



FAG



Rolling Bearing Competence for Fluid Pumps

SCHAEFFLER

Foreword

Schaeffler is a leading worldwide supplier of rolling bearings (standard and special bearings), plain bearings, accessories specific to bearings and comprehensive maintenance products and services. Schaeffler offers solutions based on approximately 225 000 products for more than 40 000 customers and has an extremely wide portfolio that gives secure coverage of applications from more than 60 industrial market sectors.

Economical solutions for fluid pumps

Schaeffler offers manufacturers of fluid pumps a comprehensive range of precision products for the reliable application of bearings for rotary motion. In this field, there is an ever increasing demand for innovative and economical solutions. As a result, it is becoming increasingly important to find precisely matched system solutions on the basis of high quality standard bearings.

This development is also reflected in this publication, in which you will also find application examples with customised solutions for fluid pumps.

Classification of fluid pumps

Fluid pumps are essentially classified in accordance with their functional principle:

- dynamic pumps
- displacement pumps
- other pumps.

This publication mainly covers rolling bearings for centrifugal pumps operating on the flow principle. Bearing solutions and bearing concepts are, however, also available for other types of pumps.

Energy-efficient bearing arrangements

The energy consumption of machines can be reduced by smaller masses and lower friction. Schaeffler is also developing new bearings and units in line with this principle.

The latest calculation tools can be used to compare and optimise the frictional performance of bearing arrangements as early as the development stage. This means that pump manufacturers can save time and development costs.

Development partners

The engineers in our Application Engineering and External Sales functions are available to support you as a development partner worldwide, so that your pumps operate more effectively, more reliably and also more economically.

This publication gives an overview of various rolling bearings that can be fitted in an application-oriented sense in fluid pumps. Fluid pumps themselves are subjected to widely varying operating conditions in their different areas of application. The selection of bearings is influenced by not only the type of operation but also other factors.

Foreword

Rolling bearings catalogue HR 1

Catalogue HR 1, Rolling Bearings, describes the rolling bearings in accordance with DIN ISO that are required for original equipment manufacture, distribution and the aftermarket, specific rolling bearing accessories and further rolling bearing types and design variants.

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

Global Technology Network

In the Global Technology Network, Schaeffler combines its local competence in the regions with the knowledge and innovative strength of its experts worldwide. With our local centres of competence known as “Schaeffler Technology Centers”, we bring our portfolio of services and our engineering and service expertise directly to your area. Through this combination, you will experience optimum support anywhere in the world and, thanks to our bundled knowledge, innovative and customised solutions of the highest quality. This makes it possible to achieve sustainable reductions in the overall costs of your machinery and plant and thus improvements in efficiency and competitiveness.



Figure 1
Our portfolio

Further information

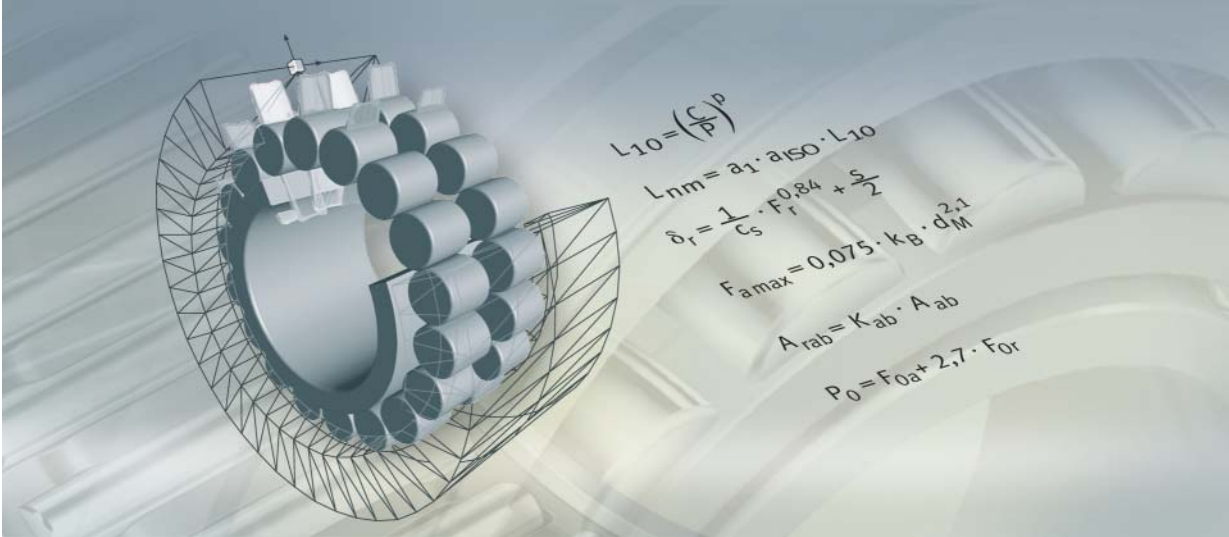
- www.schaeffler.com/gtn
- <http://medien.schaeffler.com>

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Technical principles

Dynamic load carrying capacity and life

Selection of bearing arrangement

Principles and requirements

Design example

Dynamic load carrying capacity and 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, based on DIN ISO 281, and the basic rating life.

The fatigue life is dependent on:

- load
- operating speed
- the statistical probability of the first appearance of failure.

The basic dynamic load rating C applies to rotating rolling bearings. It is:

- a constant radial load C_r for radial bearings
- a constant, concentrically acting axial load C_a for axial bearings.

The basic dynamic load rating C indicates the load of constant magnitude and direction that a sufficiently large number of apparently identical bearings can endure for a basic rating life of one million revolutions.

Dimensioning of rolling bearings

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

- rating life
- load carrying capacity
- operational reliability.

Calculation of the rating life

Calculation methods

Methods for calculating the rating life include the following:

- 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.

Basic rating life

The basic rating life L_{10} and L_{10h} is determined as follows:

$$L_{10} = \left(\frac{C}{P} \right)^p$$

$$L_{10h} = \frac{16\,666}{n} \cdot \left(\frac{C}{P} \right)^p$$

L_{10} 10⁶ revolutions

The basic rating life in millions of revolutions is the life reached or exceeded by 90% of a sufficiently large group of apparently identical bearings before the first evidence of material fatigue develops

L_{10h} h

The basic rating life in operating hours according to the definition for L_{10}

C N

Basic dynamic load rating

P N

Equivalent dynamic bearing load for radial and axial bearings

p –

Life exponent;

for roller bearings: $p = 10/3$

for ball bearings: $p = 3$

n min⁻¹

Operating speed.

Dynamic load carrying capacity and life

Equivalent dynamic bearing load

The equivalent dynamic load P is a calculated value. This value is constant in magnitude and direction; it is a radial load for radial bearings and an axial load for axial bearings.

A load corresponding to P will give the same rating life as the combined load occurring in practice.

$$P = X \cdot F_r + Y \cdot F_a$$

P	N
Equivalent dynamic bearing load	
X	—
Radial factor given in the dimension tables or product description	
F _r	N
Radial dynamic bearing load	
Y	—
Axial factor given in the dimension tables or product description	
F _a	N
Axial dynamic bearing load.	



This calculation cannot be applied to radial needle roller bearings, axial needle roller bearings and axial cylindrical roller bearings. Combined loads are not permissible with these bearings.

For radial needle roller bearings under purely radial load, $P = F_r$, for axial needle roller bearings and axial cylindrical roller bearings under purely axial load, $P = F_a$.

