating operating data
- misalignment between the shaft and housing
- insufficient or excessive operating clearance

- contamination
- corrosion
- lubricant supply
- grease operating life, particularly in the case of sealed bearings lubricated for life
- insufficient lubrication
- excessive operating temperature
- oscillating bearing movement with very small swivel angles (false brinelling)
- heavy vibration and false brinelling
- very high shock loads (static overloading)
- prior damage during mounting
- current passage

Due to the wide variety of possible installation and operating conditions, it is not possible to precisely predetermine the operating life. The most reliable way of arriving at a close estimate is by comparison with similar applications.

1.5 medias – making product information easy to find

1.5.1 What is medias?

medias combines Schaeffler's product catalogue, consultation tools and an implemented eCommerce in a single platform. medias provides essential information about industrial products, offers technical advice and allows users to check product availability and pricing.

medias is accessed as follows:

- https://medias.schaeffler.com
- enter the search query "Schaeffler medias" using any Internet search engine

	Technical advice and support, engineering tools and extensive product information including CAD models and calculation tools.
	Check current product price and availability. View an overview of current or past orders and quantities.
	Find a sales partner in your area and request a quotation.

1.5.2 medias Business

In medias Business, registered business customers gain access to an expanded product catalogue and new features designed to make their ordering process more efficient and optimise interaction with Schaeffler.

Navigation

The options for signing in, registering and selecting languages can be found in the header on the medias homepage, together with the search function. The search function can be used to navigate directly to a known product. Here, you will find the wish list function and basket in the top right-hand corner. Below, there are three navigation tabs – "Products", "Engineering Tools" and "Knowledge & Support" – where the relevant information can be accessed in just a few clicks.

Products

Product searches can either be performed using the “Products” navigation tab or directly via the search function. The main dimensions and performance data are stored under the respective product and a data sheet is available for downloading. This data sheet contains the main dimensions and performance data, the mounting dimensions, calculation factor, temperature range and material number. Additionally, this page contains further technical information on the corresponding bearing design, as well as the facility to start an individual bearing calculation and download the CAD model of the bearing or instructions on mounting and dismounting.

Knowledge and Support

The “Knowledge & Support” navigation tab opens a field with various functions, such as a knowledge database and a lexicon, which contain fundamental technical knowledge about rolling bearings.

1.5.3 Engineering Tools

In addition to product information, medias also offers a variety of engineering tools that support a wide range of tasks, from selecting the right bearing to calculating rolling bearing life at system level. These tools can be easily accessed via the “Engineering Tools” navigation tab on the medias home page.

Bearing selection assistant

The bearing selection assistant helps users select the optimal bearing. Known information or requirements, such as which loads occur, the required bearing dimensions, or the requisite basic load ratings, can be entered here. The bearing selection assistant will then display the suitable rolling bearings.

Bearing frequency calculator

Conspicuous frequency patterns can be allocated to a single bearing component (e.g. inner ring, outer ring, rolling element or cage) based on the kinematic frequencies. These frequencies can be determined with the aid of the bearing frequency calculator by inputting the corresponding geometry data.

Heating Manager

The Heating Manager enables you to select the optimal heating device for your products from the HEATER series.

Grease selection guide

The grease selection guide displays the properties and recommendations for Arcanol rolling bearing greases.

medias interchange

medias interchange assists with matching competitor rolling bearing designations to INA or FAG designations.

Single bearing calculation

If you have a potential bearing that meets the requirements, you can use the calculator symbol to run an immediate online single bearing calculation in order to verify the life requirements.

Shaft calculation Bearinx-online Easy Pump

The Bearinx-online Easy Pump module enables the calculation of bearing arrangements for fluid pumps at system level. The use of Bearinx-online Easy Pump is subject to registration only, after which the program can be used free of charge for calculations.

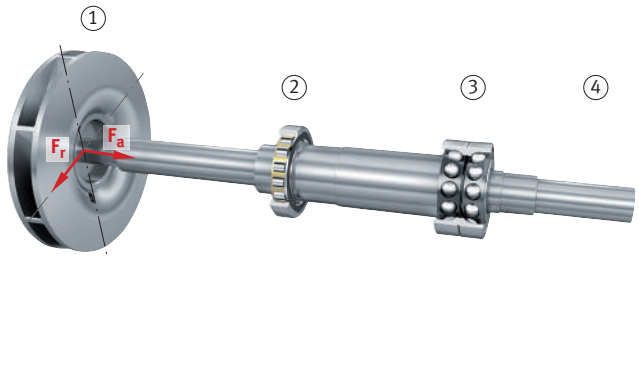
1.6 Bearinx-online Easy Pump

1.6.1 Bearinx-online Easy Pump

During the calculation process, self-explanatory dialogue pages guide users step by step through the program. This allows the rapid and easy input of data for the model structure of the pump shaft, impeller and bearing arrangement ➤27 | 13.

Alternatively, the examples can be used as templates for your design and adapted accordingly. For this purpose, a data set each is available to download for a centrifugal pump, a double flow pump and a submersible pump. This is followed by bearing selection and entry of the operating data and load case data.

13 Shaft calculation



1	Impeller	2	Non-locating bearing
3	Locating bearing	4	Motor

1.6.2 Calculation results

The internal load distribution in the bearing is calculated precisely, taking into account the actual rolling element profile and raceway profile. The fatigue life in accordance with DIN ISO is outputted for the evaluation of the bearing arrangement concept. Calculation results for operating clearance, lubrication, tilting and the maximum contact pressure of the individual bearings are also available. In addition, the program outputs guide values for selective displacement of the shaft during operation and the associated equivalent stress.

1.6.3 Radial displacement

The radial deflection or displacement at the position of the shaft seal or impeller can be displayed in Bearinx-online Easy Pump. This information can be quickly and easily incorporated when configuring shaft rigidity and bearing rigidity.

All input data, project data and calculation results are available in a detailed PDF document upon completion of the calculation.

1.7 Bearinx-online Easy Pump calculation example

https://bearinx-online-easy-pump.schaeffler.com/files

Three template files are stored in the program:

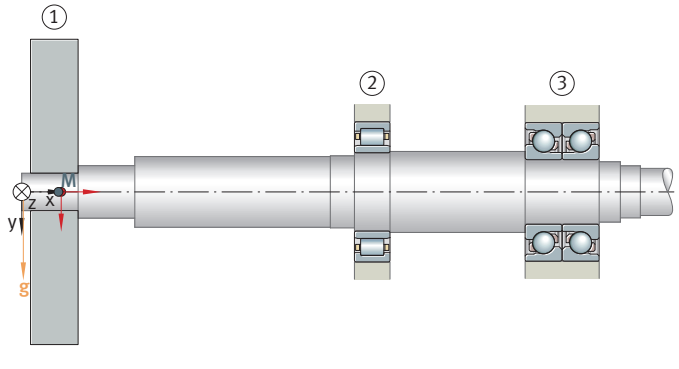
- centrifugal pump
- double flow pump
- submersible pump

Bearing arrangement of a centrifugal pump

Assumptions for calculation of the bearing arrangement:

- The impeller is overhung.
- The weight is calculated in accordance with the modelling from the shaft geometry.
- The position of the deflection measurement point was set at the impeller's centre of gravity, but can also be selected at will, for example at the seal position.
- On the drive side of the pump shaft, two angular contact ball bearings in an O arrangement are used as locating bearings. The suffix UB indicates that the bearings can be combined in a tandem arrangement, O arrangement or X arrangement as required. The bearing pair supports the axial thrust and a proportionate radial load.
- A cylindrical roller bearing is installed close to the impeller as a non-locating bearing, which is used solely to support the radial load and provide guidance.

14 Overhung bearing arrangement



1	Impeller	2	Non-locating bearing
3	Locating bearing		

Operating conditions:

- speed: 3000 min^{-1}
- loads on the impeller:
  - F_a = 9000 N
  - F_r = 7000 N
- load cases: 100 %, average operation
- temperatures
  - impeller: +70 °C
  - non-locating bearing: +80 °C
  - locating bearing: +80 °C
- oil bath lubrication: viscosity: 32 mm^2/s
- oil cleanliness code:
  - 17 in accordance with ISO 4406
  - 14 in accordance with ISO 16889

Non-locating bearing:

- rolling bearing: NU2218-E-XL-TVP2
- internal clearance: CN
- shaft fit: k6
- housing fit: H7
- mean roughness depth Rz:
  - shaft: 6,3 µm
  - housing: 12 µm

Locating bearing:

- 2 rolling bearings: 7315-B-XL-TVP-UB in an O arrangement
- internal clearance: UB = 27 to 39
- shaft fit: k6
- housing fit: H7
- mean roughness depth Rz:
  - shaft: 6,3 µm
  - housing: 12 µm

Calculation results:

- All project data, entries and results are displayed in a clearly arranged results view.
- In addition to the basic rating life $L_{10h(xy)}$, the corresponding, significantly more detailed results of the expanded rating life L_h (without the influence of lubrication) and L_{hmr} (with influence of lubrication) in accordance with ISO/TS 16281 are also displayed.

1.8 Lubrication of rolling bearings and lubricants for pumps and electric motors

1.8.1 Basic principles

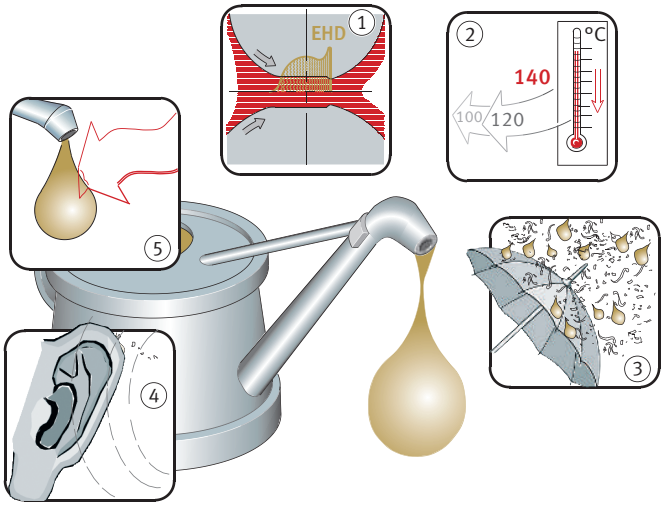
The main function of lubrication in rolling bearings is to prevent or reduce contact between rolling and sliding surfaces. As a result, friction and wear are kept to a low level. Lubricant is conveyed into the contact areas of rolling bearings and adheres to the surfaces of parts rolling against each other. The lubricant thus separates the contact surfaces and prevents metal-to-metal contact. If a

lubricant film that can fully support loads is not formed, some areas of the surfaces will not be separated by the lubricant film. Even in such cases, operation with low levels of wear is possible if tribomechanical reaction layers form between the additives in the lubricant and the rolling element or bearing ring.

The lubricant fulfils important functions in the rolling bearing:

- formation of a lubricant film sufficiently capable of supporting loads on the contact surfaces, thereby preventing wear and premature fatigue
- heat dissipation in the case of oil lubrication
- sealing function in bearings with grease lubrication to protect against external solid and liquid contaminants
- damping of running noise
- protection against corrosion

15 Functions of the lubricant



1	Formation of a lubricant film capable of supporting loads	2	Heat dissipation in the case of oil lubrication
3	Sealing of the bearing against external contaminants in the case of grease lubrication	4	Damping of running noise
5	Provide protection against corrosion		

1.8.2 Selection of the type of lubrication

A fundamental distinction is made between oil lubrication and grease lubrication, with grease lubrication being used for the most part, particularly with smaller pumps.

Oil lubrication

Oil lubrication presents itself as a sensible option if adjacent machine elements are already supplied with oil or if heat is to be dissipated by the lubricant. Heat dissipation may be necessary if high speeds or loads are present or if the bearing arrangement is subjected to heating by an external source.

Advantages of oil lubrication:

- cleaning of the lubricant in recirculating oil lubrication by means of filters or through oil replacement in oil sump lubrication
- reduction of operating temperatures

Grease lubrication

Under normal operating and environmental conditions, lifetime lubrication (for-life lubrication) is often possible for deep groove ball bearings. However, attention must be paid to the grease operating life in design of the bearing and particularly when selecting the grease. We hold a special stock range of common variants of bearings lubricated with standard and high-temperature grease.

If high demands are present, for example in terms of speed, temperature and load, relubrication at appropriate intervals must be planned. In this case, it is necessary to provide inlet and outlet ducts for grease as well as a collection chamber for used grease. For short relubrication intervals, CONCEPT lubricators are suitable, as they deliver the correct quantity on a fully automatic basis at a defined time interval.

Advantages of grease lubrication:

- very little design work required
- sealing action supported by the grease
- long operating life with maintenance-free lubrication

Grease operating life

The grease operating life describes the period over which the grease is capable, without relubrication, of lubricating the bearing to an adequate extent. Once the grease operating life has been reached, bearing functionality is restricted and the bearing will fail relatively quickly as a result of lubricant failure. The grease operating life is therefore a decisive value if it is shorter than the calculated bearing life. It is particularly relevant to function if the rolling bearings cannot be relubricated.

Factors influencing the grease operating life:

- grease quantity and distribution
- grease type (thickener, base oil, additives)
- grease production process
- bearing type and size
- magnitude and type of load
- speed parameter
- bearing temperature
- mounting conditions

Grease selection

Selecting the correct grease selection is particularly important in the case of bearings with high proportions of sliding motion and bearings subjected to heavy loads. Under high load, the lubrication capability of the thickener and the additive package are of particular importance. In grease lubrication, the amount of lubricant playing an active role in the lubrication process is very small. Grease of normal consistency is largely displaced from the rolling contact and is deposited laterally or exits the bearing arrangement through the seal. The grease that remains on the raceway surfaces and laterally in or on the bearing continuously releases the required small quantity of oil and, in some cases, thickener to lubricate the functional surfaces. The effective lubricant quantity between the rolling contact surfaces is sufficient for lubrication under moderate load over an extended period.

Factors influencing grease selection:

- bearing type and size
- operating conditions, such as speed, temperature
- magnitude and type of load

9 Arcanol lubricating greases for relubrication of all rolling bearing designs using CONCEPT lubricators

Designation	Properties	T	$n \cdot d_M$	ν_{40}	NLGI grade
		°C	mm/min	mm²/s	
Arcanol MULTITOP	Universal high performance grease	–50 [1] ... +140	800000	82	2
Arcanol TEMP90	High temperature grease, low-noise	–40 ... +160	700000	148	3

D	mm	Outside diameter
$n \cdot d_M$	mm/min	Characteristic speed
T	°C	Temperature
ν_{40}	mm²/s	Base oil viscosity of grease at +40 °C

1) Measurement values according to Schaeffler FE8 low temperature test.

10 High temperature greases for use in pumps and electric motors

Designation	Properties	T	$n \cdot d_M$	ν_{40}	NLGI grade
		°C	mm/min	mm²/s	
L069	High temperature grease, low-noise	–40 ... +180	1000000	80	2, 3
L207	High speed	–40 ... +180	900000	70	2, 3

D	mm	Outside diameter
$n \cdot d_M$	mm/min	Characteristic speed
T	°C	Temperature
ν_{40}	mm²/s	Base oil viscosity of grease at +40 °C

11 Properties of lubricating greases

Designation	Properties		T	$n \cdot d_M$	ν_{40}	NLGI grade
			°C	mm/min	mm²/s	
Standard greases according to defined grease specifications [2]	Standard grease	D ≤ 62 mm	–20 ... +120	500000	68 ... 150	2
	Ball bearing grease, low-noise	D ≤ 62 mm				
	Standard grease	D ≥ 62 mm	–20 ... +120	500000	68 ... 150	3
	Ball bearing grease, low-noise	D > 62 mm				
L069 [3]	High temperature grease, low-noise		–40 ... +180	1000000	80	2, 3
L207 [3]	High speed		–40 ... +180	900000	70	2, 3
L285 [4]	Low noise		–20 ... +120	500000	68 ... 150	3
Arcanol MULTITOP [5]	Universal high performance grease		–50 [6] ... +140	800000	82	2
Arcanol TEMP90 [5]	High temperature grease, low-noise		–40 ... +160	700000	148	3

D	mm	Outside diameter
$n \cdot d_M$	mm/min	Characteristic speed
T	°C	Temperature
ν_{40}	mm²/s	Base oil viscosity of grease at +40 °C

2) for sealed for-life deep groove ball bearings

3) preferred high temperature greases that are interchangeable in pumps and electric motor applications

4) for sealed double-row for-life angular contact ball bearings

5) for relubrication of rolling bearings of all designs using CONCEPT lubricators

6) Measurement values according to Schaeffler FE8 low temperature test.

12 Lubricating greases for sealed deep groove ball bearings

Designation	Properties	Thickener	Base oil	T	$n \cdot d_M$	ν_{40}	NLGI grade
				°C	mm/min	mm²/s	
Standard greases according to defined grease specifications	D ≤ 62 mm	Lithium soap	Mineral oil	–20 ... +120	500000	68 ... 150	2
	D ≥ 62 mm: Standard grease D > 62 mm: Ball bearing grease, low-noise	Lithium soap	Mineral oil	–20 ... +120	500000	68 ... 150	3
L069	High temperature grease, low-noise High speed	Polycarbamide	Ester oil	–40 ... +180	1000000	80	2, 3
L207	High temperature grease, low-noise High speed	Polycarbamide	Ester oil	–40 ... +180	900000	70	2, 3
L285	Low noise	Lithium soap	Mineral oil	–20 ... +120	500000	68 ... 150	3
Arcanol MULTITOP	Universal high performance grease	Lithium soap	Mineral oil PAO	–50 ... +140	800000	82	2
Arcanol TEMP90	High temperature grease, low-noise	Polycarbamide	Mineral oil PAO	–40 ... +160	700000	148	3

D	mm	Outside diameter
$n \cdot d_M$	mm/min	Characteristic speed
T	°C	Temperature
ν_{40}	mm²/s	Base oil viscosity of grease at +40 °C

13 Lubricating greases for sealed deep groove ball bearings

Designation	Properties		T	$n \cdot d_M$	ν_{40}	NLGI grade
			°C	mm/min	mm²/s	
Standard greases according to defined grease specifications	Standard grease	D ≤ 62 mm	–20 ... +120	500000	68 ... 150	2
	Ball bearing grease, low-noise	D ≤ 62 mm				
	Standard grease	D ≥ 62 mm	–20 ... +120	500000	68 ... 150	3
	Ball bearing grease, low-noise	D > 62 mm				

D	mm	Outside diameter
$n \cdot d_M$	mm/min	Characteristic speed
T	°C	Temperature
ν_{40}	mm²/s	Base oil viscosity of grease at +40 °C

14 Lubricating greases for sealed, double row angular contact ball bearings

Designation	Properties	T	$n \cdot d_M$	ν_{40}	NLGI grade
		°C	mm/min	mm²/s	
L285	Low noise	–20 ... +120	500000	68 ... 150	3

D	mm	Outside diameter
$n \cdot d_M$	mm/min	Characteristic speed
T	°C	Temperature
ν_{40}	mm²/s	Base oil viscosity of grease at +40 °C

15 Grease composition

Designation	Properties		Thickener	Base oil
Standard greases according to defined grease specifications [7]	Standard grease	D ≤ 62 mm	Lithium soap	Mineral oil
	Ball bearing grease, low-noise	D ≤ 62 mm		
	Standard grease	D ≥ 62 mm	Lithium soap	Mineral oil
	Ball bearing grease, low-noise	D > 62 mm		
L069 [8]	High temperature grease, low-noise		Polycarbamide	Ester oil
L207 [8]	High speed		Polycarbamide	Ester oil

Designation	Properties	Thickener	Base oil
L285 [9)]	Low noise	Lithium soap	Mineral oil
Arcanol MULTITOP [10)]	Universal high performance grease	Lithium soap	Mineral oil PAO
Arcanol TEMP90 [10)]	High temperature grease, low-noise	Polycarbamide	Mineral oil PAO

7) for sealed for-life deep groove ball bearings

8) preferred high temperature greases that are interchangeable in pumps and electric motor applications

9) for sealed double-row for-life angular contact ball bearings

10) for relubrication of rolling bearings of all designs using CONCEPT lubricators

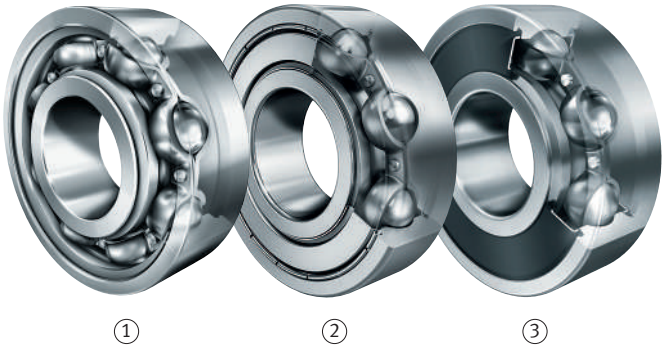
2 Rolling bearing for fluid pumps

2.1 Single row deep groove ball bearings

Single row deep groove ball bearings are versatile, self-retaining bearings with solid outer rings, inner rings and ball and cage assemblies. They are of a simple design, robust in operation and easy to maintain. They are available in open and sealed designs.

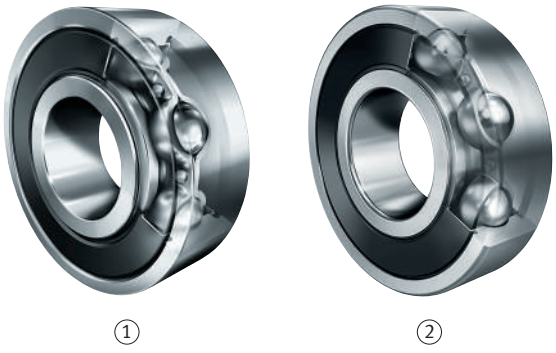
Generation C deep groove ball bearings have been specifically enhanced and, as a result of the optimised design, offer lower noise levels, better sealing and higher cost-efficiency.

16 Generation C single row deep groove ball bearings, open or with non-contact seals



1	Open	2	Sealing shields on both sides (suffix 2Z)
3	Non-contact seals on both sides (suffix 2BRS)		

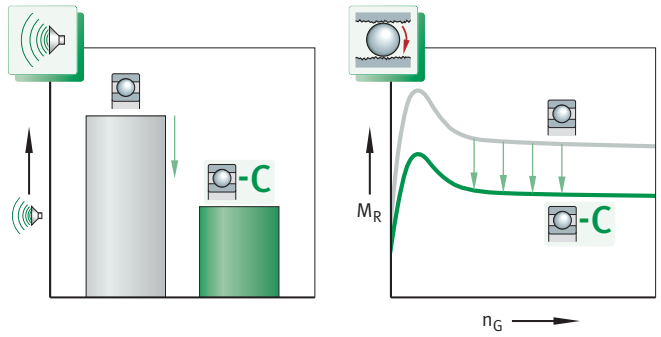
17 Single row deep groove ball bearings, Generation C, contact seals



1	Contact seals on both sides (suffix 2HRS)	2	Contact seals on both sides (suffix 2ELS)

The bearing is significantly quieter in operation due to the improved raceway surface, the higher quality of the balls, the optimised internal bearing construction, the higher stability of the cage and higher production accuracy. The frictional torque, which is already very low, is further reduced, resulting in lower energy consumption. Overall, these optimisations result in up to 50 % noise reduction and 35 % lower friction with Generation C.

18 Comparison of standard deep groove ball bearings with Generation C bearings: running noise, frictional torque



C	Generation C bearings	
M_R	Nm	Frictional torque
n_G	min^{-1}	Limiting speed

2.1.1 Radial and axial load carrying capacity

Due to the raceway geometry and the use of balls, deep groove ball bearings can support axial forces in both directions as well as radial forces.

2.1.2 Operating temperature

Open deep groove ball bearings up to an outside diameter of 90 mm can be used up to an operating temperature of +120 °C; while bearings of this type with an outside diameter greater than 90 mm to 240 mm can be used up to +150 °C.

Deep groove ball bearings with elastomer seals, e.g. BRS or HRS, can be used at operating temperatures from –30 °C to +110 °C, restricted by the grease and sealing ring material.

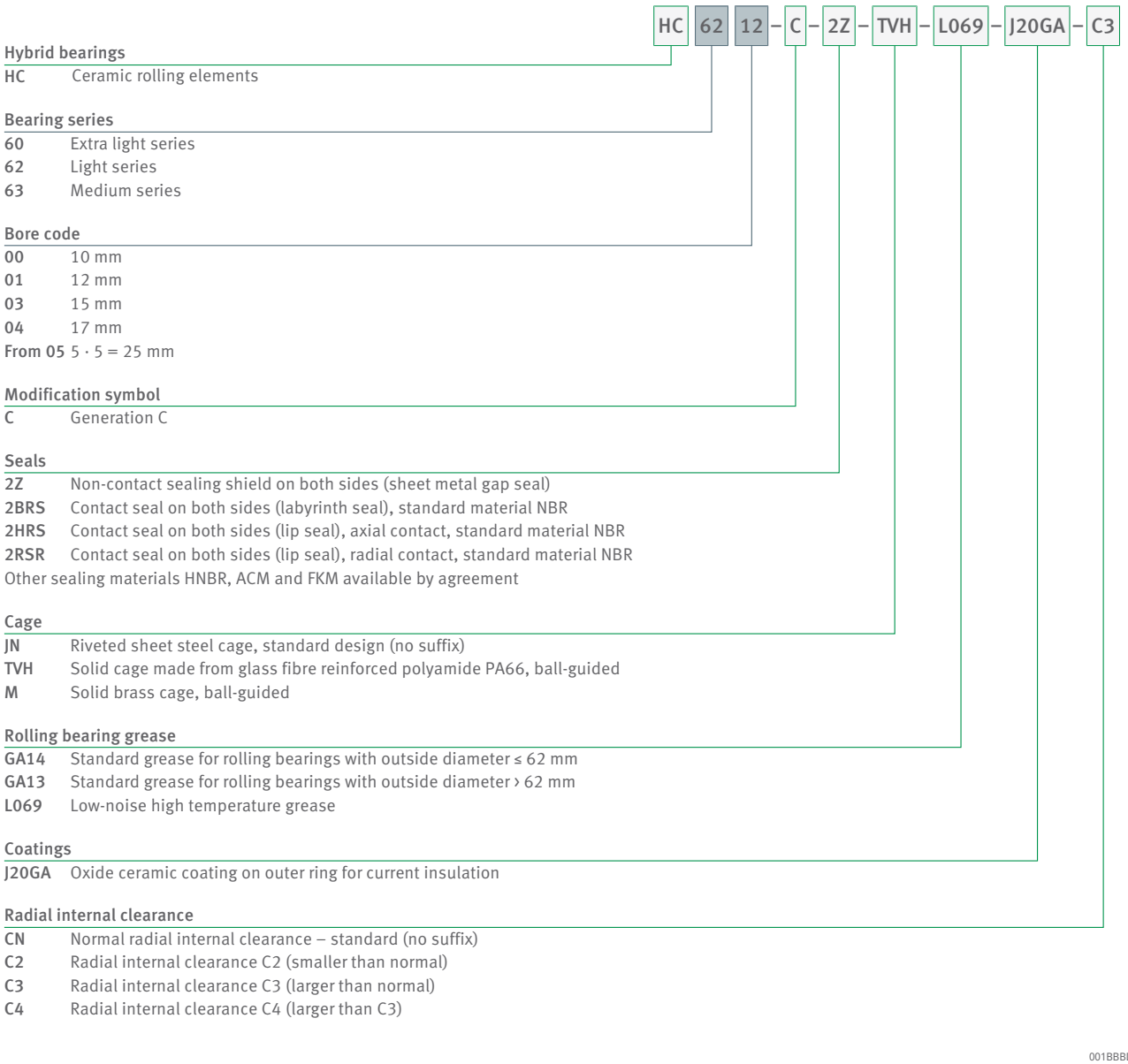
Bearings with sealing shield Z can be used from –30 °C to +120 °C.

2.1.3 Lubrication

Bearings sealed on both sides are greased with a high quality grease and are lubricated for life. Special grease applications are also available for individual requirements, such as higher temperatures. These are identified, for example, by the suffixes L069 or L207.

2.1.4 Bearing designation

19 Bearing designation



2.1.5 Further information

HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

medias | Product catalogue |
medias.schaeffler.com

TPI 165 | Deep groove ball bearings Generation C |
https://www.schaeffler.de/std/200C

2.2 Single row angular contact ball bearings

Single row angular contact ball bearings are self-retaining units with solid inner and outer rings, and ball and cage assemblies with polyamide, sheet metal or brass cages. The raceways of the inner and outer rings are offset from each other along the bearing axis. The bearings are available in open and sealed designs. Their angular adjustment facility is limited.

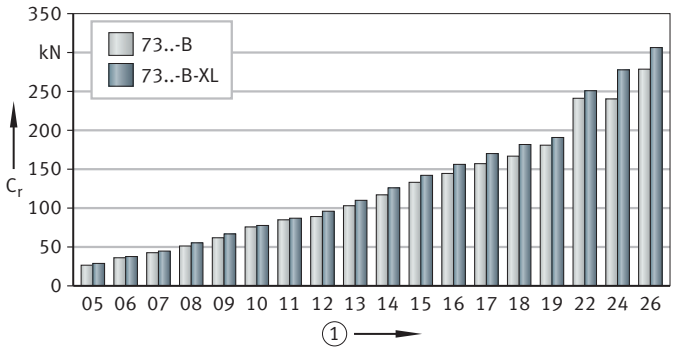
20 Single row angular contact ball bearing

0001ABAE

2.2.1 X-life

X-life stands for optimised roughness and geometrical accuracy of the raceways. The resulting higher load carrying capacity allows longer operating lives and maintenance intervals to be achieved. Many sizes of single row angular contact ball bearings are available in the X-life version. Other variants can be supplied by agreement.

21 Comparison of basic dynamic load rating C_r – bearing series 73..-B-XL, bore code 05 to 26, with a bearing which is not of X-life quality (73..-B)



0019634A

1	Bore code	
C_r	kN	Basic dynamic load rating, radial

2.2.2 Load carrying capacity

Single row angular contact ball bearings can support axial forces in one direction and high radial forces. To provide axial counter-guidance, a second bearing is required, arranged in a mirror image configuration.

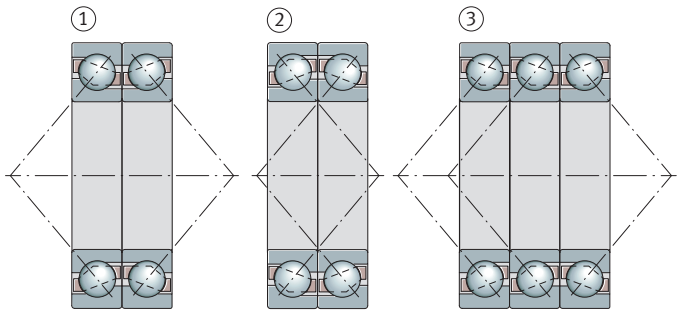
With a contact angle of 40°, these bearings can support high axial loads.

Universal design

Universal designs are intended for the following installation positions:

- X arrangement
- O arrangement
- tandem O arrangement
- fitting in groups

22 Variants of bearing arrangements



1	O arrangement	2	X arrangement
3	tandem O arrangement		

The mounted bearing pair then has a precisely defined axial clearance according to the chosen configuration, e.g.:

- UO: freedom from clearance
- UB: small axial internal clearance
- UA: slightly higher axial internal clearance

Mounting in tandem arrangement

When mounting in a tandem arrangement, the contacting end faces of the outer rings must have sufficient overlap.

Further information on this subject can be obtained from the Schaeffler engineering service.

2.2.3 Operating temperature

16 Permissible operating temperatures for angular contact ball bearings

Bearing	Operating temperature	
	min.	max.
	°C	°C
Open angular contact ball bearings	–30	+150
Open angular contact ball bearings with cages made from glass fibre reinforced polyamide	–	+120
Bearings with seals	–30	+110

2.2.4 Lubrication

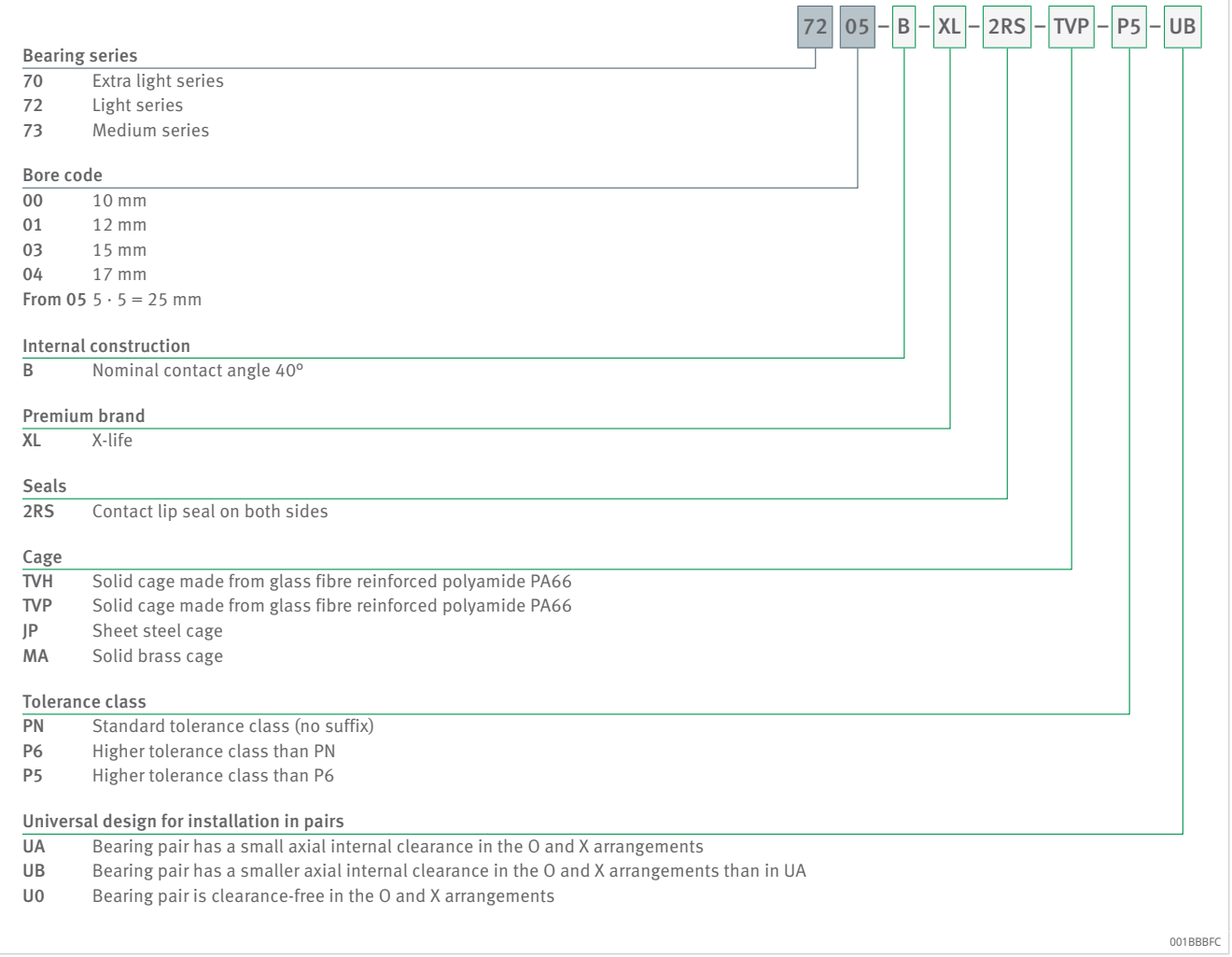
Bearings with seals on both sides are lubricated for life.

Open bearings and bearings with seals on one side are not greased and can be lubricated with grease or oil.