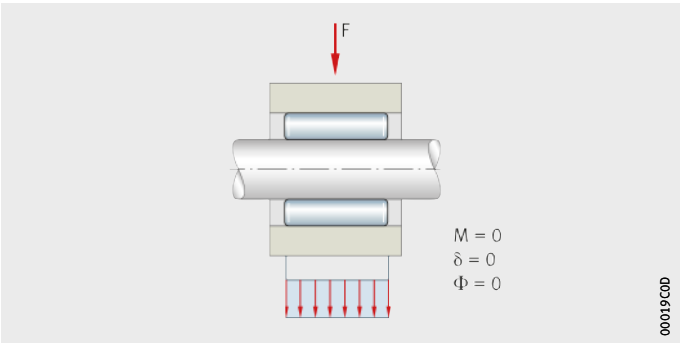
Influencing factors

Influencing factors can include, *Figure 1*:

- bearing alignment
- bearing loads
- operating clearance
- tilting and moment load
- lubrication and contamination.

F = load
M = torque
δ = radial deflection
Φ = tilting angle

Figure 1
Calculation model



Expanded rating life

The calculation of the expanded rating life L_{nm} and L_{nmh} was standardised for the first time in DIN ISO 281 Appendix 1. Since 2007, it has been standardised in the worldwide standard ISO 281. Since 2008, computer-aided calculation in accordance with DIN ISO 281 Appendix 4 has been specified in ISO/TS 16281 and standardised in DIN 26281.

L_{nm} and L_{nmh} is calculated as follows:

$$L_{nm} = a_1 \cdot a_{ISO} \cdot L_{10}$$

$$L_{nmh} = a_1 \cdot a_{ISO} \cdot L_{10h}$$

L_{nm} 10^6 revolutions
Expanded rating life to ISO 281
 a_1 –
Life adjustment factor for a requisite reliability other than 90%
Requisite reliability 90% (L_{10m}) $a_1 = 1$
Requisite reliability 95% (L_{5m}) $a_1 = 0,64$
Requisite reliability 99% (L_{1m}) $a_1 = 0,25$
 a_{ISO} –
Life adjustment factor for operating conditions
 L_{10} 10^6 revolutions
Basic rating life
 L_{nmh} h
Expanded rating life in operating hours
 L_{10h} h
Basic rating life in operating hours according to the definition for L_{10} .

The values for the life adjustment factor a_1 were redefined in ISO 281:2007 and differ from the previous data.

Life adjustment factor a_{ISO}

The standardised method for calculating the life adjustment factor a_{ISO} essentially takes account of the following factors:

- the load on the bearing
- the lubrication conditions (viscosity and type of lubricant, speed, bearing size, additives)
- the fatigue limit of the material
- the type of bearing
- the residual stress in the material
- the ambient conditions
- contamination of the lubricant.

$$a_{ISO} = f \left[\frac{e_C \cdot C_u}{P}, \kappa \right]$$

a_{ISO} –
Life adjustment factor for operating conditions
 e_C –
Life adjustment factor for contamination
 C_u N
Fatigue limit load
 P N
Equivalent dynamic bearing load
 κ –
Viscosity ratio;
for $\kappa > 4$, a value of $\kappa = 4$ should be expected
for $\kappa < 0,1$, this calculation method cannot be used.

Dynamic load carrying capacity and life

Operating life

The operating life is defined as the life actually achieved by the bearing. It may differ significantly from the calculated value.

This may be due to wear or fatigue as a result of:

- deviations in the operating data
- misalignment between the shaft and housing
- insufficient or excessive operating clearance
- contamination
- inadequate lubrication
- excessive operating temperature
- oscillating bearing motion with very small swivel angles (false brinelling)
- high vibration and false brinelling
- very high shock loads (static overloading)
- prior damage during mounting.



Due to the wide variety of possible mounting 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.

Lubrication Principles

Lubrication and maintenance are important for the reliable operation and long operating life of rolling bearings.

Functions of the lubricant

The lubricant fulfils important functions in the rolling bearing, *Figure 2*.

- ① Formation of a lubricant film capable of supporting loads
- ② Heat dissipation in the case of oil lubrication
- ③ Additional sealing for the bearing against external solid and fluid contaminants in the case of grease lubrication
- ④ Damping of running noise
- ⑤ Protection against corrosion

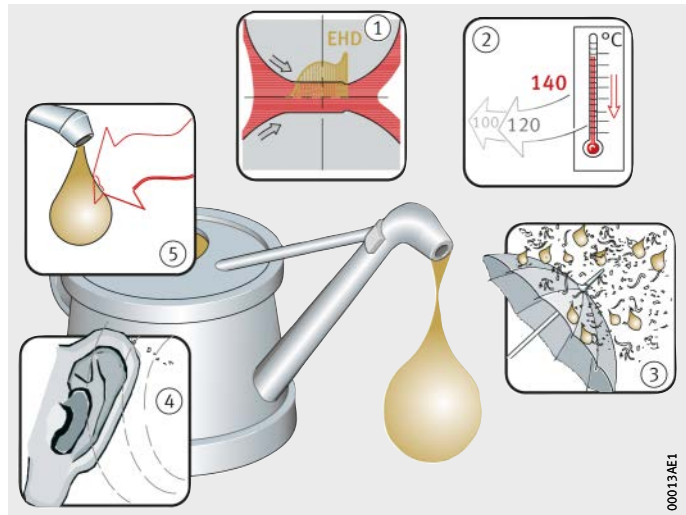


Figure 2
Functions of the lubricant

Selection of the type of lubrication	<p>It should be determined as early as possible in the design process whether bearings should be lubricated using grease or oil.</p> <p>The following factors are decisive in determining the type of lubrication and quantity of lubricant:</p> <ul style="list-style-type: none"> ■ the operating conditions ■ the design and size of the bearing ■ the adjacent construction ■ the lubricant feed.
Criteria for grease lubrication	<p>In the case of grease lubrication, the following must be considered:</p> <ul style="list-style-type: none"> ■ very little design work required ■ sealing action ■ reservoir effect ■ long operating life with little maintenance work (lifetime lubrication possible in certain circumstances) ■ in the case of relubrication, the provision of collection areas for old grease and feed ducts ■ no heat dissipation by the lubricant ■ no rinsing out of wear debris and other particles.
Criteria for oil lubrication	<p>In the case of oil lubrication, the following must be considered:</p> <ul style="list-style-type: none"> ■ good lubricant distribution and supply to contact areas ■ the possibility for dissipation of heat from the bearing (significant principally at high speeds and loads) ■ rinsing out of wear debris ■ very low friction losses with minimal quantity lubrication ■ more demanding requirements in terms of feed and sealing. <p>Under extreme operating conditions (such as very high temperatures, vacuum, aggressive media), it may be possible to use special lubrication methods such as solid lubricants in consultation with the engineering service.</p>
Rolling bearing greases Arcanol	<p>For users who wish to charge their rolling bearings with grease themselves, there is a range of particularly suitable rolling bearing greases Arcanol.</p> <p>The greases in the range are graded in terms of their performance capability such that they can be used to cover almost all areas of application.</p>

Dynamic load carrying capacity and life

Viscosity ratio

The viscosity ratio κ is an indication of the quality of lubricant film formation and an assessment of the separation of contact surfaces:

$$\kappa = \frac{\nu}{\nu_1}$$

K

Viscosity ratio

 $\nu \quad \text{mm}^2 \cdot \text{s}^{-1}$

Kinematic viscosity of the lubricant at operating temperature

$$v_1 \quad \text{mm}^2 \cdot \text{s}^{-1}$$

Reference viscosity of the lubricant at operating temperature.

At values of $\kappa = 4$ and above, full lubrication is present, i.e. the partners are not in contact.

At $\kappa \geq 4$ and very high cleanliness as well as moderate load, rolling bearings can be fatigue-resistant. Experience shows that, at values of $\kappa = 2$ and above, a lubricant film fully capable of supporting load can be anticipated.

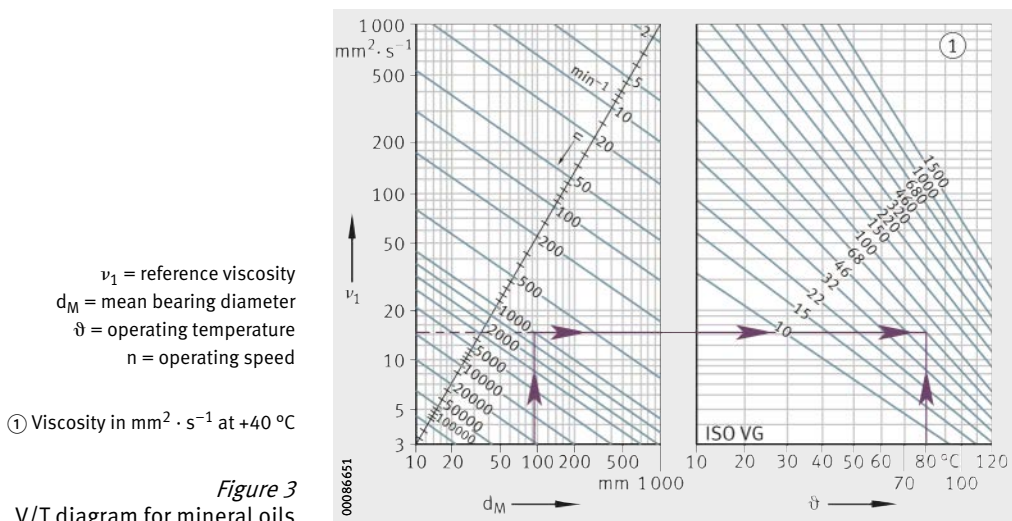
At values of $\kappa = 1$ and above as well as good cleanliness, a life corresponding approximately to the basic rating life can be achieved.

If κ is in the range between 0,4 and 1, a reduction in the basic rating life can be anticipated and the regime can be described as moderate mixed friction.

At $\kappa < 0,4$, mixed friction is present. If unblended lubricants are used in this case, wear must additionally be anticipated. If the lubricant contains suitable anti-wear additives, however, separation in the contact area may also be achieved by the reaction layers formed by the additives. Through this chemical lubrication, it is also possible to achieve low-wear operation.

The reference viscosity ν_1 is determined from the diagram using the mean bearing diameter d_M and the operating speed n , *Figure 3*.

The nominal viscosity of the oil at +40 °C is determined from the required operating viscosity ν and the operating temperature ϑ .



Further information

- Catalogue HR 1, Rolling Bearings
- TPI 168, Rolling Bearing Greases Arcanol
- TPI 176, Lubrication of Rolling Bearings.

Selection of bearing arrangement

Types of bearing arrangements

Locating/non-locating bearing arrangement

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, a decision is made between a locating/non-locating bearing arrangement, an adjusted bearing arrangement and a floating 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. Examples of locating/non-locating bearing arrangements are shown in *Figure 1* and *Figure 2*.

Non-locating bearings

Non-locating bearings are subjected exclusively to radial load, for which in particular cylindrical roller bearings with cage N and NU as well as needle roller bearings are suitable. In these bearings, the roller and cage assembly can be displaced on the raceway of the bearing ring without ribs. All other bearing types, for example deep groove ball bearings and 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 bearings

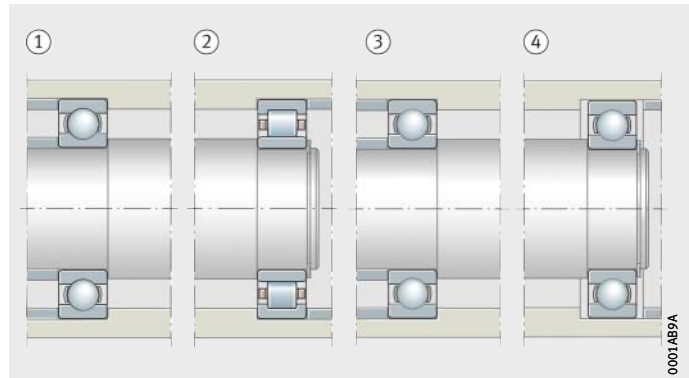
The locating bearing guides the shaft in an axial direction and supports external axial and radial forces. The type of bearing selected as a locating bearing depends on the magnitude of the axial forces and the accuracy with which the shafts must be axially guided.

Examples of locating/non-locating bearing arrangements

- Deep groove ball bearing
 - ① Locating bearing
- Cylindrical roller bearing NU
 - ② Non-locating bearing
- Deep groove ball bearings
 - ③ Locating bearing
 - ④ Non-locating bearing

Figure 1

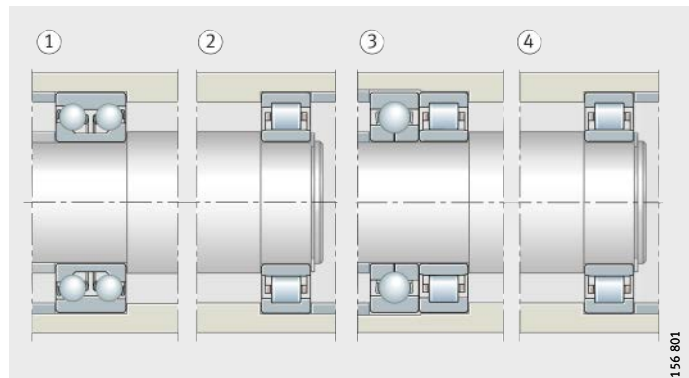
Locating/non-locating bearing arrangements



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

Figure 2

Locating/non-locating bearing arrangements



Selection of bearing arrangement

Adjusted bearing arrangement

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 guidance is required.

X and O arrangement

A fundamental distinction is drawn between the O arrangement, *Figure 3* ① and the X arrangement, *Figure 3* ② of the bearings. In the O arrangement, the cones and their apexes S formed by the contact lines point outwards; in the X arrangement, the 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.

S = apexes of the contact cones
H = support distance

Angular contact ball bearings
① O arrangement
② X arrangement

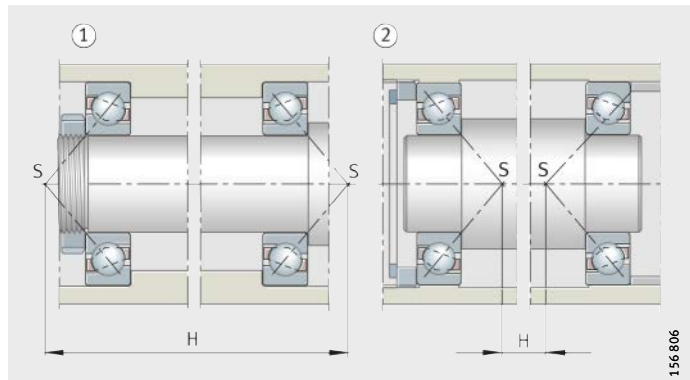


Figure 3
Adjusted bearing arrangement

Elastic adjustment

Adjusted bearing arrangements can also be achieved by preloading using springs, *Figure 4* ①. 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.