For relubrication with grease, Schaeffler recommends using the CONCEPT automatic lubricators.

2.2.5 Bearing designation

23 Bearing designation



2.2.6 Further information

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https://www.schaeffler.de/std/1D3D

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2.3 Double row angular contact ball bearings

Double row angular contact ball bearings are units with solid inner rings, outer rings and ball and cage assemblies with polyamide, brass or sheet steel cages. Their construction is similar to a pair of single row angular contact ball bearings in an O arrangement, but they are narrower to a certain extent. They differ in the size of the contact angle and the design of the bearing rings.

Due to the raceway geometry and the two rows of balls, the bearings can support both radial and axial forces. They are therefore particularly suitable for use in pumps.

The angular adjustment facility of double row angular contact ball bearings is limited.

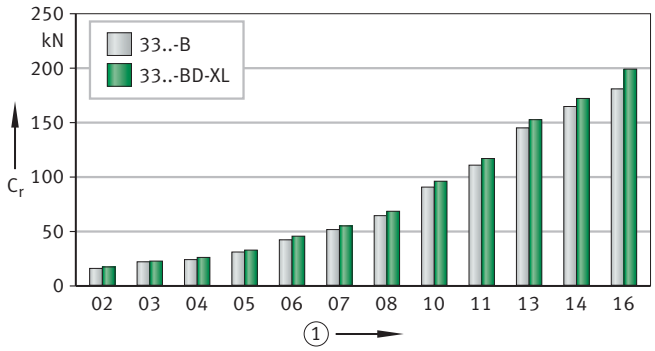
24 Double row angular contact ball bearing

0001ABB2

2.3.1 X-life

X-life stands for quieter bearings with higher basic load ratings. The reduced friction leads to lower temperatures and, in the case of bearings lubricated for life, to a longer grease operating life. Many sizes of double row angular contact ball bearings are available in the X-life version. Other variants can be supplied by agreement.

25 Comparison of basic dynamic load rating C_r – bearing series 33..-BD XL, bore code 02 to 16, with a bearing which is not of X-life quality (33..-B)



0018FEA7

1	Bore code	
C_r	kN	Basic dynamic load rating, radial

2.3.2 Load carrying capacity

Double row angular contact ball bearings can support high radial loads as well as axial loads in both directions, making them suitable for bearing arrangements that require rigid axial guidance. The axial load carrying capacity is dependent on the contact angle: The greater the contact angle, the higher the axial load to which the bearing can be subjected.

Double row angular contact ball bearings are available with the following contact angles:

- 25°
- 30°, only in X-life quality
- 35°
- 45°, only with split inner ring

Bearings with a contact angle of 45° have a split inner ring. In addition, the larger number of balls gives a significant increase in basic load ratings. The brass cage also gives an improvement in the emergency running characteristics of the bearing.

2.3.3 Operating temperature

17 Permissible operating temperatures of double row angular contact ball bearings

Bearing	Operating temperature
	max.
	°C
Double row angular contact ball bearings with elastomer contact seals RSR or HRS	+110
Non-contact sealing shield Z and glass fibre reinforced polyamide cage TVP	+120

Open bearings with suitable lubrication are recommended if the temperatures exceed these values.

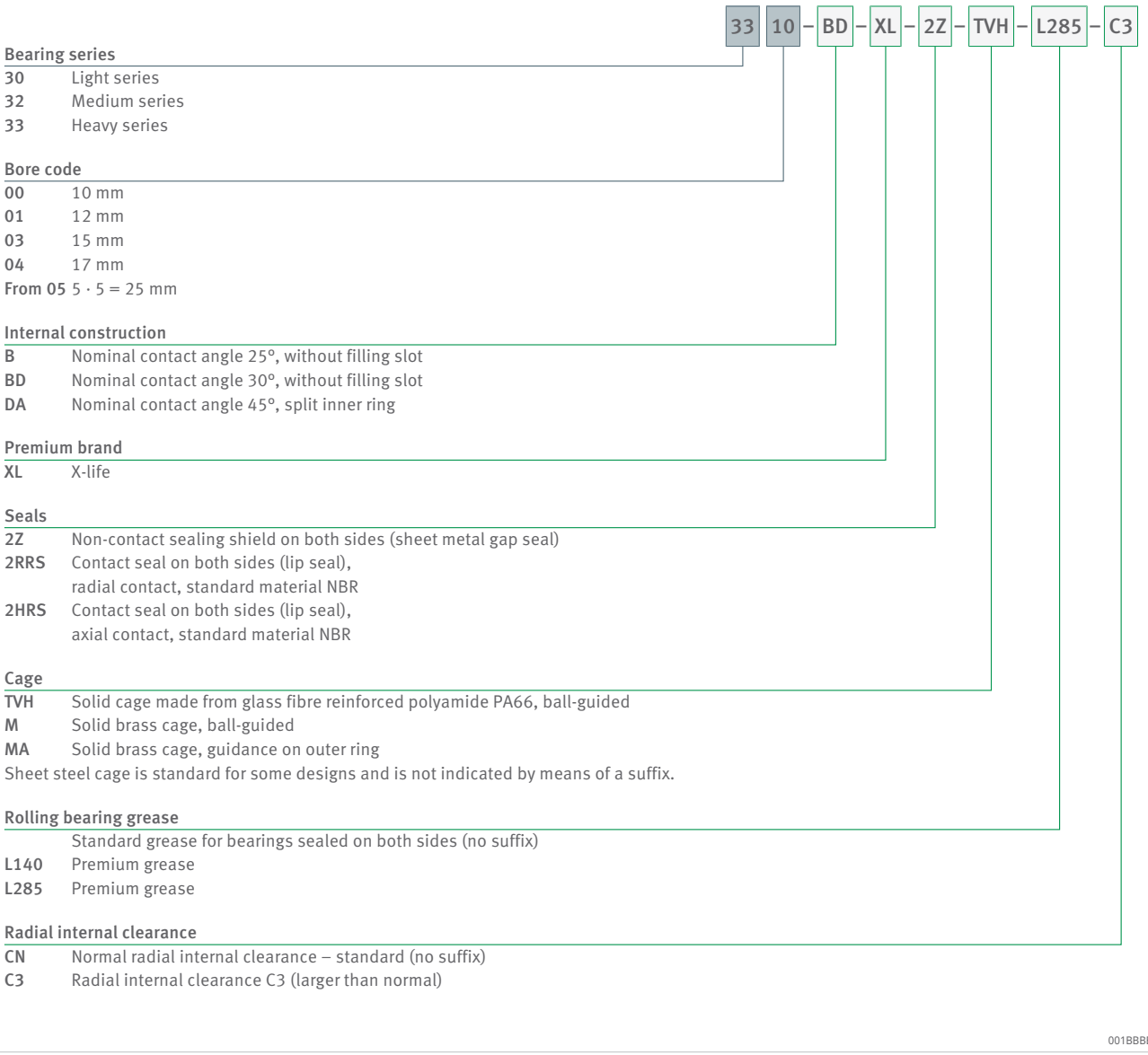
2.3.4 Lubrication

Open double row angular contact ball bearings are not greased. They can be lubricated with grease or oil. The use of automatic lubricators is recommended for relubrication with grease.

Sealed bearings are greased with a standard high-quality grease and are lubricated for life. Premium greasing, which is identified by the suffixes L140 or L285, is available for application-specific requirements.

2.3.5 Bearing designation

26 Bearing designation



2.3.6 Further information

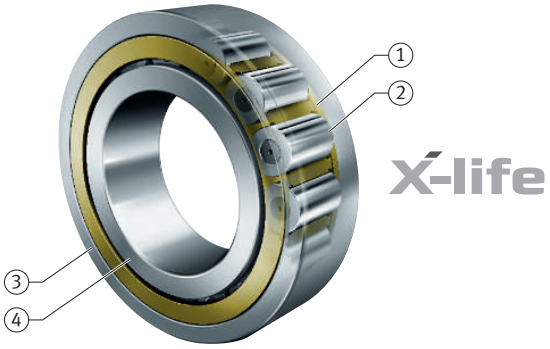
HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

medias | Product catalogue |
medias.schaeffler.com

2.4 Single row cylindrical roller bearings

Single row cylindrical roller bearings with cage are units comprising solid inner and outer rings and cylindrical roller and cage assemblies. The outer rings have rigid ribs on both sides or no ribs, the inner rings have one or two rigid ribs or are designed without ribs. The cage type bearings are very rigid, can support high radial loads and are suitable for higher speeds than the full complement designs. The bearings are separable and are therefore easier to mount and dismount. As a result, both bearings can be mounted with a tight fit. Depending on requirements and the corresponding design, single row cylindrical roller bearings with cage are used as non-locating, semi-locating and locating bearings.

27 Single row cylindrical roller bearings in X-life design



1	Brass cage	2	Cylindrical roller, honed
3	Outer ring, honed	4	Inner ring, honed

The advantages of cylindrical roller bearings with cage take effect precisely where ball bearings are not sufficient due to higher pump loads. These bearings have significantly higher basic load ratings to support radial loads and are ideal non-locating bearings. As a result of the radial rigidity which is inherent to their design, small gap dimensions in the pump geometry can be reliably maintained.

As the shafts in pumps are often generously dimensioned to meet the requirements for deflection and high strength, narrower series are usually sufficient. In the event of conflicts with minimum load requirements and potential slippage problems, series NU10 can be used. This series is not designed as a reinforced version with suffix E, meaning that the small rollers are less prone to slippage.

2.4.1 X-life

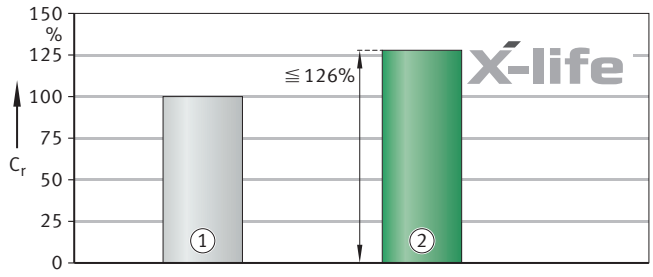
Single row cylindrical roller bearings of X-life quality exhibit considerably higher performance than comparable standard cylindrical roller bearings.

This improvement in performance is achieved through:

- improved internal construction
- optimised contact geometry between rollers and raceways
- better surface quality
- optimised roller guidance and lubricant film formation

These optimisations lead to significantly reduced heat generation and a measurable increase in the rating life of the rolling bearings.

28 Cylindrical roller bearing:with cage: comparison of basic dynamic load rating C_r with bearings without X-life quality



1	Basic dynamic load rating C_r for bearings without X-life quality	2	Basic dynamic load rating C_r for bearings with X-life quality

2.4.2 Non-locating bearing

Cylindrical roller bearings NU and N are non-locating bearings and can support radial forces only. In series NU, the outer ring has 2 ribs, while the inner ring has no ribs. Bearings of series N have 2 ribs on the inner ring and an outer ring without ribs.

Axial displacement

The outer and inner ring can be axially displaced relative to each other from the central position by the value s.

2.4.3 Operating temperature

18 Permissible operating temperatures for single row cylindrical roller bearings

Bearing	Operating temperature	
	min.	max.
	°C	°C
Single row cylindrical roller bearings with plastic cage	–30	+120
Single row cylindrical roller bearings with metal cage	–	+150

For continuous operating temperatures above +120 °C, please contact us.

2.4.4 Sealing

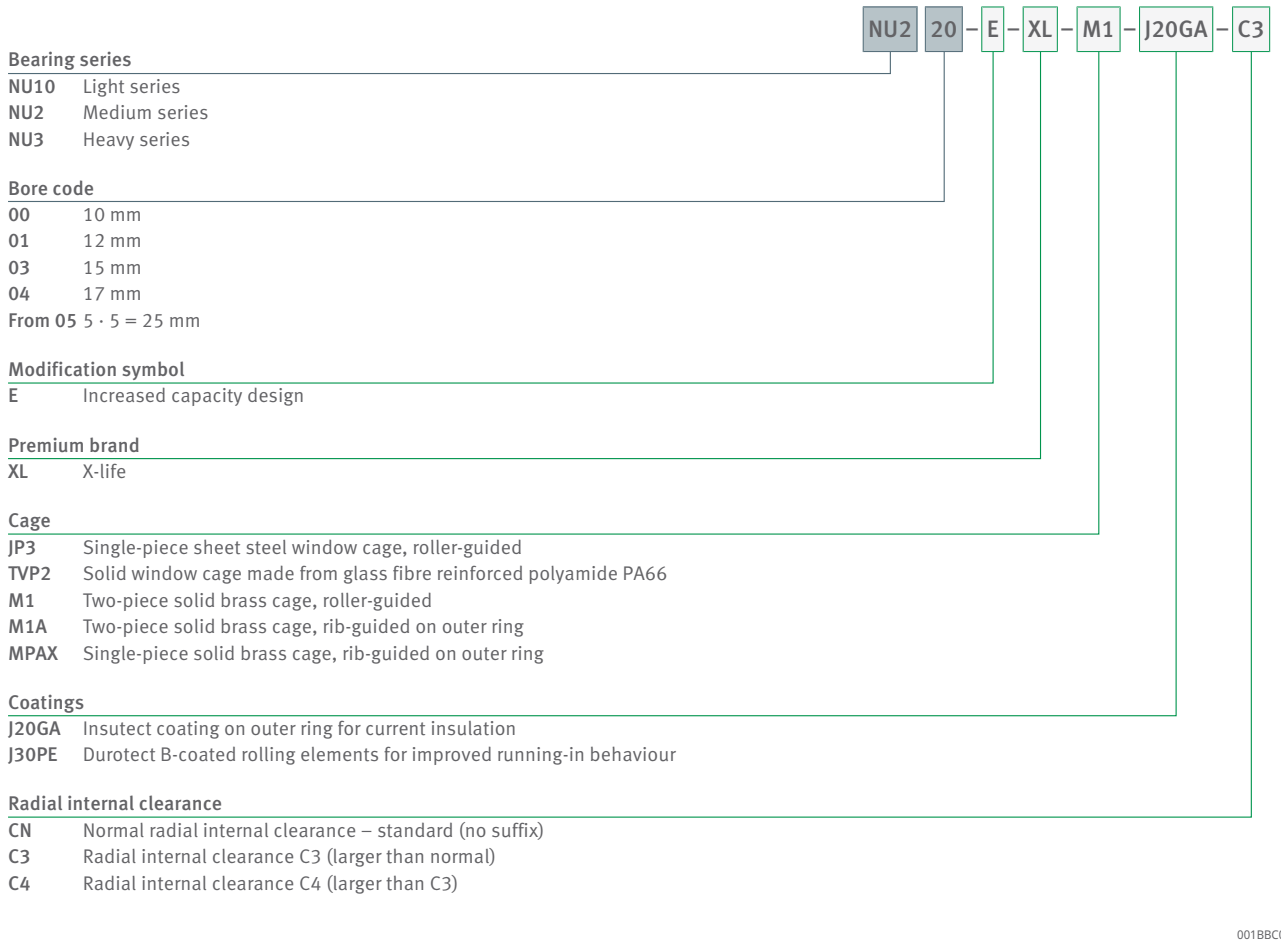
Single row cylindrical roller bearings are supplied without seals.

2.4.5 Lubrication

The bearings can be lubricated with grease or oil via the end faces.

2.4.6 Bearing designation

29 Bearing designation



2.4.7 Further information

HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

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2.5 Spherical roller bearings

Spherical roller bearings are double row, self-retaining units comprising solid outer rings with a concave raceway, solid inner rings and barrel rollers with cages. The inner rings have cylindrical or tapered bores.

The symmetrical barrel rollers orient themselves freely on the concave outer ring raceway. As a result, shaft flexing and misalignment of the bearing seats are compensated.

For use in large, heavily loaded centrifugal pumps, the combination of high basic load rating, angular adjustment facility and the ability to support both radial and axial forces makes these bearings an interesting option.

30 Spherical roller bearings

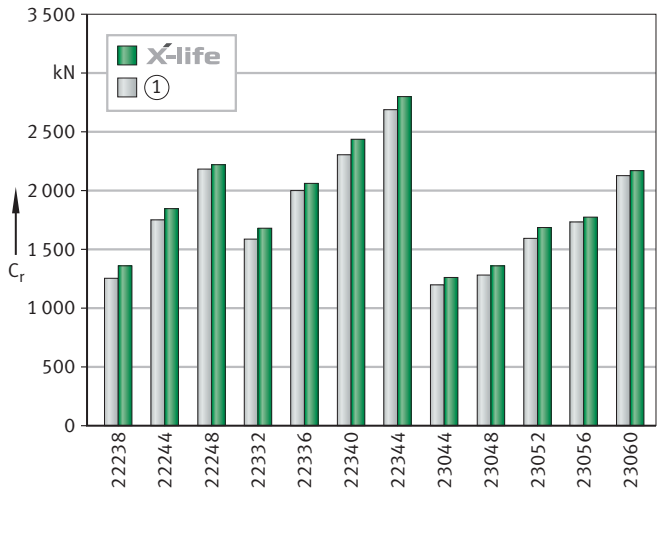
0001ABB8

2.5.1 X-life

Many sizes of spherical roller bearings are available in the X-life version. These bearings are characterised by the following features:

- optimised internal construction
- higher load carrying capacity
- reduced friction
- reduced bearing temperature
- improved surface quality and contact geometry

31 Comparison of basic dynamic load ratings, series 222, 223 and 230



1 Benchmark competitor (premium product)

2.5.2 Load carrying capacity

Spherical roller bearings can support axial loads in both directions and high radial loads. Spherical roller bearings are designed for very high load carrying capacity and, since they have the maximum possible number of large and particularly long barrel rollers, are also suitable for the heaviest loads.

2.5.3 Compensation of angular misalignments

Spherical roller bearings compensate for angular misalignments. The permissible adjustment angle is given for loads:

$P < 0{,}1 \cdot C_r$

These adjustment angles are permissible in the following cases:

- constant angular deviation (static angular misalignment)
- rotating inner ring

2.5.4 Operating temperature

19 Permissible operating temperatures for spherical roller bearings

Bearing	Operating temperature	
	min.	max.
	°C	°C
Spherical roller bearings with metal cages	–30	+200
Spherical roller bearings with cages made from glass fibre reinforced polyamide	–	+120

The selection of a suitable lubricant is also crucial.