Deep groove ball bearing preloaded
by means of spring washer

① Spring washer

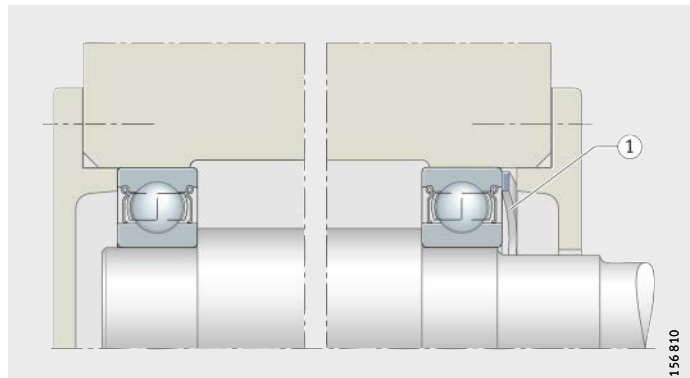


Figure 4
Adjusted bearing arrangement

Floating bearing arrangement

The floating bearing arrangement is an economical solution where close axial guidance of the shaft is not required, *Figure 5*. The construction is similar to that of the adjusted bearing arrangement.

In the floating bearing arrangement, however, 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, self-aligning ball bearings and spherical roller bearings.

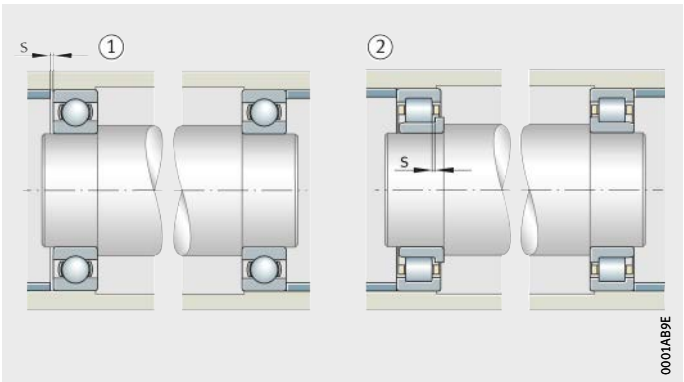
In both bearings, one ring, usually an outer ring, has a fit that allows displacement.

In floating bearing arrangements and cylindrical roller bearings of type NJ, the length compensation takes place within the bearings, *Figure 5*. The inner and outer rings 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.

- s = axial clearance
- ① Two deep groove ball bearings
 - ② Two cylindrical roller bearings NJ

Figure 5
Floating bearing arrangements



Selection of bearing arrangement

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 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 locking or form fit in order to prevent lateral creep. The bearing rings must only be in contact with the shaft 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, *Figure 6* and *Figure 7*.

In non-separable bearings, one bearing ring must have a tight fit, while the other ring is retained by the rolling elements.

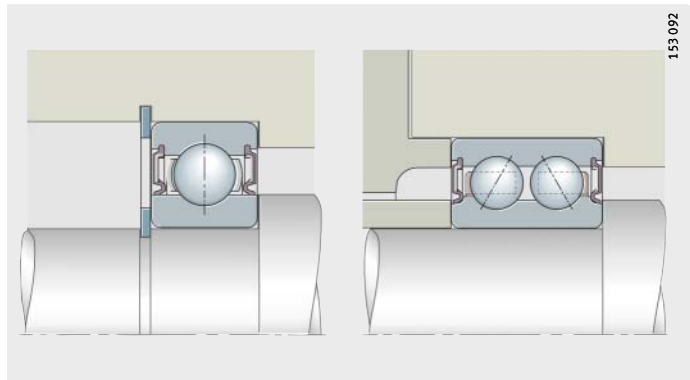
Since bearings in adjusted and floating arrangements support axial forces in one direction only, the bearing rings only need to be supported on one side. Counterguidance is performed by a second, symmetrically arranged bearing. Shaft nuts, ring nuts, covers or spacer washers are suitable as adjustment elements.

In floating bearing arrangements, lateral movement of the rings is prevented by shaft or housing shoulders, covers, snap rings.

Examples of retaining elements

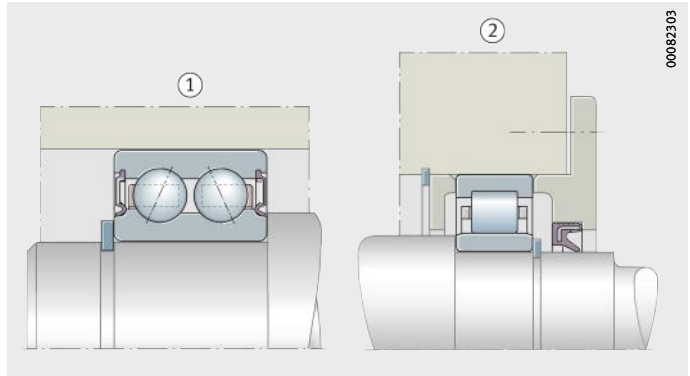
Axial location by form fit on the inner and outer ring

Figure 6
Locating bearings



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

Figure 7
Non-locating bearings



Conditions of rotation

The conditions of rotation indicate the motion of one bearing ring with respect to the load direction and are expressed as either circumferential load or point load. The conditions of rotation that normally occur in fluid pumps are given in the table Conditions of rotation.

Point load on the outer ring

If the ring remains stationary relative to the load direction, there are no forces that displace the ring relative to its seating surface.

There is no risk that the seating surface will be damaged and a loose fit is possible.


Circumferential load on the inner ring

If forces are present that displace the ring relative to its seating surface, every point on the raceway is subjected to load over the course of one revolution of the bearing.



As damage to the bearing seating surface can occur, a tight fit should be used.

Conditions of rotation

Conditions of motion	Example	Schematic	Load case	Fit
Rotating inner ring	Shaft with weight load		Circumferential load on inner ring and	Inner ring: tight fit necessary
Stationary outer ring			Point load on outer ring	Outer ring: loose fit permissible
Non-variable load direction				

Shaft and housing tolerances

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

Housing tolerances

Condition of rotation	Displacement facility Load	Operating conditions	Tolerance zone
Point load on outer ring	Outer ring easily displaced, housing unsplit	The tolerance grade is determined by the running accuracy required	H7 (H6) ¹⁾
	Outer ring easily displaced, housing split		H8 (H7)
	Outer ring not easily displaced, housing unsplit	High running accuracy required	H6 (J6)
	Outer ring not easily displaced, angular contact ball bearings and tapered roller bearings with adjusted outer ring, housing split	Normal running accuracy	H7 (J7)
	Outer ring easily displaced	Heat input via shaft	G7 ²⁾

¹⁾ G7 for housings made from GG if bearing outside diameter $D > 250$ mm and temperature differential between outer ring and housing > 10 K.

²⁾ F7 for housings made from GG if bearing outside diameter $D > 250$ mm and temperature differential between outer ring and housing > 10 K.

Selection of bearing arrangement

Shaft tolerances

Condition of rotation	Bearing type	Shaft diameter mm	Displacement facility Load	Tolerance zone
Circumferential load on inner ring or indeterminate load direction	Ball bearings	up to 50	Normal loads ¹⁾	j6 (j5)
		50 to 100	Low loads ²⁾	j6 (j5)
			Normal and high loads ³⁾	k6 (k5)
		100 to 200	Low loads ¹⁾	k6 (m6)
			Normal and high loads ⁴⁾	m6 (m5)
		over 200	Low loads	m6 (m5)
			Normal and high loads	n6 (n5)
	Roller bearings	up to 60	Low loads	j6 (j5)
			Normal and high loads	k6 (k5)
		60 to 200	Low loads	k6 (k5)
			Normal loads	m6 (m5)
			High loads	n6 (n5)
		200 to 500	Normal loads	m6 (n6)
			High loads, shocks	p6
		over 500	Normal loads	n6 (p6)
			High loads	p6

1) $C/P > 10$.

2) $C/P > 12$.

3) $C/P < 12$.

4) $C/P < 10$.

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, for example m6 instead of k6.

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

Operating clearance

A lower preload has proved to be appropriate in relation to the rating life of bearings, since the load is then distributed over several rollers 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 then be anticipated due to the higher contact stresses, *Figure 8*.

On the other hand, an excessively large operating clearance can lead to sliding effects, unfavourable load distribution and unsatisfactory running behaviour.

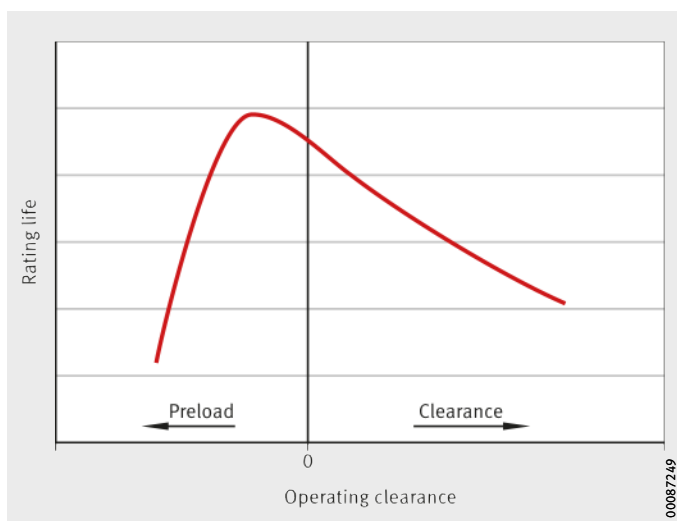


Figure 8
Operating clearance

Principles and requirements

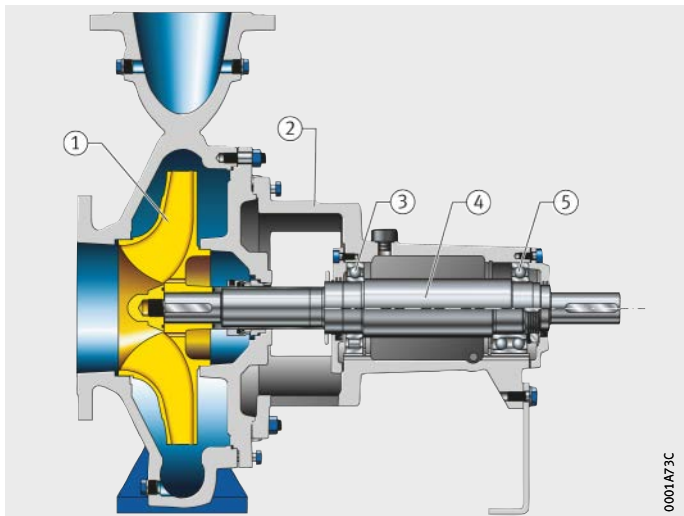
Principles

Many fluid pumps can be reduced to the basic design of the single stage, single flow centrifugal pump, *Figure 1*. These pumps operate on the flow principle, in which the transmission of energy is based on hydrodynamic processes. The fluid is accelerated by centrifugal force in a circumferential direction by means of an impeller. A portion of the hydrodynamic pressure generated by the acceleration is decelerated by a feed mechanism, the volute casing, in the same way as in a diffuser. As a result, it is possible to convert a large portion of the hydrodynamic pressure into hydrostatic pressure. This basic design is adjusted and developed further as a function of the specific requirements and the area of application.



Figure 1
Standardised chemical pump
© KSB Aktiengesellschaft
MegaCPK

Various concepts of bearing arrangement can be used for single flow centrifugal pumps, *Figure 2*.



① Impeller
② Bearing bracket
③ Bearing position, pump side
④ Shaft
⑤ Bearing position, drive side
Figure 2
Standardised chemical pump
© KSB Aktiengesellschaft
Cross-section of MegaCPK

Requirements for pump bearing arrangements

Bearing arrangements in fluid pumps are subject to a wide variety of requirements. The requirements of pump manufacturers and the characteristics of the rolling bearings must be matched as closely as possible.

The existing requirements for rolling bearings are:

- cost-effective bearing solutions
- use of standard rolling bearings
- support of radial and axial loads
- support of vibrations and shocks
- long operating life
- low maintenance outlay.

Further requirements for rolling bearings could be:

- longer relubrication intervals, moving towards lifetime lubrication
- corrosion resistance
- energy-efficient rolling bearings and complete solutions
- lower friction
- lower noise levels
- higher temperature range
- media lubrication
- condition monitoring.

The requirements for rolling bearing manufacturers are:

- design tools
- technical advice
- failure analysis.

Requirements for electric motor bearing arrangements

Electric motors are used in preference as drive units in fluid pumps.

The bearing arrangement in an electric drive must take account of influencing factors including:

- load
- speed
- shaft arrangement and design envelope
- vibration and noise behaviour
- rating life
- low friction
- sealing
- suitability for higher temperatures
- lubrication (grease life)
- current insulation
- maintenance and mounting.

Further information

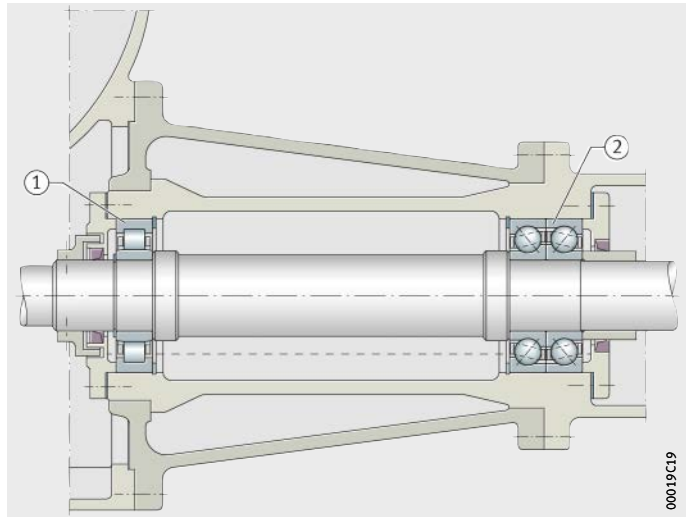
- TPI 206, Current-insulating Bearings.

Design example

Bearing arrangement in a centrifugal pump

The bearing arrangement in a centrifugal pump is calculated using the following technical data:, *Figure 1*

- power rating 44 kW
- delivery rate 24 000 l/min
- delivery height 9 m
- speed $n = 1\,450 \text{ min}^{-1}$
- axial thrust $F_a = 7,7 \text{ kN}$
- radial load $F_r = 11 \text{ kN}$ on the non-locating bearing ①
- radial load $F_r = 5,9 \text{ kN}$ on the locating bearing ②.



- ① Non-locating bearing
- ② Locating bearing

Figure 1
Bearing arrangement
in a centrifugal pump

Bearing selection

The impeller has a floating bearing arrangement.

The drive side of the pump shaft is fitted with two angular contact ball bearings FAG7314-B-TVP.UA (XL) in an X arrangement. The suffix UA indicates that the bearings can be combined as necessary in a tandem O or X arrangement. The O or X arrangement has a tolerance of j5 on the shaft and J6 in the housing. The bearing pair has a locating bearing function and supports an axial thrust F_a of 7,7 kN. The radial load F_r is approx. 5,9 kN.

The non-locating bearing located close to the impeller is a cylindrical roller bearing FAG NU314-E-TVP2 (XL). The radial load F_r is approx. 11 kN.

X-life

Further information on bearings of X-life quality (XL), see page 24.

Lubrication, sealing

Lubrication of the rolling bearings is carried out by means of oil bath lubrication. The oil level should reach the centre line of the lowest rolling element. The bearing space is sealed by means of shaft sealing rings. An additional labyrinth is fitted in front of the impeller.

BEARINX®

More precise calculation of the influences on the bearing, such as shaft deflection, lubrication or contamination can be carried out using the calculation program BEARINX®, page 47.