2.5.5 Sealing

Sealed and greased bearings are available by agreement.

2.5.6 Lubrication

Open spherical roller bearings can be lubricated with oil or grease.

2.5.7 Bearing designation

32 Bearing designation

Bearing series

213	Light series
222	Light series
223	Light series
230	Medium series
231	Medium series
232	Medium series
240	Heavy series
241	Heavy series

Bore code

22	22 · 5 = 110 mm

Explicitly indicated from 500 mm bore diameter.

Modification symbol

A, AS	Inner ring with retaining ribs and central rib
B, BE, BEA	Fixed central rib on inner ring
E1	Design without central rib on inner ring
E1A	Inner ring with two lateral ribs

Premium brand

XL	X-life

Tapered bore

K	Taper 1:12, standard
K30	Bearings of heavy series 240 and 241 have a taper of 1:30

In bearings of standard design (without K), the bore is cylindrical.

Cage

JPA	Two sheet steel cages, guidance on outer ring
TVB	Two window cages made from glass fibre reinforced polyamide PA66, guidance on inner ring
M	Single-piece double comb brass cage, roller-guided
MA	Two-piece solid brass cage, guidance on outer ring
MB	Two-piece solid brass cage, guided on inner ring
MB1	Single-piece double comb brass cage, guidance on inner ring
MA1	Two-piece brass cage, guidance on outer ring

For bearings of design E1, a two-piece sheet steel cage guided on the outer ring is used,
for bearings of design BE a two-piece sheet steel cage guided on the inner ring is used as standard (no suffix).

Radial internal clearance

CN	Normal radial internal clearance – standard (no suffix)
C3	Radial internal clearance C3 (larger than normal)
C4	Radial internal clearance C4 (larger than C3)

Accessories

H	Adapter sleeve
AH	Withdrawal sleeve
KM	Locknut
MB	Tab washer
HMZ	Shaft nut

001BBC22

2.5.8 Further information

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MON 90 | Grease-lubricated, split FAG spherical roller bearings and housings |
https://www.schaeffler.de/std/1F91

ORP | X-life – Proven To Be Better |
https://www.schaeffler.de/std/1FF9

TPI 218 | Sealed Spherical Roller Bearings |
https://www.schaeffler.de/std/1FCF

TPI 250 | Split spherical roller bearings |
https://www.schaeffler.de/std/1F81

WL80384 | Split bearings - split costs |
https://www.schaeffler.de/std/1FFA

2.6 Axial spherical roller bearings

Axial spherical roller bearings are single row, non-self-retaining bearings. The inner and outer rings comprise solid shaft and housing locating washers with corresponding raceways for the rolling elements. The large number of asymmetrical barrel rollers are guided by cages. The raceways are arranged oblique to the bearing axis, with the raceway in the housing locating washer being of concave design.

Axial spherical roller bearings are particularly suitable for large, vertically arranged bearing arrangements with high axial loads. Additionally, dynamic or static misalignments of the shaft relative to the housing, as well as deflections of the shaft, can be compensated by the bearing. In addition to large axial forces, these bearings can also support radial loads up to a maximum of 55 % of F_a. Relatively high speeds or shock type loads do not pose a problem for the bearings.

33 Axial spherical roller bearing in X-life design

1	Cage	2	Barrel roller
3	Housing locating washer	4	Shaft washer

2.6.1 X-life

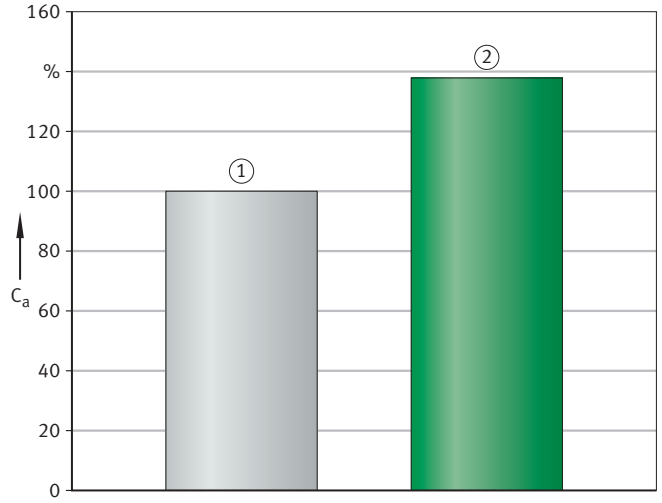
X-life bearings exhibit considerably higher performance than conventional axial spherical roller bearings. These bearings are characterised by the following features:

- improved internal construction
- optimised contact geometry between the rollers and raceways
- improved cage design
- higher steel quality
- better surface quality
- optimised roller guidance and lubricant film formation

These features provide the following benefits:

- optimised load distribution and higher basic load rating
- reduced friction and bearing temperature
- better suitability for high speeds

34 Comparison of basic dynamic load rating C_a



1	Benchmark competitor (premium product) – 100 %	2	X-life – up to 138 %

2.6.2 Load carrying capacity

Since their raceways are inclined relative to the bearing axis, axial spherical roller bearings can support very high axial loads in one direction while simultaneously supporting radial loads. The radial load F_r and F_{0r} must not exceed 55 % of the axial load. These bearings are designed for very high axial load carrying capacity and, since they have the maximum possible number of large and long barrel rollers, are also suitable for the heaviest loads.

2.6.3 Compensation of angular misalignments

Due to the concave rolling element raceway in the housing locating washer, axial spherical roller bearings are capable of angular adjustment.

20 Permissible skewing under static angular misalignment

Bearing series	Permissible skewing D ≤ 320 mm	Permissible skewing D > 320 mm
292..-E1	1,5°	1°
293..-E1	2,5°	1,5°
294..-E1	3°	2°

2.6.4 Operating temperature

21 Permissible operating temperatures for axial spherical roller bearings

Bearing	Operating temperature	
	min.	max.
	°C	°C
Axial spherical roller bearings with metal cages	−30	+200

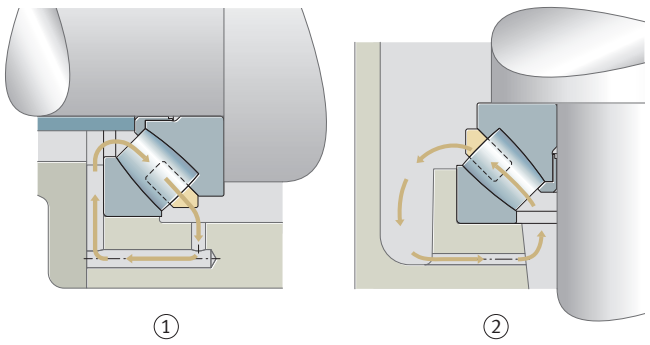
2.6.5 Sealing

Axial spherical roller bearings are supplied without seals. The required sealing of the bearing position must be carried out in the adjacent construction.

2.6.6 Lubrication

The bearings are not greased. They are lubricated with oil. Due to their internal construction, a pumping action occurs in bearings with an asymmetrical cross-section, which must be taken into account.

35 Oil recirculation by means of pumping action, ducts for the purposes of oil return



1	Bearing arrangement with horizontal shaft	2	Bearing arrangement with vertical shaft

In some cases, lubrication with grease containing EP additives is also possible. However, it must be ensured that the contact points between the rollers and the guidance rib are always adequately supplied with grease. This is best achieved with the CONCEPT series of automatic lubricators.

2.6.7 Cages

Axial spherical roller bearings are supplied with sheet steel cages or solid brass cages, depending on the bearing series and bore size.

22 Cage, cage suffix, bore code

Bearing series	Sheet steel cage Bore code		Solid brass cage MB Bore code	
	min.	max.	min.	max.
292..-E1	–	–	30	1180 mm
293..-E1-XL	17	64	68	800 mm
293..-E1	–	–	850 mm	1600 mm
294..-E1-XL	12	68	72	710 mm
294..-E1	–	–	750 mm	1060 mm

2.6.8 Bearing designation

36 Bearing designation

2.6.9 Further information

HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

medias | Product catalogue |
medias.schaeffler.com

MH 1 | Mounting Handbook |
https://www.schaeffler.de/std/1D53

PAX | The most powerful bearings on the market |
https://www.schaeffler.de/std/1FFC

2.7 Tapered roller bearings

Tapered roller bearings comprise solid outer and inner rings with tapered raceways and tapered rollers in a window cage.

The bearings are available as a standard design, as open variants matched in pairs and as integral designs sealed on one side JKOS.

Open bearings are not self-retaining. As a result, the inner ring with the rollers and cage can be mounted separately from the outer ring.

The advantages of this design lie in the higher basic load rating compared with angular contact ball bearings. For this reason, they are particular interesting for larger pumps with higher forces. High radial loads or axial loads can be supported. With an adjusted bearing arrangement (locating bearing), a highly rigid and well-guided bearing support with high running accuracy can be achieved in an axial direction.

37 Tapered roller bearing

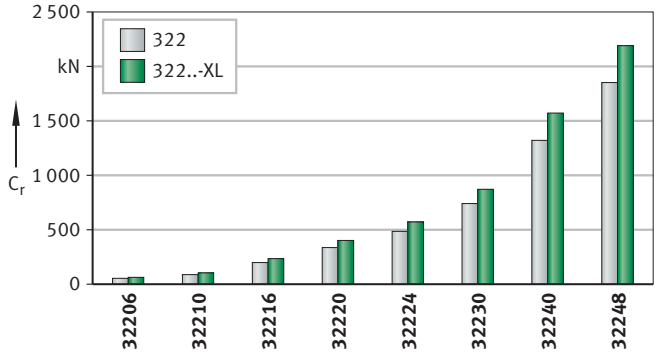
0001AC38

2.7.1 X-life

Many sizes of tapered roller bearings are available in the X-life version. Other variants can be supplied by agreement.

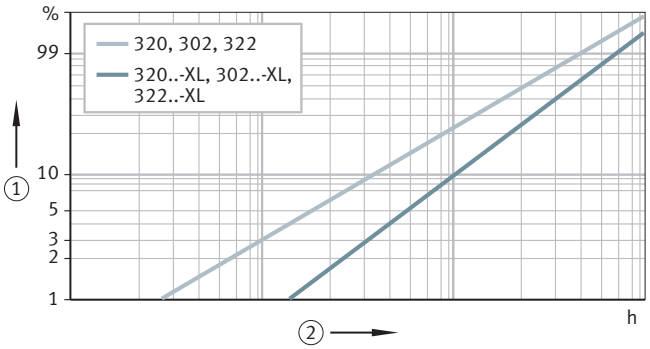
The optimised internal construction with up to 20 % higher basic dynamic load ratings is demonstrated by a significant increase in the calculated rating life. Friction is reduced by up to 50 % due to improved surface quality and contact geometry, resulting, for example, in a reduced bearing temperature, which has a positive effect on lubrication. Higher speeds are possible as a result of the improved running accuracy.

38 Comparison of basic dynamic load ratings C_r of X-life tapered roller bearings and bearings without X-life performance



C_r	Basic dynamic load rating		

39 Comparison of fatigue running time in Weibull diagram of X-life tapered roller bearings and bearings without X-life performance



1	Probability of failure	2	Running time in hours

2.7.2 Load carrying capacity

Tapered roller bearings can support axial loads in one direction and high radial loads.

However, to provide axial counter-guidance, a second bearing is always required, arranged in a mirror image configuration. This bearing combination is then mounted in an O or X arrangement.

2.7.3 Compensation of angular misalignments

The modified line contact between the tapered rollers and the raceways ensures optimum stress distribution at the contact points, prevents edge stresses and allows the bearings to undergo angular adjustment.

If the load ratio $P/C_{0r} < 0,2$, the tilting of the bearing rings relative to each other must not exceed 4 angular minutes. This is, however, subject to the position of the shaft axis and housing axis remaining constant (no dynamic movements).

2.7.4 Operating temperature

23 Possible operating temperatures for tapered roller bearings

Bearing	Operating temperature	
	min.	max.
	°C	°C
Open tapered roller bearings	–30	+120
Open tapered roller bearings with contact lip seal	–30	+110

2.7.5 Sealing

Tapered roller bearings of standard design and matched in pairs are not sealed. Integral tapered roller bearings JKOS have a lip seal on one side.

2.7.6 Lubrication

Tapered roller bearings of standard design and matched in pairs can be lubricated with oil or grease.

Integral tapered roller bearings JKOS are filled with a high-quality standard grease.

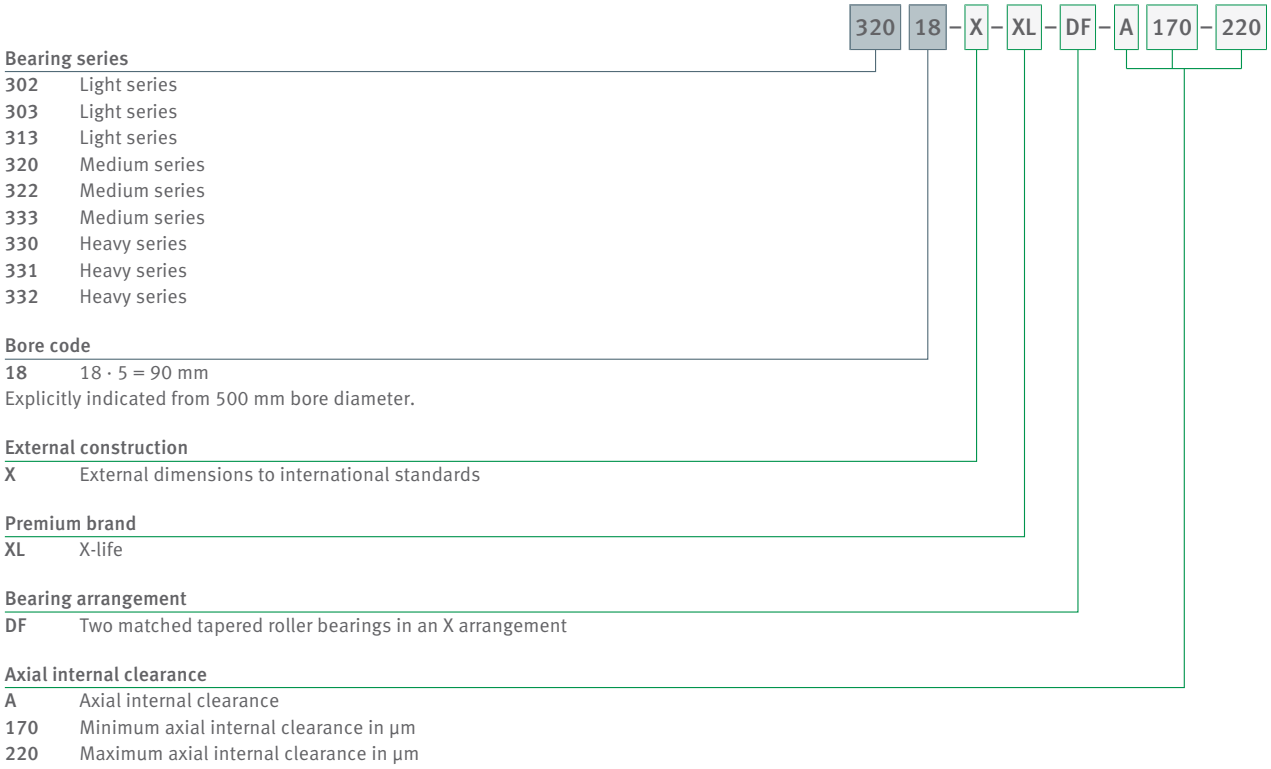
2.7.7 Cages

Tapered roller bearings are available with the following cage designs:

- sheet steel cages (open tapered roller bearings)
- cages made from glass fibre reinforced polyamide (integral bearings JKOS)

2.7.8 Bearing designation

40 Bearing designation



2.7.9 Further information

HR 1 | Rolling Bearings |
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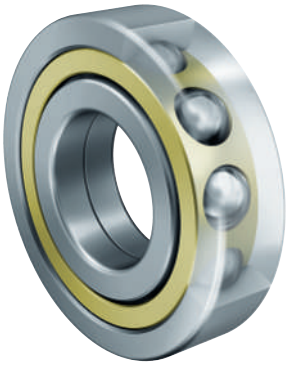
2.8 Four point contact bearings

Four point contact bearings belong to the family of single row angular contact ball bearings and, therefore, require significantly less space in an axial direction than double row designs.

The bearings comprise solid outer rings, split inner rings and ball and cage assemblies with brass or polyamide cages. The two-piece inner rings allow a large complement of balls to be accommodated. The inner ring halves are matched to the particular bearing and must not be interchanged with inner ring halves of other bearings of the same size. The outer ring with the ball and cage assembly can be mounted separately from the two inner ring halves.

41 Four point contact bearing



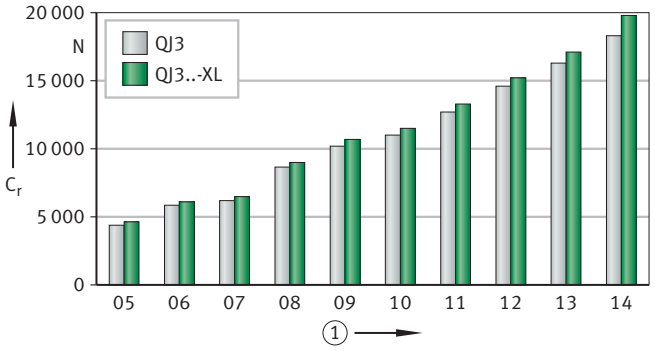
0001ABB4

2.8.1 X-life

Many sizes of four point contact bearings are available in the X-life version. Other variants can be supplied by agreement.

The optimised load distribution in the bearing, combined with the higher basic load ratings, results in greater operational reliability and a longer operating life. X-life bearings have optimised friction characteristics, thus enabling high speeds at lower bearing temperatures.

42 Comparison of basic dynamic load rating C_r of bearing series QJ3..-XL, bore code 5 to 14, with a bearing that is not of X-life quality



0019001D

C_r	Basic dynamic load rating
1	Bore code

2.8.2 Load carrying capacity

Due to the design of the rolling element raceways with their high raceway shoulders, the contact angle of 35° and the large number of rolling elements, four point contact bearings can support high axial loads with an alternating load direction.

2.8.3 Operating temperature

24 Possible operating temperatures for four point contact bearings

Bearing	Operating temperature	
	min.	max.
	°C	°C
Four point contact bearings with solid brass cages	–30	+150
Four point contact bearings with cages made from glass fibre reinforced polyamide	–	+110

2.8.4 Sealing

Four point contact bearings are not sealed.

2.8.5 Lubrication

Four point contact bearings are not greased and can be lubricated with grease or oil.

2.8.6 Bearing designation

43 Bearing designation

2.8.7 Further information

HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

medias | Product catalogue |
medias.schaeffler.com

2.9 Needle roller bearings

Needle roller bearings are rolling bearings with a low radial section height and high load carrying capacity, which are used as non-locating bearings and are part of the group of radial needle roller bearings. These bearings comprise machined outer rings, needle roller and cage assemblies and removable inner rings. This means that they can be supplied with or without an inner ring in accordance with the application. Unlike the outer cups of drawn cup needle roller cups, which are produced by forming methods, the bearing rings are machined. Due to their non-locating bearing function, the bearings cannot guide the shaft axially in either direction.

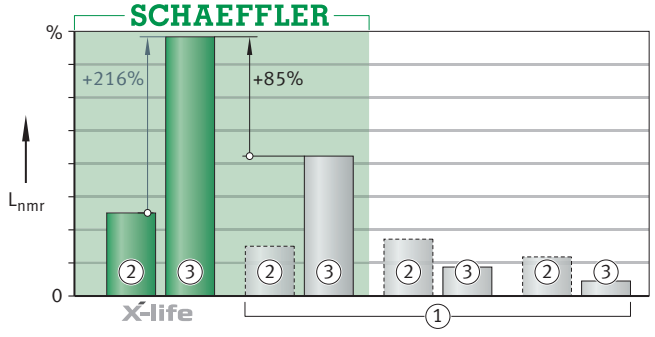
44 Needle roller bearings

00017B74

2.9.1 X-life

Many sizes of needle roller bearings are available in the X-life version. This stands for an optimised internal construction giving a basic load rating which is up to 25 % higher, as well as reduced friction and lower bearing temperature due to improved surface quality and contact geometry.

45 Calculated rating life and rating life verified in tests of X-life needle roller bearings in a comparison with bearings without X-life quality



0018FFFC

L_{nm}	Adjusted reference rating life		
1	Bearing without X-life quality	2	Calculated rating life
3	Rating life verified in tests		

2.9.2 Load carrying capacity

Radial needle roller bearings support very high radial forces due to the presence of line contact, but may only be subjected to purely radial load. If the bearing position is also required to support axial forces, the radial needle roller bearings can be combined, for example, with axial needle roller bearingsAXW. An extensive range of combined needle roller bearings is also available for combined loads.

2.9.3 Compensation of angular misalignments

Needle roller bearings are not suitable for compensating angular misalignments.

2.9.4 Operating temperature

25 Permissible operating temperatures for needle roller bearings

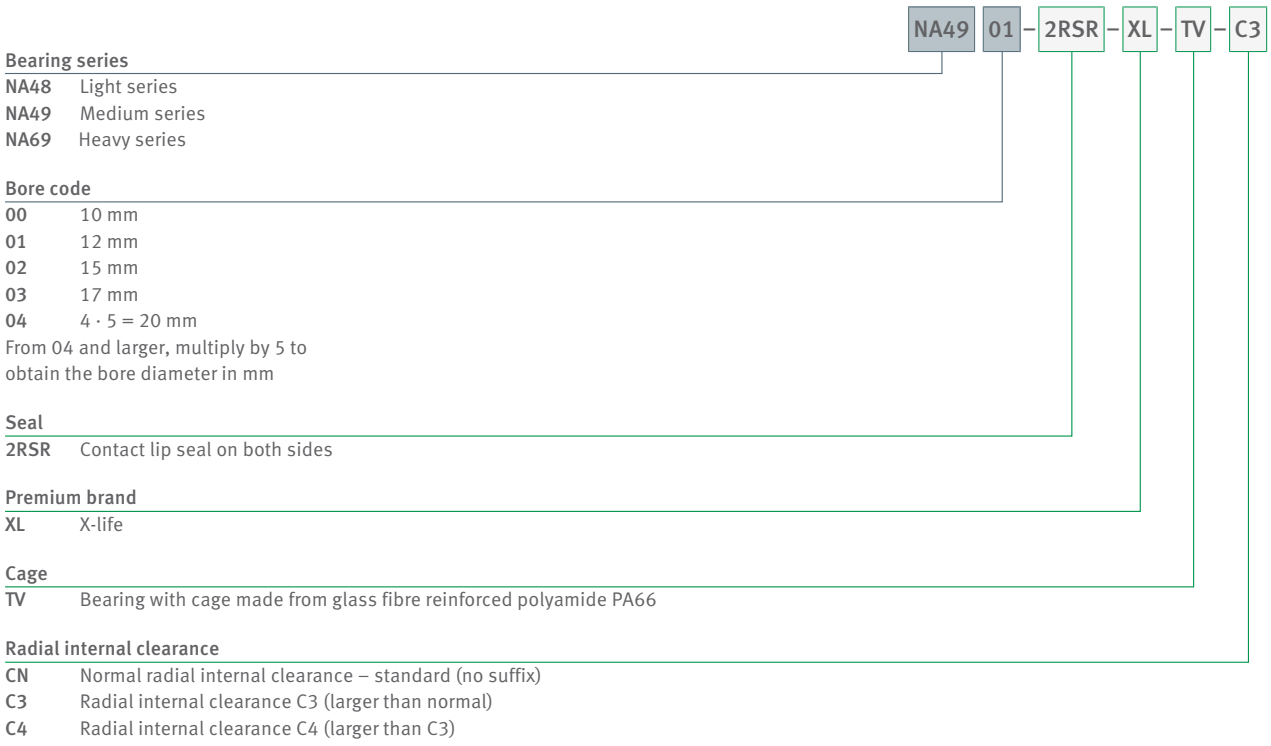
Bearing	Operating temperature	
	min.	max.
	°C	°C
Open bearings	–30	+120
Sealed bearings, including versions with plastic cage	–20	+120

2.9.5 Sealing

Needle roller bearings are available open or sealed. Under normal operating conditions, contact seals give protection against contamination, spray water and the loss of lubricant. The sealing material used is the oil-resistant and wear-resistant elastomer material NBR.

2.9.6 Bearing designation

46 Bearing designation



2.9.7 Further information

HR 1 | Rolling Bearings |
https://www.schaeffler.de/std/1D3D

medias | Product catalogue |
medias.schaeffler.com

2.10 Coatings for rolling bearings

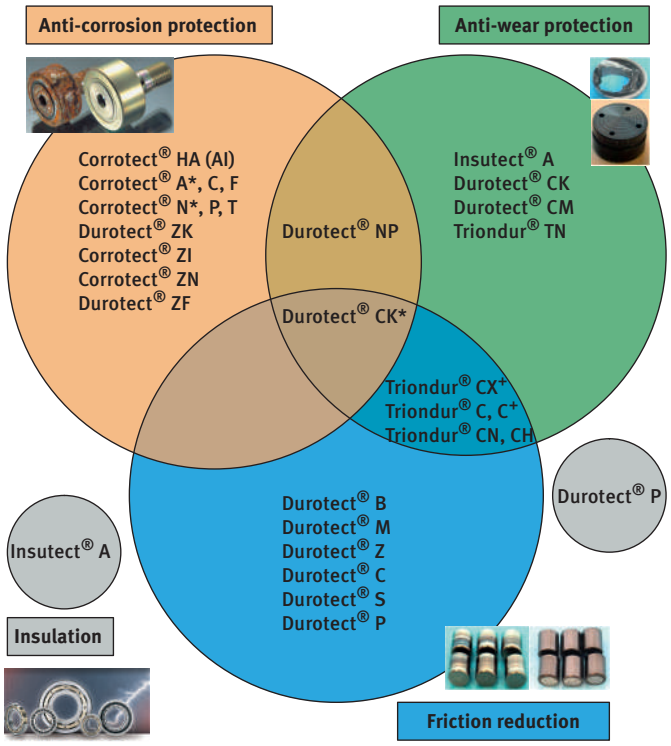
Bearings and precision components from Schaeffler offer high performance capacity and a long operating life, enabling fully developed and economical solutions to be achieved for most requirements. Nevertheless, operating conditions sometimes occur that are beyond the limits of the standard designs. In such cases, one of the very wide range of coatings available can be used as a solution to increase the operating life of a component.

2.10.1 Coatings

Coatings are applied to the surfaces of components without thermo-chemical diffusion taking place between the coating and the base material. At Schaeffler, a large number of coatings are used. They are applied by a wide variety of methods and give widely differing advantages for the component. They should always be individually matched to the mounting situation. In many cases, it is sufficient to coat only one of the components in rolling contact or only a part thereof.

Coatings can significantly increase the performance capacity of rolling or plain bearings. Under extreme conditions or in special applications in particular, the use of rolling bearings is only possible by means of coatings.

47 Coatings



Coatings can be used for the following purposes:

- to ensure electrical insulation where there is a risk of current passage
- to minimise friction (energy efficiency)
- to increase protection against corrosion
- to reduce wear under conditions of dry running

Depending on the intended purpose, Schaeffler can supply finish coated products. For example, a significant reduction in friction and can be achieved by using rolling bearings with a Triondur coating. In order to fulfil increasing requirements, our surface technology centre is continuously developing new coatings and the appropriate deposition methods. At present, a range of more than 40 different surface coatings is available.

2.10.2 Current-insulating bearings as a preventive measure

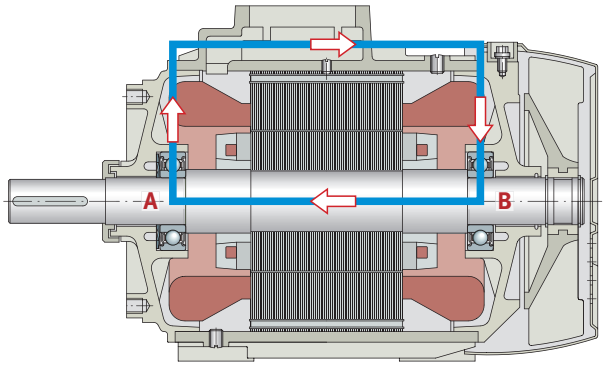
Depending on the motor, frequency converter and operating conditions, different types of unwanted electric currents can occur in the electric motor. Remedial measures should also be selected according to the cause. Particularly good results have been obtained with discharge elements, improved earthing and insulating rolling bearings. In general, a distinction is made between coated bearings, which have an insulating ceramic oxide coating on the inner or outer ring, and hybrid bearings, which have ceramic rolling elements. A brief explanation of which rolling bearing design can best reduce parasitic bearing currents is provided below.

Induced voltage along a shaft

An induced voltage along a shaft leads to a circuit that is completed via bearing 1, the housing and bearing 2.

The cause of such shaft voltage in very large motors or generators with a small number of poles is the magnetic asymmetries and, in motors operated with frequency converters (from a shaft height of 100), the housing ground current. Insutect rolling bearings from Schaeffler which feature a ceramic oxide layer, constitute an effective solution to these circuits which is easy to implement. In many cases, the bearing on the non-driven side is insulated.

48 Current flow due to induced voltage along a shaft



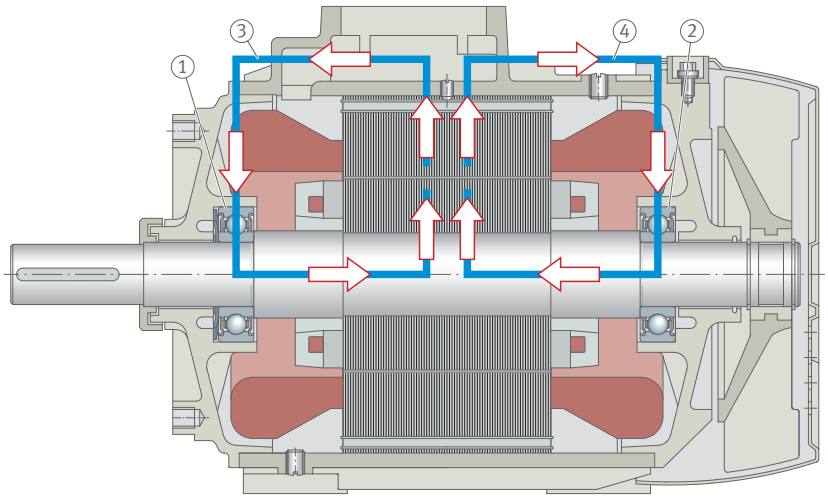
A	Bearing 1 (drive side)	B	Bearing 2 (non-driven side)

Current flow between shaft and housing

Common mode voltage is an unwanted occurrence in electric motors that are operated with frequency converters. This voltage, which is present between the shaft and housing, can lead to electrical discharge machining (EDM) currents, particularly in small electric motors with shaft heights of up to 280 mm, that can flow separately through each of the two bearings.

2 hybrid bearings with ceramic rolling elements and/or diversion solutions have proven to be effective remedies against EDM currents. Alternatively, a solution is also available in the form of an Insutect A coating, which must be selected in a suitable layer thickness. The motor and adjacent parts determine which is the better solution for the respective application.

49 Discharge currents



1	Bearing, drive end side	2	Bearing, fan side
3	Possible current path 1	4	Possible current path 2

Insutect-coated bearings

The very hard oxide ceramic coating with good thermal conductivity is usually applied to the outer ring of the bearing. The external dimensions of the current-insulated rolling bearings correspond to the standardised dimensions in accordance with DIN 616:2022 (ISO 15:2017), making them interchangeable with standard bearings. For use in pumps, the Insutect A coating with a layer thickness of 120 µm, suffix J20GA, has proven effective. Due to a special sealing process, this coating maintains an insulating effect even under high humidity conditions. The J20GB coating, also applied to the outer ring with a layer thickness of 200 µm provides even greater security, particularly against high-frequency currents.

Benefits:

- high insulation protection due to oxide ceramic coating
- J20GA coating thickness of 120 µm up to DC 3000 V
- Insutect coatings are established for open and sealed deep groove ball bearings as well as for cylindrical roller bearings.

Ordering designation:

- 6316-J20GA-C3

Hybrid bearings

In the smaller diameter range, hybrid bearings are the best remedial measure against damage from current passage. The rings of the hybrid bearings are made from rolling bearing steel, while the rolling elements are made from ceramic. In this application, the ceramic rolling elements take on the function of ensuring current insulation. Additionally, hybrid bearings offer further advantages over bearings with steel rolling elements.

Benefits:

- optimum insulation as a result of very high resistance to current passage
- higher speeds with lower friction and temperatures in operation
- better emergency running characteristics than standard bearings
- ceramic rolling elements which are extremely resistant to wear

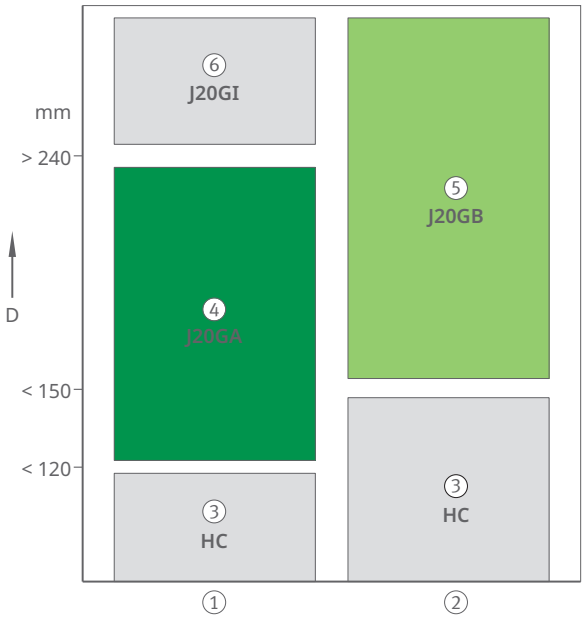
Hybrid bearings are identified by the prefix HC.

Ordering designation:

- HC6309-2Z-L207-C3

2.10.3 Standard recommendation for use

50 Recommendation for the use of current-insulated bearings



1	Electric motors for industrial applications	2	Traction motors and applications with increased requirements
3	Hybrid bearings, ceramic rolling elements	4	Ceramic oxide coating on outer ring (120 µm)
5	Ceramic oxide coating on outer ring (200 µm)	6	Ceramic oxide coating on inner ring (120 µm)

D	mm	Bearing outside diameter

2.10.4 Further information

TPI 67 | Corrotect Corrosion Protection Systems |
https://www.schaeffler.de/std/1FDD

TPI 186 | Surface Technology |
https://www.schaeffler.de/std/1F39

TPI 206 | Current-Insulated Bearings |
https://www.schaeffler.de/std/1FE8

medias | Stromisolierende Wälzlager
https://www.schaeffler.de/std/2024

3 Maintenance and servicing

3.1 Condition monitoring

With its Service Solutions, Schaeffler offers comprehensive solutions for the entire life cycle of rolling bearings, from intelligent condition monitoring and automatic lubricators through to Expert Services. The following options are available to help you operate your rolling bearings at optimal costs:

- Monitoring systems:
  - OPTIME:
    the inexpensive and wireless solution design specifically for ancillary units with constant operating conditions
  - SmartCheck and ProLink CMS:
    the solutions designed specifically for units with more demanding requirements
- Lubrication systems:
  - CONCEPT1:
    continuously lubricating single-point lubricators
  - OPTIME C1:
    inexpensive and wireless solution for monitoring single-point lubricators
  - CONCEPT series 2 to 8:
    piston-driven multi-point lubricators
- Expert Services:
  - temporary offline measurements
  - root cause and damage analyses including recommended actions
  - customer training

Advantages:

- lower costs
- reduced working time
- minimal risk
- user-friendly and safe working conditions
- optimal utilisation of service life
- less unplanned downtime
- innovative solutions, even for units where preventive or predictive measures have previously been too costly

3.1.1 Schaeffler OPTIME

The OPTIME system is a complete solution for the condition monitoring and lubrication of a large number of machines. With OPTIME, condition-based maintenance becomes economical even for subsystems, as unscheduled downtimes are avoided. The system detects damage to the respective components, such as pumps, electric motors and fans, as well as imbalances, misalignment and impacts, enabling warnings several weeks in advance.