Angular contact ball bearings in X arrangement (locating bearing)

Angular contact ball bearing FAG 7314-B-TVP.UA (XL):

- basic dynamic load rating $C_r = 126\,000\text{ N}$
- basic static load rating $C_{0r} = 93\,000\text{ N}$
- limiting speed $n_G = 5\,500\text{ min}^{-1}$.

Basic dynamic load rating $C_{r\text{ tot}}$ of the bearing pair:

- $C_{r\text{ tot}} = 1,625 \cdot C_r$
- $C_{r\text{ tot}} = 1,625 \cdot 126\,000\text{ N} = 204\,750\text{ N}$.

The factor 1,625 is only valid for ball bearings.

Since $F_a/F_r = 1,3 > e = 1,14$, the equivalent dynamic bearing load P of the bearing pair is calculated for a contact angle of 40° as follows:

- $P = X \cdot F_r + Y \cdot F_a$
- $P = 0,57 \cdot 5\,900\text{ N} + 0,93 \cdot 7\,700\text{ N} = 10\,524\text{ N}$.

Calculation of the basic rating life:

$$L_{10h} = \frac{16\,666}{n} \cdot \left(\frac{C_{r\text{ tot}}}{P} \right)^p$$

$p = 3$ for ball bearings:

$$L_{10h} = \frac{16\,666}{1450} \cdot \left(\frac{204\,750}{10\,524} \right)^3 = 84\,643\text{ h}$$



Both rows of the angular contact ball bearings must be subjected equally to a minimum load. In continuous operation, angular contact ball bearings with cage must be subjected to a minimum radial load of the order of $P/C_r > 0,01$. In the example, $P/C_{r\text{ tot}} = 0,05$.

Cylindrical roller bearing (non-locating bearing)

Cylindrical roller bearing FAG NU314-E-TVP2 (XL):

- basic dynamic load rating $C_r = 242\,000\text{ N}$
- basic static load rating $C_{0r} = 222\,000\text{ N}$
- limiting speed $n_G = 5\,500\text{ min}^{-1}$.

Equivalent dynamic bearing load P :

- $P = F_r = 11\,000\text{ N}$.

Basic rating life:

$$L_{10h} = \frac{16\,666}{n} \cdot \left(\frac{C_r}{P} \right)^p$$

$p = 10/3$ for roller bearings:

$$L_{10h} = \frac{16\,666}{1450} \cdot \left(\frac{242\,000}{11\,000} \right)^{10/3} = 342\,930\text{ h}$$



Do not overspecify the bearing. If the calculated rating life is $> 60\,000\text{ h}$, this normally means that the bearing arrangement is overspecified. In continuous operation, a minimum radial load of the order of $F_{r\text{ min}} = C_{0r}/60$ is necessary. In the example, $F_{r\text{ min}} = 222\,000\text{ N}/60 = 3\,700\text{ N}$.

Design example

Guidelines on design

In the design of a rotating system, various calculations and certain assumptions are necessary. Based on its technical know-how and experience in the field of fluid pumps, Schaeffler has the most suitable methods for bearing design and calculation. It is not sufficient to examine just one operating point with a certain combination of shaft and impeller. In order to achieve a thorough analysis, it is necessary to consider other load cases with the different impellers and shafts available for the specific pump type.

Since it is not possible to calculate certain influences on the bearing arrangement, and in order to validate new developments, Schaeffler has its own testing department. This can be used to test a wide spectrum of products under conditions that are closely representative of practice. In order to achieve a good fit with the wishes of the customer, these tests can be planned, implemented and evaluated on the basis of cooperation.

On the basis of activities such as these investigations, it is possible to continuously improve Schaeffler products and develop new, innovative products. As a result, we can supply our customers with products that have improved performance capability, quality and reliability.

The many years of experience and expertise of Schaeffler is valued by customers worldwide.

Our objective

Customer's global engineering partner number 1!



Selection of suitable rolling bearings

X-life

Deep groove ball bearings

Single row angular contact ball bearings

Double row angular contact ball bearings

Single row cylindrical roller bearings

Four point contact bearings

Self-aligning ball bearings

Spherical roller bearings

Tapered roller bearings

X-life

Features

X-life is the premium brand that identifies particularly high performance products under the FAG and INA brands. They are characterised by longer rating life and operating life, due to higher basic dynamic load ratings compared to the previous standard.

This higher performance results from the use of state of the art manufacturing techniques and improved internal constructions. They lead to better and more uniform surfaces and contact areas and thus optimised load distribution in the bearing, *Figure 1*.

This opens up expanded design possibilities:

- Under the same load and with an unchanged design envelope, X-life bearings have a longer rating life and maintenance intervals can be extended.
- Conversely, an X-life bearing in the same design envelope and with the same rating life can support higher loads.
- Where the rating life and load remain unchanged, X-life bearings allow higher performance density, facilitating optimisation of the design envelope and reductions in mass.

As a result, the X-life bearing makes a significant contribution to improved overall cost-efficiency under the philosophy of Total Cost of Ownership (TCO).

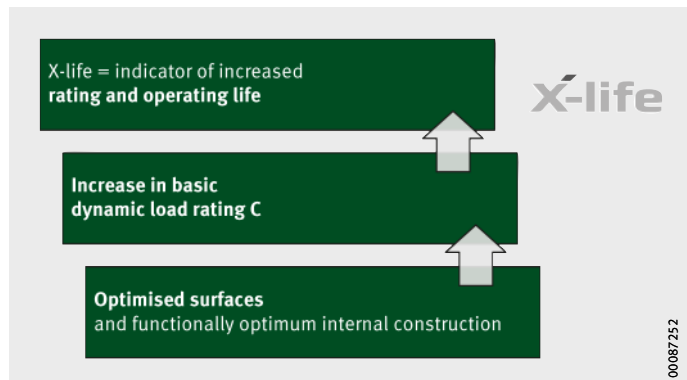


Figure 1
Key characteristics of X-life

Deep groove ball bearings

Features

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. Deep groove ball bearings of Generation C were specially developed and offer dimensional and raceway tolerances to P6, lower noise levels, better sealing and higher cost-efficiency, *Figure 1*. Deep groove ball bearings of Generation C are available in the series 6000, 6001, 6002, 6004, 6200 to 6210 and 6305 to 6310. The innovative Generation C range is rounded out by the existing range of FAG deep groove ball bearings.



Figure 1
Deep groove ball bearing,
Generation C

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.

Operating temperature

Open deep groove ball bearings can be used up to an operating temperature of +120 °C (up to an outside diameter of 90 mm) and up to +150 °C (for an outside diameter over 90 mm and up to 240 mm).

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

Bearings with gap seals can be used at temperatures from –30 °C to +120 °C.

Sealing

Deep groove ball bearings are available with reduced friction contact seals (HRS, ELS) and non-contact sealing shields (Z, BRS).

Lubrication

Sealed bearings are greased with a high quality grease and are lubricated for life.

Cages

Single row deep groove ball bearings of Generation C have an optimised riveted sheet metal cage.

Further information

- TPI 165, Deep Groove Ball Bearings, Generation C
- www.FAG-GenerationC.com
- Product catalogue **medias**®
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Single row angular contact ball bearings

Features

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, *Figure 1*. 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.



Figure 1
Single row angular
contact ball bearing

X-life

Many sizes of single row angular contact ball bearings are classified as X-life products. Other variants can be supplied by agreement.

Radial and axial load carrying capacity

Single row angular contact ball bearings can support axial forces in one direction and high radial forces. They must be axially adjusted against a second bearing fitted in a mirror image arrangement.

Due to the contact angle of 40° , these bearings can support high axial loads.