To minimise the effort required on the part of the user for each individual process step, the following points were considered in particular during the development of the OPTIME systems:

- straightforward commissioning
- seamless expansion
- versatile application options

Advantages

- comprehensive and automated lubrication
- wireless IoT solution that can be extended at any time
- ability to integrate 100 units without issue in a single day
- up to 50 % lower costs compared with manual lubrication

The concept features special wireless OPTIME sensors which combine with the OPTIME gateway to form a mesh network. A further key component of the system are the associated services in the cloud, which use special algorithms based on Schaeffler know-how to carry out automated data evaluation.

51 OPTIME concept

00191E08

52 OPTIME

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The results can then be displayed on a user-specific basis in the OPTIME app and assist the user by prioritising notifications and with recommended actions.

The results are also available via the web-based dashboard, which can be used to conduct further analyses of time signals or spectra, for example, if required. Furthermore, the entire installation can be managed in the dashboard.

Further information

BA 68 | OPTIME Ecosystem: Condition monitoring |
https://www.schaeffler.de/std/1F40

Service Info | What is OPTIME and how does it work? |
https://www.schaeffler.de/std/1FF0

OPTIME | Ecosystem |
https://www.schaeffler.de/std/1FFF

FOT General | Condition Monitoring with Schaeffler OPTIME |
https://www.schaeffler.de/std/1FEF

3.1.2 Schaeffler SmartCheck

SmartCheck is a compact online measuring system for continuous machine monitoring.

53 SmartCheck

0018F062

Despite its compact size, SmartCheck is a complete monitoring device and includes an acceleration sensor and full electronic evaluation system.

The device can be mounted very easily on the unit to be monitored. Through the pre-installed measurement task and learning mode, simple units such as pumps, motors or fans can be monitored without any additional configuration. This measurement task can be adjusted and expanded at any time to accommodate changing requirements.

SmartCheck facilitates the following:

- correlation of machine parameters with process parameters
- condition-based maintenance
- increased plant availability

The optional interface in accordance with the OPC UA standard (Open Platform Communication Unified Architecture) standard allows all measurement data and alarm information to be easily transferred or integrated into the customer infrastructure. For example, the alarm system can be displayed in the system visualisation, or work orders can be triggered in a maintenance planning system.

Furthermore, an optional status can be sent cyclically or alarm-controlled to the maintenance personnel. The email can also be provided with measurement data and sent directly to Schaeffler Monitoring Services GmbH for detailed analysis.

The characteristic value set thus generated allows highly precise monitoring of the pump.

Further information

TPI 214 | Schaeffler SmartCheck |
https://www.schaeffler.de/std/1B6C

medias | Lifetime solutions
https://www.schaeffler.de/std/2037

3.1.3 ProLink Condition Monitoring System (CMS)

The ProLink Condition Monitoring System (CMS) from Schaeffler is a multi-channel system for monitoring complex machines or entire plant.

The ProLink CMS has a modular structure and consists of a main processor module for signal processing and up to four vibration modules for signal acquisition of machine vibrations.

Machine vibration is recorded using up to 16 acceleration sensors, digitalised in the vibration modules and sent to the processor module for evaluation.

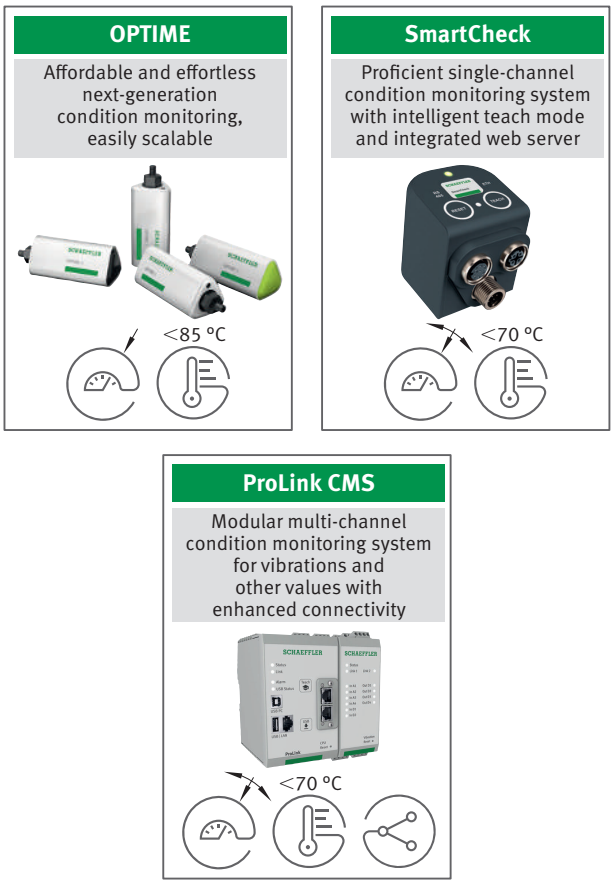
54 ProLink CMS

Thanks to its separate sensor technology, the ProLink CMS can be used wherever the use of OPTIME sensors or SmartCheck is not possible on account of the environment.

As with SmartCheck, a measurement task is also automatically pre-installed for each sensor in the ProLink CMS. The learning module makes it easy to get started in condition monitoring.

As integration into the customer infrastructure is particularly useful for a multi-channel system, optional functionalities such as OPC UA or email are also available in ProLink CMS.

55 Overview of OPTIME, SmartCheck and ProLink CMS



Further information

OPL | ProLink CMS - Systematic Condition Monitoring |
https://www.schaeffler.de/std/1FF4

Benutzerhandbuch | Schaeffler ProLink CMS |
https://www.schaeffler.de/std/1FF1

GTS 0129 | Integrated condition monitoring system for a water treatment facility |
https://www.schaeffler.de/std/1FF3

3.2 Relubrication systems

3.2.1 CONCEPT

Automatic lubricators

Almost 80 % of bearing damage can be traced back to problems with lubrication. These problems are often caused by the following:

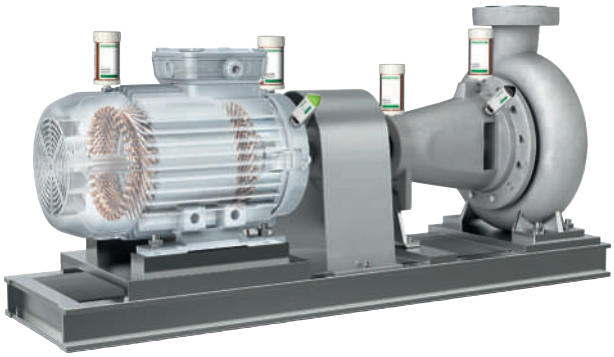
- grease ageing
- unsuitable grease quantities or grease types
- ingress of contaminants

With lubricators or lubrication systems, these causes can often be avoided and the bearings automatically supplied with the correct quantity of lubricant at the right intervals. Automatic lubricators significantly extend the life of rolling bearings. With automatic lubricators, fresh lubricant is conveyed in the defined quantity at the correct time to the contact points of the rolling bearing. The lubricators adhere to the lubrication intervals and prevent both under-supply and over-supply of grease. Plant downtime and maintenance costs are reduced as a result.

For hard-to-reach lubrication points, work is made easier than with manual lubrication and occupational safety is increased. The lubricators are selected in accordance with the bearing positions and are versatile in application, for example, in:

- electric motors
- gearboxes
- compressors and fans
- linear systems
- conveyor systems
- machine tools
- fluid pumps

56 Automatic lubricators on centrifugal pumps



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The portfolio ranges from the CONCEPT1 lubricator with a single-point lubrication connector through to the CONCEPT8 lubricator with 8 multi-point lubrication connectors.

57 Automatic lubricators

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1	CONCEPT1	2	CONCEPT2
3	CONCEPT4	4	CONCEPT8

Advantages of lubricators:

- suitable for hard-to-reach locations or ancillary equipment
- economical
- ready for immediate use due to simple installation
- flexible, as lubricators are pre-filled with Arcanol rolling bearing greases or available as empty devices for in-house filling
- device variants with up to 8 lubrication line outlets, expandable by means of sub-distributors
- continuous or piston-driven dispensing quantities
- increased bearing life by avoiding over-lubrication and under-lubrication and the resulting temperature increases in the bearing
- increased plant availability and reduced downtime costs
- reduced personnel costs
- variants with battery operation
- variants with DC 24 V mains operation
- variants with integrated gas drive unit
- wide operating temperature range
- reduced risk of contaminant ingress or of incorrect lubricant selection

Further information

FBS | Systematic Lubrication |
https://www.schaeffler.de/std/1F5C

ICA | ARCALUB.CONCEPT1 |
https://www.schaeffler.de/std/1F5D

ICB | ARCALUB CONCEPT2 |
https://www.schaeffler.de/std/1F7A

ICC | ARCALUB CONCEPT4 |
https://www.schaeffler.de/std/1F7B

ICD | ARCALUB CONCEPT8 |
https://www.schaeffler.de/std/1FF5

TPI 252 | Lubricators |
https://www.schaeffler.de/std/1D4E

Arcanol rolling bearing greases

The choice of the right lubricant plays a decisive role for electric machines. The Arcanol range from Schaeffler includes the rolling bearing grease MULTITOP, a high-quality standard lubricant that has proven effective for a variety of electric machines. For slightly higher temperature requirements, Arcanol TEMP90 or TEMP110 greases are suitable, guaranteeing extended relubrication intervals at high temperatures.

58 Arcanol rolling bearing greases

0018DA32

Further information

FAS | Arcanol Rolling Bearing Grease |
https://www.schaeffler.de/std/1F67

TPI 168 | Arcanol Rolling Bearing Greases |
https://www.schaeffler.de/std/1F66

TPI 176 | Lubrication of Rolling Bearings |
https://www.schaeffler.de/std/1F83

3.2.2 Schaeffler OPTIME

The OPTIME system is a complete solution for the condition monitoring and lubrication of a large number of machines. OPTIME makes automatic lubrication in maintenance even more cost-effective, as unplanned downtimes caused by over-lubrication or lubricant starvation are avoided. Furthermore OPTIME eliminates the need for regular rounds to check the lubricators. The OPTIME system warns the user if a lubricator is malfunctioning or when the CONCEPT1 lubricant cartridge needs replacing.

Particular consideration was given to the following points during the development of the OPTIME system:

- straightforward commissioning
- seamless expansion
- versatile application options

Advantages:

- comprehensive and automated lubrication
- wireless IoT solution that can be extended at any time
- ability to integrate 100 units without issue in a single day
- up to 50 % lower costs compared with manual lubrication

The effort required from the user is kept as low as possible at every process step. One component of the OPTIME system is the wireless OPTIME C1 lubricators, which are used with a CONCEPT1 cartridge and combine with the gateway to form a mesh network. OPTIME sensors can be integrated to expand the

mesh network. A further component of the OPTIME system is the associated cloud services, which allow the condition of the lubricators and the condition of the machines to be checked using a suitable end device via an app or dashboard.

59 OPTIME concept with OPTIME C1, OPTIME sensors, gateway and digital service

001AB2CE

Further information

CSS 0179 | No Surprises with the Lubricators |
https://www.schaeffler.de/std/1FF6

TPI 271 | Lubricator | OPTIME C1 |
https://www.schaeffler.de/std/1FC2

medias | Lifetime solutions
https://www.schaeffler.de/std/2037

3.2.3 OPTIME C1

OPTIME C1 is an easy-to-use and economical solution for automatic single point lubrication. OPTIME C1 represents a further expansion of the OPTIME system developed for the condition monitoring of rolling bearings and integrates the lubricators of the CONCEPT1 series.

During the development of the system, particular emphasis was placed on ensuring very simple start-up, easy scalability and a diverse range of potential uses. Every single process step was designed to minimise the effort required from the user. As a result of these characteristics, OPTIME is particularly suitable for the automated and economical monitoring and lubrication of a large number of machines.

Advantages of OPTIME C1:

- economical and reliable relubrication
- reduced number of failures and downtimes as a result of reliable lubrication
- hidden costs are avoided, as regular maintenance and inspection rounds are no longer required
- extended bearing life as a result of optimised and controlled lubrication
- guided and simple installation, commissioning and maintenance

60 OPTIME C1 with cartridge, gateway and digital service

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3.3 Mounting and dismounting of rolling bearings

3.3.1 Mounting made simple

The right mounting tools save time and reduce the risk of mounting errors to a minimum.

Schaeffler supports its customers during mounting with a range of products and services, including:

- a large selection of mounting and dismounting tools
- induction heating devices
- devices for optimal alignment of electric machines
- mounting service for particularly challenging projects

61 Mounting tools

00191ED5

Further information

MH 1 | Mounting Handbook |
https://www.schaeffler.de/std/1D53

OOS | E-Learning Training Course on medias-campus |
https://www.schaeffler.de/std/1FDC

PDB 31 | Products for Maintenance |
https://www.schaeffler.de/std/1FD5

OWT | Product Training Rolling and plain bearings |
https://www.schaeffler.de/std/1FF7

TPI 195 | Hydraulic Pumps |
https://www.schaeffler.de/std/1F8D

TPI 196 | Hydraulic Nut HYDNUT |
https://www.schaeffler.de/std/1FBE

TPI 216 | Tools for the Mechanical Mounting and Dismounting of Rolling Bearings |
https://www.schaeffler.de/std/1FDE

medias | Mounting
https://www.schaeffler.de/std/2043

3.3.2 Services

In addition to innovative solutions and products relating to rolling and plain bearings, Schaeffler offers a wide range of customer-specific services in the area of plant maintenance and quality assurance. This service portfolio includes:

- conducting routine measurements and routine inspections
- professional installation of delicate measurement technology
- troubleshooting and fault resolution on complex industrial plant
- comprehensive full-service packages

Always with the aim of helping customers save on maintenance costs, optimise plant availability and avoid unforeseen machine downtimes, our service experts support customers worldwide using state-of-the-art technology, for example through remote diagnosis via augmented reality. When personal intervention is required, our highly qualified technicians and engineers are ready to assist. Countless customers worldwide are already benefiting from the fast, reliable and professional service provided in close customer proximity.

The close cooperation with in-house rolling bearing design and direct access to the expert know-how of the application-specific engineering service, also allow condition analyses and condition diagnoses to be performed at a level that is unique to the market. This represents a considerable advantage in terms of results accuracy for our customers. Thanks to many years' experience and qualified experts, Schaeffler is the competent partner for customer-oriented solutions relating to the life cycle of rolling bearings.

62 Services

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3.3.3 Training

Schaeffler's training programme offers a large selection of product and analysis training. The training sessions are designed to specifically strengthen internal skills through practical, first-hand experience. The training sessions start with basic knowledge and an overview of the products that can be used. Advanced training sessions enhance theoretical know-how and complement it with practical exercises. These exercises prepare participants for having their condition monitoring knowledge tested and certified at various levels in certification courses according to DIN ISO 18426-2.

Further information

medias | Schaeffler Trainings
https://www.schaeffler.de/std/2033

3.4 Typical damage patterns and remedial measures

Rolling bearings are, along with sealing systems, among the most important components of a pump in terms of high reliability and long life. The end of a bearing's service life is reached when the following negative operational changes occur, leading to a loss of functionality:

- material fatigue
- wear
- thermal stress
- changes in the lubricant

Correct bearing selection and dimensioning must lead to a calculated rating life.

Examples of operating parameters used in the life calculation include the following:

- adjacent construction
- fits
- radial load and axial load
- speed
- temperature
- lubricant

Not all factors involved in the operation of rolling bearings are fully incorporated into the life calculation. As a result, the actual service life achieved may deviate from the calculated rating life in individual cases. An extreme deviation of the service life from the rating life indicates premature bearing damage. The cause of the bearing damage must be identified and a suitable remedial measure implemented.

Causes of bearing damage

- lubricant starvation
- unsuitable or aged lubricant
- inadequate cleanliness due to particles or undesirable media
- excessively high operating temperature, which has a negative impact on the lubricant and the material, particularly on the plastic cage or sealing material, for example
- temperature differences in the bearing rings affecting the operating clearance

- incorrect mounting
- shock loads and vibrations
- material fatigue
- electrical passage of current
- defective bearing location in the housing or on the shaft
- overload
- minimum load not reached

Types of bearing damage

- fatigue below and on the surface
- abrasive and adhesive wear
- corrosion due to moisture or frictional corrosion, such as fretting corrosion or false brinelling
- electrical erosion due to stray current or current passage
- plastic deformation due to overload or indentations caused by particles or handling errors
- forced rupture, fatigue fracture or hot cracking

To improve the overall service life of the electric machine, premature bearing damage should not be regarded as a total bearing failure. Bearing damage should be viewed as a reduction in the system's performance capability. A bearing can only run flawlessly if all operating and design influences are appropriately coordinated. In order to identify the cause and implement suitable remedial measures, all criteria must be considered, for example:

- lubrication
- temperatures
- sealing
- adjacent construction
- materials

The following tables provide an overview of possible influences and interrelationships in the development of bearing damage. Based on the damage patterns of failed bearings, potential causes can be derived and examined in more detail. Often, assigning the actual applicable damage hypothesis based on the removed, non-disassembled bearing is ambiguous. Therefore, a systematic approach must be taken when deriving the damage patterns to identify the actual cause of failure.

Further information

WL82102/2 | Rolling Bearing Damage |
https://www.schaeffler.de/std/1FF8

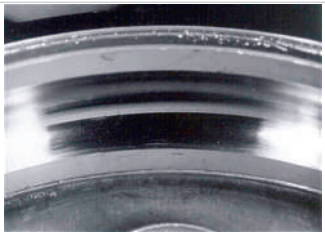
3.4.1 Sealing

26 Damage patterns due to incorrect sealing

	Contamination	Corrosion
		
Characteristics	Particle indentations on rolling elements and raceways. These become apparent during further operation in the form of increased noise, vibrations or surface-induced damage.	Red or brown spots or deposits on the rolling elements, raceways or rings. Increased vibrations followed by wear and deterioration.
Cause	Airborne dust, contaminants or abrasive substances from contaminated work areas, dirty hands or tools and foreign bodies in lubricants or cleaning solutions.	Damage to the bearings caused by aggressive media or environmental influences, formation of condensate due to temperature changes.
Remedy	Filter the lubricant, clean the work areas and store the bearings in their original packaging until fitting is due to take place. In the case of contaminated operating environments, sealing options should be considered.	Protect the bearing against aggressive media. Use bearings with integral seals and possibly external seals in particularly harsh environments.

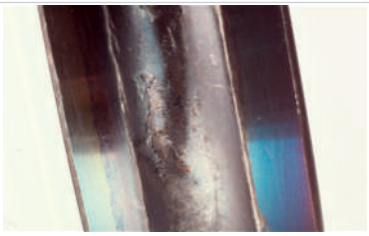
3.4.2 Current passage

27 Damage patterns due to current passage

	Matting of the raceway	False brinelling
		
Characteristics	Microscopically small melt craters on the raceway produce a greyish matt raceway.	Indentations running parallel to the axis in the single-digit µm range at seemingly regular intervals. In the application, these flutes lead to increased noise and a rise in temperature.
Cause	Depending on the motor, frequency converter and operating conditions, different types of unwanted, parasitic electric currents can occur in the electric motor. If these currents flow through the rolling bearing, the grease, rolling elements and raceways may become damaged above a certain current intensity.	Depending on the motor, frequency converter and operating conditions, different types of unwanted, parasitic electric currents can occur in the electric motor. If these currents flow through the rolling bearing, the grease, rolling elements and raceways may become damaged above a certain current intensity. Flutes only form above a certain current intensity.
Remedy	Depending on the type of electrical current involved (drive train system), derivation, earthing or insulation must be used to reduce or prevent the passage of current through the bearing. Current-insulating bearings, such as hybrid bearings with ceramic balls (prefix HC) or Insutect-coated bearings with a ceramic coating on the outside ring surfaces (e.g. with the suffix J20GA), provide an easily implemented insulation option.	Depending on the type of electrical current involved (drive train system), derivation, earthing or insulation should be used to reduce or prevent the passage of current through the bearing. Current-insulating bearings, such as hybrid bearings with ceramic balls (prefix HC) or Insutect-coated bearings with a ceramic coating on the outside ring surfaces, e.g. with the suffix J20GA or J20GB with double layer thickness, provide an easily implemented insulation option.

3.4.3 Lubrication

28 Damage patterns due to incorrect lubrication

	Lubricant failure	Micropitting
		
Characteristics	Dry running due to insufficient, unsuitable or aged lubricant.	Areas of the raceway surface exhibit a large number of extremely small, very flat material ruptures, which give the raceway a partially stained appearance. This is also described as grey staining.
Cause	Restricted lubricant flow or excessive temperatures, leading to deterioration of the lubricant.	Inadequate lubrication condition (type, quantity, contamination, particularly water) under moderate to low loads. Simultaneous occurrence of sliding motion.
Remedy	Use a suitable lubricant in the correct quantity, avoid grease loss and adhere to suitable relubrication intervals, e.g. by using CONCEPT lubricators and Arcanol rolling bearing greases. Ensure correct bearing seating and monitor preload to reduce the bearing temperature.	Ensure a separating lubricant film. Prevent contamination. Use suitable surface coatings, e.g. with suffix J30PE such as Durotect B.

3.4.4 Excessive load

29 Damage patterns under excessive load

	Overload	Material fatigue
		
Characteristics	Often starting with pressure-polished running marks. At the most heavily loaded points, conchiform flaking initially occurs, which can spread over the entire running surface during further operation.	Often referred to as peeling, emanating from cracks on or beneath the running surfaces. Removal of particles, usually starting with the inner ring. Rapidly propagating damage during further operation with significantly increasing vibrations and running noise.
Cause	Overloading of the bearing, sometimes combined with insufficient cleanliness or lubrication.	Overloading, excessive preload, excessively tight fits. The bearing's fatigue life has been reached.
Remedy	Use bearings with a higher basic load rating. Carry out design modifications. Reduce the load. Use rolling bearings of X-life quality.	Use rolling bearings of X-life quality. Optimise lubrication. Improve sealing and check or adjust the load situation.

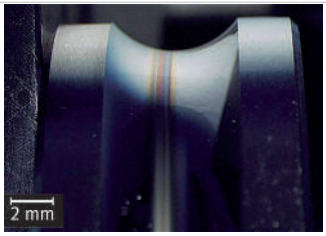
3.4.5 Insufficient load

30 Damage patterns under insufficient load

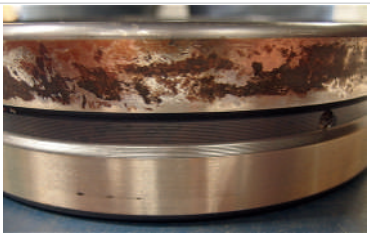
	Slippage marks
	
Characteristics	Patchy smearing or deep scratches in the material combined with micropitting of the rolling elements or raceways.
Cause	Due to insufficient load, the rolling elements do not roll on the raceways but slide over them. This is especially critical in combination with poor lubrication. Strong acceleration of the rolling elements on entering the load zone. Rapid changes in speed can also lead to slippage and consequently to surface-induced damage.
Remedy	Choose bearings with a lower load carrying capacity. Reduce bearing clearance. Improve lubrication. Choose bearings with ceramic rolling elements, indicated by the prefix HC. Choose rolling elements with a coating, e.g. Triondur C with the suffix J48BB.

3.4.6 Design considerations

31 Damage patterns due to design considerations

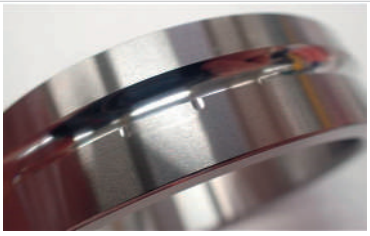
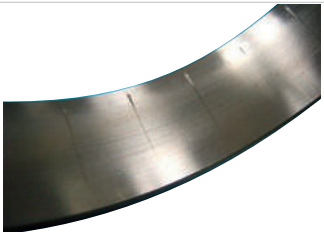
	Hot running	Excessive preload
		
Characteristics	Discolouration of the rings, rolling elements and cages from gold to blue. Temperatures above +150 °C can change the ring and rolling element materials. These changes can reduce the bearing load carrying capacity and potentially lead to premature failures. An increase in temperature has a detrimental effect on lubrication.	Distinct running mark due to forced guidance on the raceway floor. This can lead to overheating and consequently cause the bearing to jam.
Cause	Tight fits. Insufficient radial internal clearance or operating clearance. Excessive speeds or load. Inadequate heat dissipation and lubrication issues.	Preload in the bearing. Excessively tight fit. Insufficient radial internal clearance. Housing issues, e.g. roundness or stiffness.
Remedy	Higher radial internal clearance. Select suitable bearings in terms of speeds and loads. Appropriate heat dissipation.	Alter the fits. Higher radial internal clearance.

32 Damage patterns due to design considerations

	Fretting corrosion	Co-rotating rings
		
Characteristics	Reddish or black spots on the outside surface, bore or lateral faces of the bearing. These spots are oxidised wear particles. They lead to uneven seating conditions, possibly to fatigue fractures and malfunction of the non-locating bearing function.	Incipient to severe wear on the seating surface of the inner and outer ring.
Cause	Micromovements between the matched parts, with fits which are excessively loose relative to the acting forces and the presence of moisture.	Excessively loose fit or insufficient consideration of the operating conditions.
Remedy	Observe mounting specifications and fit recommendations, using a tighter fit if necessary.	Modify fits on the shaft or housing, using a tighter fit if necessary. Adjust the radial internal clearance as needed.

3.4.7 Mounting

33 Damage patterns due to fitting

	Rolling element indentations on ball bearings	Mounting-induced score marks on cylindrical roller bearings
		
Characteristics	Mounting marks appear as plastic deformations, corresponding to the spacing of the rolling elements, in the raceways. This leads to increased bearing vibrations and noise. Severe indentations can result in premature failure due to fatigue or fractures.	Score marks running parallel to the axis, typically on the inner ring. Preliminary damage prior to commissioning.
Cause	Static overloading of the bearing or significant application of force to the bearing, for example, from using a hammer during fitting, dropping or knocking the mounted parts or pressing a bearing onto the shaft by applying force to the inner ring.	Incorrect mounting of the loose ring in the cylindrical roller bearing.
Remedy	Fit the bearing using suitable equipment. Apply force only to the ring that is to be pressed in.	Mount the loose ring under rotation. If necessary, heat the bearing components.

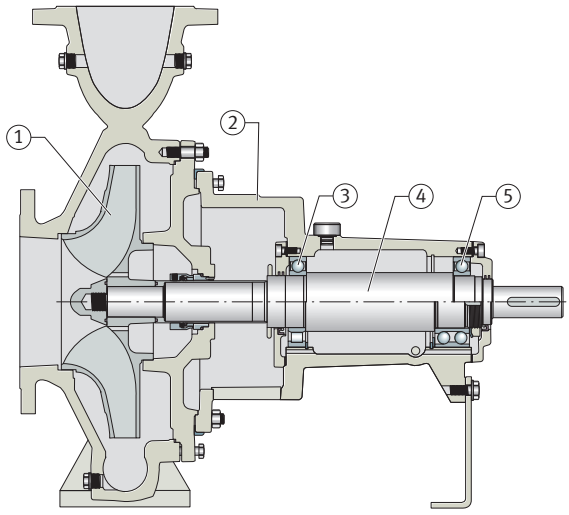
4 Application examples

4.1 Chemical standard pump

The designation “chemical standard pump” refers principally not to the fluid conveyed but to the fact that the pumps correspond to the requirements for dimensions and power ratings in the standard ISO 2858. However, chemical standard pumps often also need to meet additional standards, such as ISO 5199 (EN 25199). These specifications allow pumps from different manufacturers to be easily fitted and interchanged within an existing pipework system.

The widely varying areas of application include not only the chemical and petrochemical industry but also, for example, the food industry. The fluids conveyed thus vary considerably and, in some cases, differ significantly in their characteristics. The structure of the pump corresponds to a single stage, single flow centrifugal pump.

63 Bearing arrangement of a chemical standard pump



1	Impeller	2	Housing
3	Non-locating bearing	4	Shaft
5	Locating bearing		

The standardisation of standard chemical pumps results in certain requirements and restrictions that differ as a function of the power and size of the pumps. The specifications in the standards also affect the bearing positions. For example, ISO 2858 specifies the diameter of the shaft end and thus the minimum bearing diameter as a function of the power rating.

Under normal conditions, no additional shocks or similar phenomena occur aside from the operating forces. Chemical standard pumps are operated at speeds up to 3600 min^{-1}. However, the speed can also be matched to the current requirements by means of an optional frequency inverter.

Standards such as EN 22858, for example, focus on mounting dimensions, interchangeability and availability of replacement parts. Other standards also provide more detailed specifications for the design of the pump bearing arrangement. ISO 5199, Technical specifications for centrifugal pumps – Class II, and the American ASME/ANSI B73.1, Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process, are similar in terms of design specifications for the adjacent construction and sealing of the bearing arrangement.

Specifications that must be considered in rolling bearing design and design of the adjacent construction:

- basic rating life $L_{10\,h}$ > 17500 h
- adherence to limit values for shaft deflection and shaft run-out by means of a suitable bearing arrangement
- The bearings must be axially secured in the corresponding housing or adjacent construction using shaft locknuts, shaft shoulders and bearing covers.

The bearing position is protected against the ingress of contaminants by labyrinth seals.

A locating/non-locating bearing arrangement is typically used in chemical standard pumps.

The radial loads on the non-locating bearing can be supported by a deep groove ball bearing without axial retention. In many cases, a cylindrical roller bearing of NU design is used, which has no rib on the inner ring, allowing for axial displacement. The remaining radial forces and additionally the axial forces are supported by the locating bearing on the drive side.

This can be achieved by means of double row angular contact ball bearings or matched pairs of single row angular contact ball bearings. In addition to this bearing arrangement, special solutions such as a floating bearing arrangement with two deep groove ball bearings can also be considered. The use of this arrangement is generally more economical but also gives less accurate guidance of the shaft.

Lubrication of the bearing positions can be carried out with either oil or grease lubrication.

The following bearings are used in chemical standard pumps:

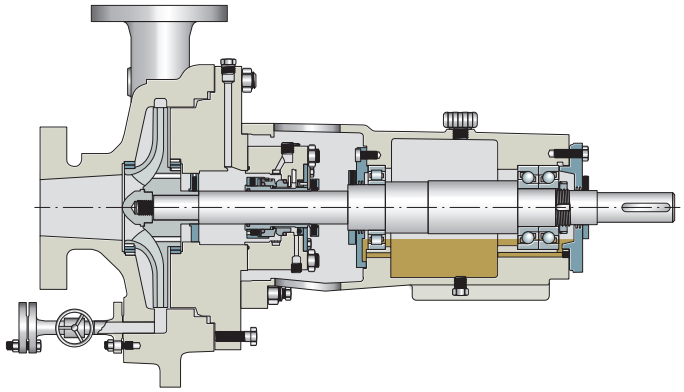
- single-row deep groove ball bearings
- single row and double row angular contact ball bearings
- cylindrical roller bearings

4.2 Process pump according to API 610

Against the background of heavy-duty operation and high-temperature applications, API 610 imposes extensive, tight and high demands on the design of rolling bearings.

- Since leakage cannot be tolerated when transporting potentially hazardous media, special sealing solutions are used.
- In terms of sealing, labyrinth seals are stipulated for the bearing housings and mechanical seals for the pump housings.
- The demanding and, in some cases, very large mechanical seals result in an increased bearing distance from the impeller and thus in a greater moment load.
- system life > 25000 h for nominal load (rated)
- system life > 16000 h for maximum load

64 Bearing arrangement of a chemical standard pump according to API 610



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The example provided shows the non-locating bearing on the pump side. Cylindrical roller bearings of width series NU2 or NU3 are used due to their high load carrying capacity and rigid bearing design. As metal cages are stipulated and solid designs are recommended, solid brass cages are used. The standard-compliant locating bearing is shown on the drive side. Here, a matched pair of angular contact ball bearings in an O arrangement (stipulated in the standard!) and produced to internal clearance class UA or UB is used, which is highly suitable for supporting axial forces due to the 40° contact angle.

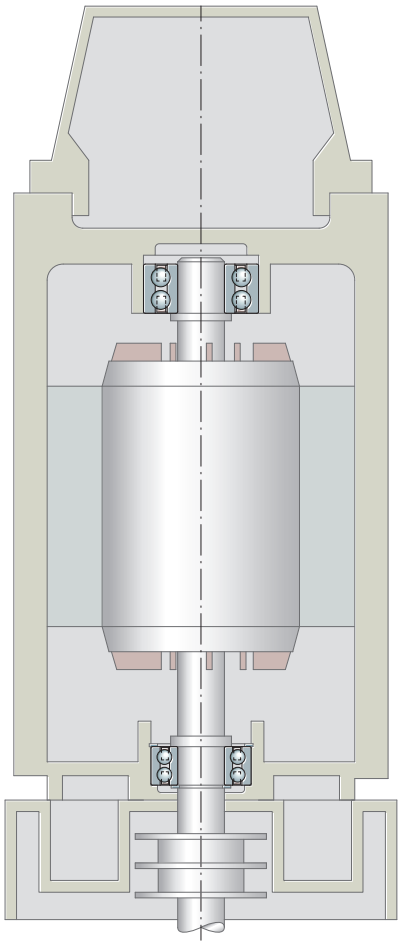
4.3 Submersible pump

Submersible pumps are centrifugal pumps that are either transportable or permanently installed. They convey the maximum amount of fluid but build up only a low pressure level.

Their area of application lies principally in the removal and transport of water and contaminated water, for example in the drainage of buildings or removal of water from rivers and containers. This involves submerging the entire unit in the liquid, thereby eliminating the need for a suction line.

Submersible pumps differ from the basic centrifugal pump design in that they are normally fitted with a vertical shaft on which the drive motor is mounted directly (block construction). The electric motor is encapsulated in the design. The drive train is designed without a coupling and the electric motor rotor runs directly on the pump shaft.

65 Bearing arrangement of a submersible pump



Requirements for rolling bearing design and arrangement:

- The rigidity of the shaft and bearing arrangement is subject to higher requirements due to the motor gap.
- To optimally support the rotor, it is arranged between the two bearing positions.

The relevant forces for the bearing arrangement in a submersible pump are determined not only by operation of the pump but also by its design. During operation, in addition to loads generated by pressure generation, slight shocks resulting from waste water containing solid particles may also occur.

As a result of the design structure, axial loads occur due to the mass forces of the vertical shaft and the rotor mounted on the shaft. The speed range of such units is normally up to 3600 min^{-1}.

In order to achieve an efficient, reliable and maintenance-free shaft bearing arrangement, a locating/non-locating bearing arrangement comprising robust, sealed bearings lubricated for life is normally used.

In the example shown, the locating bearing in the lower bearing position is designed as a double row angular contact ball bearing. The small manufacturing tolerances of the bearings ensure particularly precise guidance of the impeller, leading to small gap dimensions and thus also to reduced losses. Due to its contact angle, the angular contact ball bearing is highly suitable for supporting axial loads.