Universal design

Single row angular contact ball bearings of the universal design have the suffix UA, UL or UO and are intended for mounting in pairs in an X, O or tandem arrangement or mounting in groups. These bearings can be mounted in any arrangement required, *Figure 2*.

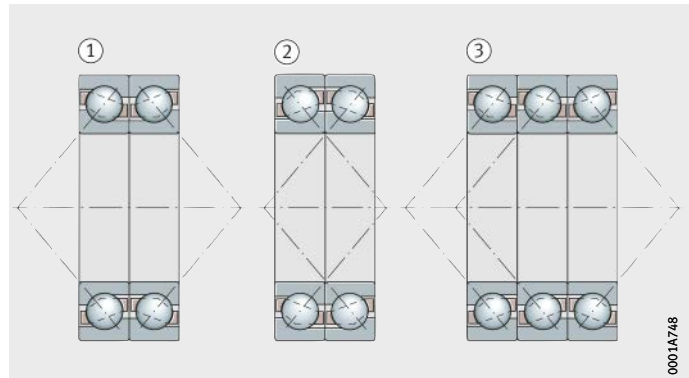
Angular contact ball bearings of the universal design are supplied by Schaeffler not only in the standard tolerances PN but also with increased accuracy in the tolerance class P5.

Exceptions: bore tolerances for bearings of all tolerance classes uniformly to P5 (no special suffix).

- ① O arrangement
- ② X arrangement
- ③ Tandem O arrangement

Figure 2

Variants of bearing arrangements



The suffix UA indicates slight axial internal clearance, the suffix UL indicates slight preload and the suffix UO indicates freedom from clearance in an X or O arrangement. The universal design is available by agreement with a different axial internal clearance value.

Mounting in tandem arrangement



If single row angular contact bearings are mounted in a tandem arrangement, it must be ensured that the end faces of the outer rings in contact with each other have sufficient overlap. If in doubt, please contact the Schaeffler engineering service.

Operating temperature

Open angular contact ball bearings can be used at operating temperatures from $-30\text{ }^{\circ}\text{C}$ to $+150\text{ }^{\circ}\text{C}$.

Angular contact ball bearings with cages made from glass fibre reinforced polyamide are suitable for operating temperatures up to $+120\text{ }^{\circ}\text{C}$.

Bearings with seals are suitable for operating temperatures from $-30\text{ }^{\circ}\text{C}$ to $+110\text{ }^{\circ}\text{C}$.

Sealing

Bearings with the suffix 2RS have lip seals on both sides. Contact RS seals are suitable for giving protection against dust, contamination and damp atmospheres.

Lubrication

Bearings with lip seals on both sides are greased with a high quality grease and are lubricated for life.

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

Cages

Single row angular contact ball bearings are available with:

- solid window cages made from glass fibre reinforced polyamide
- solid window cages made from brass
- window cages made from sheet steel.

The bearings with metallic cages fulfil the requirements of API 610.

Further information

- Product catalogue **medias**[®]
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Double row angular contact ball bearings

Features

Double row angular contact ball bearings are units with solid inner and outer rings and ball and cage assemblies with polyamide, brass or sheet steel cages, *Figure 1*. 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 bearing can support forces in both radial and axial directions. They are therefore particularly suitable for use in pumps.

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

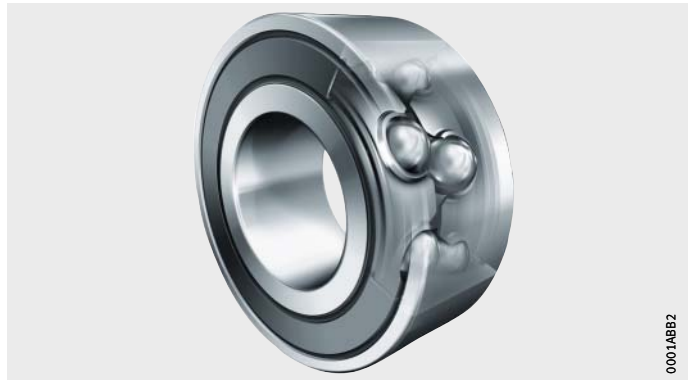


Figure 1
Double row angular
contact ball bearing

X-life

Many sizes of double row angular contact ball bearings are classified as X-life products. Other variants can be supplied by agreement.

Radial and axial load carrying capacity

Double row angular contact ball bearings can support axial loads in both directions and high radial loads. They are particularly suitable for bearing arrangements where rigid axial guidance is required.

The axial load carrying capacity is dependent on the contact angle; i. e. the larger the angle, the higher the axial load to which the bearing can be subjected.

Double row angular contact ball bearings are available with contact angles of 25°, 35° and 45°, while double row angular contact ball bearings of X-life quality have a contact angle of 30°.

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.

Operating temperature	The temperature conditions of double row angular contact ball bearings correspond to the operating temperatures of single row angular contact ball bearings.
Sealing	<p>Double row angular contact ball bearings can be sealed using lip seals RSR or HRS. These contact seals are suitable for giving protection against dust, contamination and damp atmospheres.</p> <p>Double row angular contact ball bearings can also be sealed using non-contact sealing shields Z.</p>
Lubrication	Sealed bearings are greased with a high quality grease and are lubricated for life.
Cages	<p>Depending on their design, single row angular contact ball bearings are available with:</p> <ul style="list-style-type: none"> ■ snap or window cages made from glass fibre reinforced polyamide ■ brass cages ■ snap cages made from sheet steel. <p>The bearings with metallic cages fulfil the requirements of API 610.</p>
Further information	<ul style="list-style-type: none"> ■ TPI 213, Double Row Tapered Roller Bearings, X-life Quality ■ Product catalogue medias® ■ Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Single row cylindrical roller bearings

Features

Single row cylindrical roller bearings with cage are units comprising solid inner and outer rings and cylindrical roller and cage assemblies, *Figure 1*. 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. Both bearing rings can be given a tight fit by this process. Single row cylindrical roller bearings with cage are available as non-locating, semi-locating and locating bearings.

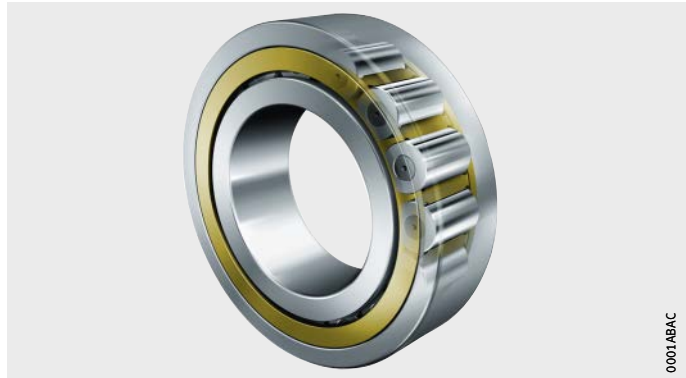


Figure 1
Cylindrical roller bearing

X-life

Many sizes of single row cylindrical roller bearings are classified as X-life products. Other variants can be supplied by agreement.

Non-locating bearings

Cylindrical roller bearings NU and N are non-locating bearings and can support radial forces only. In series NU, the outer ring has two ribs, while the inner ring has no ribs. Bearings N have two 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".

Operating temperature

Single row cylindrical roller bearings with cage can be used at operating temperatures from $-30\text{ }^{\circ}\text{C}$ to $+120\text{ }^{\circ}\text{C}$ (plastic cage) or up to $+150\text{ }^{\circ}\text{C}$ (metal cage). For continuous operating temperatures above $+120\text{ }^{\circ}\text{C}$, please contact us.

Sealing

The bearings are supplied without seals.

Lubrication

They can be lubricated from the end faces using grease or oil.

Cages

- Cylindrical roller bearings are available with:
- solid cages made from glass fibre reinforced polyamide
 - solid brass cages
 - window cages made from sheet steel.