The function of the non-locating bearing is also performed by a double row angular contact ball bearing here, but one that is not axially retained. This lack of axial retention allows for bearing displacement where there is thermal expansion of the shaft.

The identical bearing design gives advantages in terms of standardisation. An alternative to a perfect non-locating bearing function would be a cylindrical roller bearing. However, the low radial load needs to be considered here. A narrow series must be selected to avoid the risk of slippage. Series NU10 is highly suitable here due to the non-reinforced version corresponding to suffix -E.

For smaller pumps, the bearings in these applications are sealed and lubricated for life, while the bearing positions for larger units must have relubrication facilities. Due to the vertical shaft, oil lubrication is not possible.

Common rolling bearing types for submersible pumps:

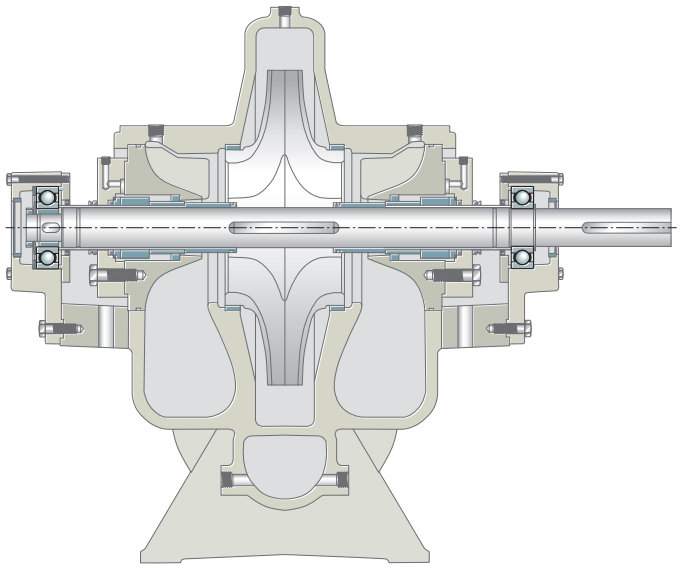
- single-row deep groove ball bearings
- single row and double row angular contact ball bearings
- cylindrical roller bearings

4.4 Double flow pump

The double flow pump contains two single flow impellers arranged back to back, improving the suction behaviour of the pump through this symmetrical design. While the pumping head remains constant due to the parallel arrangement, the volume flow doubles.

Compared to a single flow pump, a double flow pump can be operated at significantly lower supply pressures. This design is used in pipelines for drinking water supply, in cooling water supply as well as in district heating networks or fire protection systems.

66 Bearing arrangement of a double flow pump



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Requirements for pump and rolling bearing design:

- very high demands on operational reliability
- minimal maintenance work
- double volute housing to minimise radial hydraulic forces
- longitudinally split housing for efficient maintenance, allowing the housing to be opened without dismantling the drive train, bearing arrangement and pipework
- impeller supported on both sides for minimal shaft deflection
- minimal seal wear
- long rolling bearing life

Due to the symmetrical design of the impeller, the axial forces compensate each other almost completely. However, the higher impeller mass, especially in large pumps, can lead to increased shaft deflection.

The use of a double volute housing in the example shown ensures reduced deflection of the shaft and reduces the radial loads occurring. If the units are correctly installed, the pumps can be expected to give uniform, shock-free operation.

In contrast to the overhung bearing arrangement used in submersible pumps and chemical standard pumps, the impeller in a double flow pump is normally located between the two bearing positions.

As a result, the radial loads occurring are distributed more uniformly over the relevant bearings. Due to the symmetry of the impeller, the axial loads are almost zero. The bearing arrangement suitable for double flow pumps is a combination of locating bearing and non-locating bearing.

As a result of the low axial load, the locating bearing can be mounted on either the drive side or the pump side.

For lower loads, single row deep groove ball bearings can be used at both bearing positions, as their generously dimensioned shafts provide sufficient basic load ratings over the specified bore diameter. In order to ensure a displacement facility on the non-locating bearing side, the corresponding bearing must be free of axial retention at this point. Where larger forces occur, single row or double row angular contact ball bearings are used as locating bearings.

In terms of lubrication, common methods include oil sumps with ring oil lubrication or grease lubrication, for which a relubrication facility is provided. The CONCEPT lubricators are particularly suitable for this application.

Common rolling bearing types for double flow pumps:

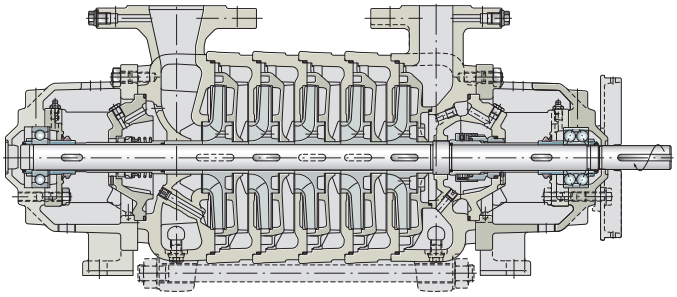
- single-row deep groove ball bearings
- single row and double row angular contact ball bearings

In addition to these rolling bearings, it is possible to use other bearing solutions, such as those with split bearing rings to allow easier assembly in large pumps. These are matched to the relevant requirements and are designed specially for these cases. For further assistance, please contact Schaeffler External Sales.

4.5 Multi-stage centrifugal pump

Multi-stage centrifugal pumps are used in process technology to achieve extremely high pressures. For this purpose, several single-flow stages are connected in series, arranged on a modular basis on a pump shaft and connected using tie rods. As the hydraulic forces of the individual stages mount up, an axial bearing arrangement is no longer capable of supporting them above a certain ratio. This is avoided in the design by arranging the impellers of successive stages in a counter-rotating (back-to-back) configuration. However, this requires a more elaborate system for guiding the flow. Alternatively, a compensating mechanism can be provided to equalise the axial forces on the bearings.

67 Bearing arrangement of a multi-stage centrifugal pump



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In the illustrated example, this is resolved in the design by a sealing gap in the impeller side chamber on the pressure side and by compensating holes in the impeller. With good thrust compensation, the demands on the bearings are manageable. However, the long pump shaft requires support on both sides, implemented as a locating/non-locating bearing arrangement with a deep groove ball bearing and two angular contact ball bearings.

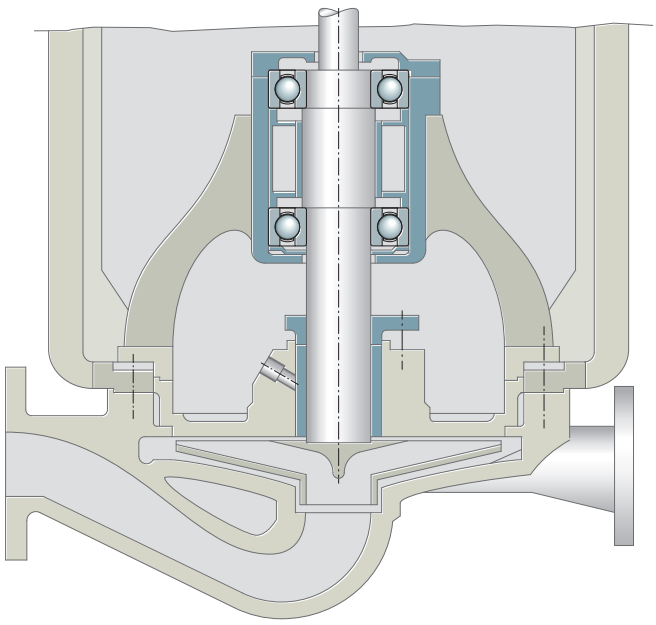
For the non-locating bearing, shown on the left in the example, which comprises a deep groove ball bearing of series 63 or 62, with the outer ring sliding in the housing, appropriate fit selection is required.

For the locating bearing, either double row angular contact ball bearings or single row angular contact ball bearings in an adjusted design can be used, depending on the requirements. The double row angular contact ball bearings shown can be operated with CN clearance, with a tight fit and slight bearing clearance through to light preload, enabling close axial guidance of the impellers in the housing.

4.6 Inline pump

In inline pumps, the suction and discharge nozzles lie in a straight line of piping. These pumps are used as pipeline pumps in building technology or industrial applications.

68 Bearing arrangement of an inline pump



Requirements for the rolling bearing design:

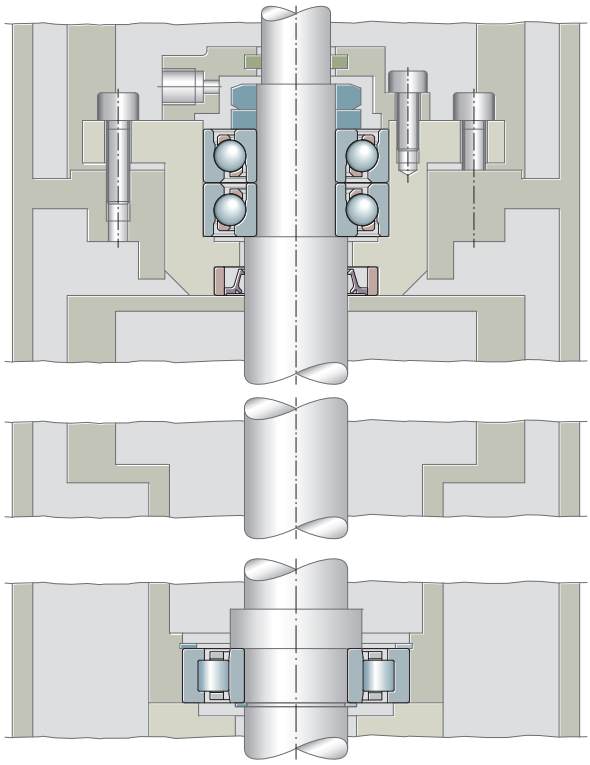
- Pumps with a rigid coupling use the electric motor bearing arrangement, where necessary in a reinforced design, to give better support of axial load or transverse forces.
- When using a flexible coupling, such as the API class OH3 vertical inline pump, a dedicated pump bearing arrangement is required.
- suitability for flexible installation of the pump, in both a horizontal and vertical arrangement

The example shows a bearing arrangement with two deep groove ball bearings of series 63. Both the non-locating bearing with the outer ring sliding in the housing and the locating bearing for supporting axial forces are greased for-life and sealed with 2Z seals. This design is usually sufficient for standard requirements. Additionally, grease lubrication also offers the advantage over oil lubrication of enabling either horizontal or vertical installation without the need for design changes. A spring adjustment is provided for the bearing to the impeller, allowing clearance-free setting for this during installation.

4.7 Shaft-driven submersible pump

In vertical immersion pumps, the extended pump shaft allows the impeller to be immersed in the fluid, while the pump itself is mounted much higher, such as on a shaft. As the pump is not completely submerged, there is no need for complex shaft seals to prevent penetration of the medium.

69 Bearing arrangement of a shaft-driven submersible pump



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Requirements for the pump and rolling bearings:

- transport of aggressive media
- reinforced, generously dimensioned pump shaft due to high tilting moments

The example shows the locating bearing on the drive side (upper position). Angular contact ball bearings of series 73, in universal design and O arrangement, with clearance class UA or UB are highly suitable for supporting axial forces due to their 40° contact angle. In addition to the radial rigidity provided by its design, the non-locating bearing – an NU10 cylindrical roller bearing in the lower position – also provides a non-locating bearing function that is free of axial forces.

Due to the vertical arrangement, the bearing arrangements are lubricated with grease and require the provision of an appropriate relubrication facility. The CONCEPT lubricators are particularly suitable for this application.

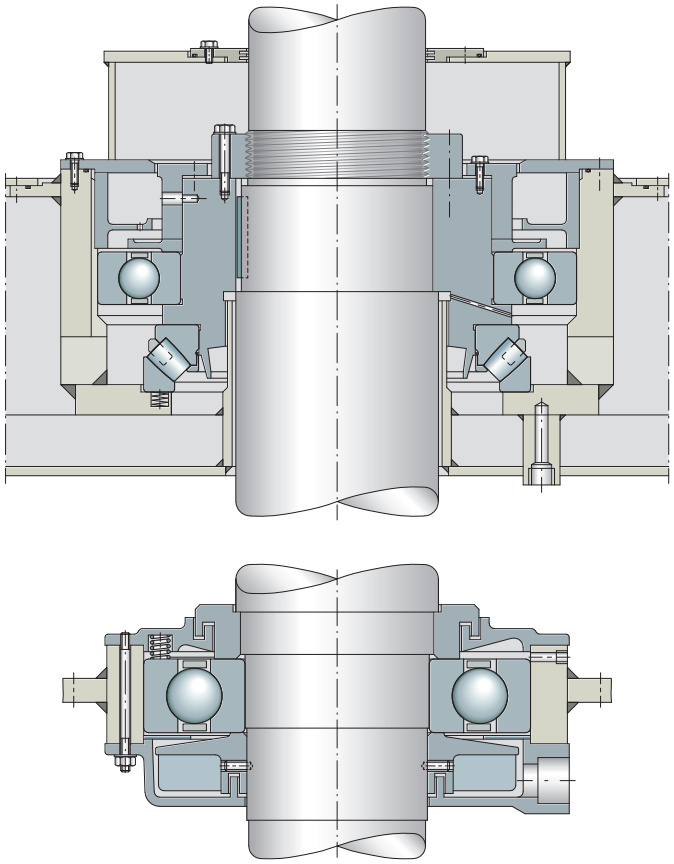
4.8 Multi-stage borehole pump

Borehole pumps are multi-stage, shaft-driven submersible pumps for pump sumps located deep underground. They are used in irrigation, water extraction, cooling towers and other similar applications.

Requirements for the pump and rolling bearings:

- The long pump shaft requires intermediate support of the radial force, which is fulfilled by the design in the form of water-lubricated plain bushes.
- A rigid coupling is typically used on the drive.
- The high axial weight force of the rotor and the axial hydraulic force are usually supported by the motor bearing arrangement.

70 Bearing arrangement of a borehole pump



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The motor bearing arrangement shown is implemented in flanged housing units on the motor housing.

In order that the high axial forces occurring in the main load direction can be reliably supported, axial spherical roller bearings with a very high axial load carrying capacity are mounted in the upper position. A deep groove ball bearing is also required in order to achieve the radial guidance accuracy. Axial spherical roller bearings offer many advantages; however, due to their kinematics, oil lubrication is necessary. This requires a complex housing design to provide both sealing and oil circulation for the two bearings at this position.

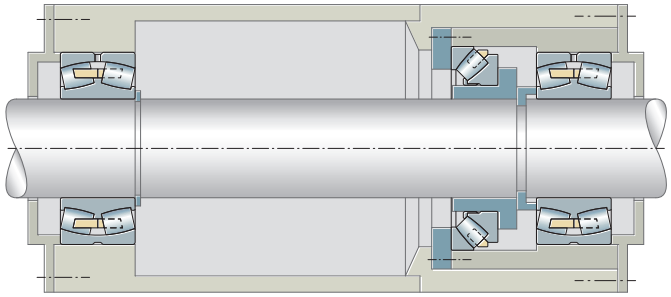
Spring-adjusted deep groove ball bearings are used in the lower position for both axial counter-guidance and radial guidance of the motor forces. Spring adjustment is required here for clearance-free operation.

Schaeffler supplies manufacturers of electric machines with oil-lubricated, flanged housing units, which are designed for specific projects. These offer the advantage of a holistic concept, as they consider not only the housing but also the rolling bearings, lubrication and sealing solution.

4.9 Solids handling pump

Some solids handling pumps are designed as very large units, in order to achieve high delivery volumes for fluids containing solids. Areas of application include dredging, conveying equipment and mining.

71 Bearing arrangement of a solids handling pump



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Requirements for the pump and rolling bearings:

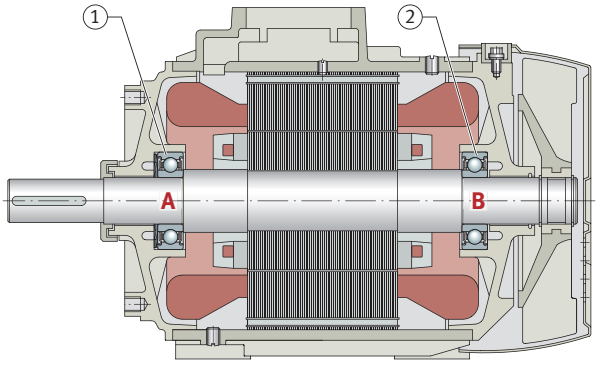
- high imbalance forces due to weight and wear, as well as shock loads
- robust bearing arrangement in a dedicated bearing housing

As a result of the high radial loads and overhung bearing arrangement, the locating/non-locating bearing arrangement is designed using two radial spherical roller bearings, with the non-locating bearing mounted in a radially free position in the housing. The locating bearing position with separate, spring-preloaded axial bearing arrangement is realised using axial spherical roller bearings in the main load direction. The preload is required to ensure the minimum load in load-free operation. Axial counter-guidance during load changes is provided by the radial spherical roller bearing. Double row tapered roller bearings capable of supporting combined axial and radial loads can be used as an alternative.

4.10 Three-phase motor

A current-insulated FAG 6316-J20GA-C3 deep groove ball bearing is fitted on the ventilation side of a three-phase motor controlled by a frequency converter. On the drive side, an FAG 6320-C3 deep groove ball bearing is fitted. The current-insulated deep groove ball bearing interrupts the flow of current that is generated by the induced voltage along the shaft. Both bearings are lubricated using grease. In the example shown, a relubrication facility is provided, for which our CONCEPT lubricators are particularly suitable.

72 Bearing arrangement of a three-phase motor



A	Drive side	B	Ventilation side
1	Deep groove ball bearingFAG 6320-C3	2	Deep groove ball bearing FAG 6316-J20GA-C3

This example focuses on the topic of “current-insulated” bearings. A large proportion of the bearing arrangements used in electric motors are achieved using sealed ball bearings of series 60 and 62 with for-life lubrication, combined with C3 radial internal clearance and special grease application. To ensure availability, especially for smaller aftermarket requirements, the current-insulated versions with suffix J20GA are a constituent part of our preferred product range.

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