Further information

- Product catalogue **medias**®
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Four point contact bearings

Features

Four point contact bearings are single row angular contact ball bearings and therefore require significantly less space in an axial direction than double row designs, *Figure 1*.

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 those 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.

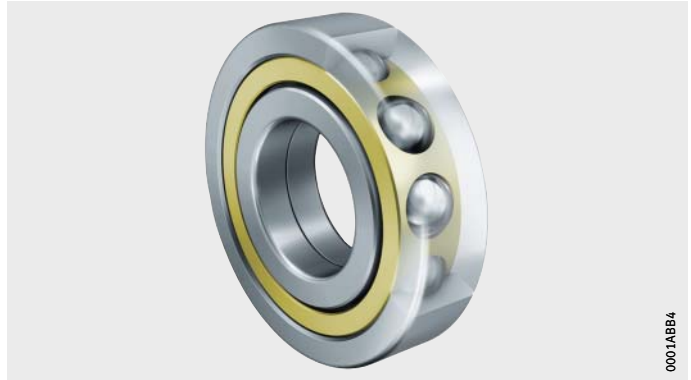


Figure 1

Four point contact bearing

X-life

Many sizes of four point contact bearings are classified as X-life products. Other variants can be supplied by agreement.

Axial load capacity in both directions

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.

Operating temperature

Bearings with solid brass cages can be used at operating temperatures from -30 °C to +150 °C.

Bearings with cages made from glass fibre reinforced polyamide are suitable for operating temperatures up to +120 °C.

Sealing

Four point contact bearings are not sealed.

Lubrication

They are not greased and can be lubricated with grease or oil.

Cages

Four point contact bearings are available with the following cages:

- solid window cages made from brass
- window cages made from glass fibre reinforced polyamide.

Further information

- Product catalogue **medias**®
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Self-aligning ball bearings

Features

Self-aligning ball bearings are double row, self-retaining units comprising outer rings with a concave raceway, inner rings with a cylindrical or tapered bore and ball and cage assemblies. The bearings are available in open and sealed designs, *Figure 1*.



Figure 1
Self-aligning ball bearing

Radial and axial load carrying capacity

Self-aligning ball bearings can support axial forces in both directions as well as radial forces.

Compensation of angular misalignments

Under normal operating conditions and with a rotating inner ring, self-aligning ball bearings can swivel approx. 4° about their central position; sealed bearings can swivel by max. 1,5°. As a result, they permit skewing between the inner and outer ring and can thus compensate misalignments, shaft deflections and housing deformations.

If the outer ring rotates or the inner ring undergoes tumbling motion, the angular adjustment facility is smaller. In this case, please contact us.

Operating temperature

Open bearings with brass cages can be used at operating temperatures from -30 °C to +150 °C.

Bearings with cages made from glass fibre reinforced polyamide are suitable for operating temperatures up to +120 °C.

Sealed self-aligning ball bearings are suitable for operating temperatures from -30 °C to +100 °C, restricted by the grease.

Sealing

Sealed bearings have contact seals on both sides.

Lubrication

Sealed bearings are greased with a high quality grease and are maintenance-free.

Cages

Self-aligning ball bearings are available with:

- solid cages made from glass fibre reinforced polyamide
- solid brass cages.

Further information

- Product catalogue **medias**®
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Spherical roller bearings

Features

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, *Figure 1*.

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.



Figure 1
Spherical roller bearing

X-life

Many sizes of spherical roller bearings are classified as X-life products. Other variants can be supplied by agreement.

Radial and axial load carrying capacity

Spherical roller bearings can support axial loads in both directions and high radial loads. They 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.

Compensation of angular misalignments

Spherical roller bearings compensate for angular misalignments. The permissible adjustment angle is stated for loads $P < 0,1 \cdot C_r$.

These adjustment angles are permissible if:

- the angular deviation is constant (static angular misalignment)
- the rotating component is the inner ring.

Operating temperature

Bearings with metal cages can be used at operating temperatures from -30 °C to $+200\text{ °C}$.

Bearings with cages made from glass fibre reinforced polyamide are suitable up to $+120\text{ °C}$.

Sealing

Sealed and greased bearings can be supplied by agreement.

Lubrication

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

Cages

Spherical roller bearings are available with:

- solid cages made from brass or glass fibre reinforced polyamide
- sheet steel or brass cages.

Further information

- TPI 218, Sealed Spherical Roller Bearings
- Product catalogue **medias**®
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.

Tapered roller bearings

Features

Tapered roller bearings comprise solid inner and outer rings with tapered raceways and tapered rollers in a window cage, *Figure 1*.

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 the cage can be mounted separately from the outer ring.



Figure 1
Tapered roller bearing

X-life

Many sizes of tapered roller bearings are classified as X-life products. Other variants can be supplied by agreement.

Radial and axial load carrying capacity

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

They must normally be axially adjusted against a second bearing fitted in a mirror image arrangement.

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.

Operating temperature

Open tapered roller bearings can be used at operating temperatures from $-30\text{ }^{\circ}\text{C}$ to $+120\text{ }^{\circ}\text{C}$.

Bearings with a lip seal can be used at operating temperatures from $-30\text{ }^{\circ}\text{C}$ to $+110\text{ }^{\circ}\text{C}$, restricted by the grease and sealing ring material.

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.

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 grease.

Cages

Tapered roller bearings are available with:

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

Further information

- Product catalogue **medias**[®]
- Technical principles and dimension tables: see Catalogue HR 1, Rolling Bearings.



Innovative products

Tandem angular contact ball bearings
Media lubricated bearings
Coatings for rolling bearings
Mechatronics and sensors

Tandem angular contact ball bearings

Features

Tandem angular contact ball bearings are double row angular contact ball bearings in which the two rows can be configured in different ways in relation to the selected contact angle, pitch circle diameter and ball set, *Figure 1*. The bearings are designed in accordance with the specific application, in order to achieve low friction as well as optimum load support and distribution in the bearing as well as very high rigidity. Normally, the outer ring can be mounted separately from the inner ring, which forms a unit together with the balls and cages.



Figure 1
Tandem angular
contact ball bearing

The very good friction characteristics of tandem angular contact ball bearings have been confirmed in experimental investigations. The use of tandem angular contact ball bearings has led in various applications to a significant increase in efficiency.

Tandem angular contact ball bearings from Schaeffler represent a design measure for the design of large fluid pumps with optimised efficiency.

Radial and axial load carrying capacity

Tandem angular contact ball bearings can support axial and radial forces. Due to the design of tandem angular contact ball bearings, there is no loss of preload as a result of smoothing effects at the roller/rib contact.

Lubrication

Small quantities of oil are sufficient to achieve adequate lubrication of the raceways.

Further information

- For further information on tandem angular contact ball bearings, please contact Schaeffler External Sales or the technical department.

Media lubricated bearings

Features

In classical applications, the bearings in fluid pumps are separated from the medium being conveyed by means of sealing systems. One of the principal causes of failure in pumps can be attributed to failure of the sealing technology. The medium conveyed penetrates the bearing carrier and the bearings fail due to the ingress of contamination, impaired performance capability of the lubricant or even washing out of the lubricant.

There is an increasing demand for media lubricated bearings, which are lubricated by the medium being conveyed. The main media conveyed in pumps can be water, acids, alkalis, benzols and fluids that in some cases contain solids.

There is therefore a wide range of challenges relating to media lubricated rolling bearings, *Figure 1*. For example, the bearings in a corrosive environment must be not only resistant to corrosion but also to overrolling. Furthermore, the rolling bearing must have increased wear resistance to abrasion and the rolling bearing components in contact should have a low tendency for adhesion to each other.

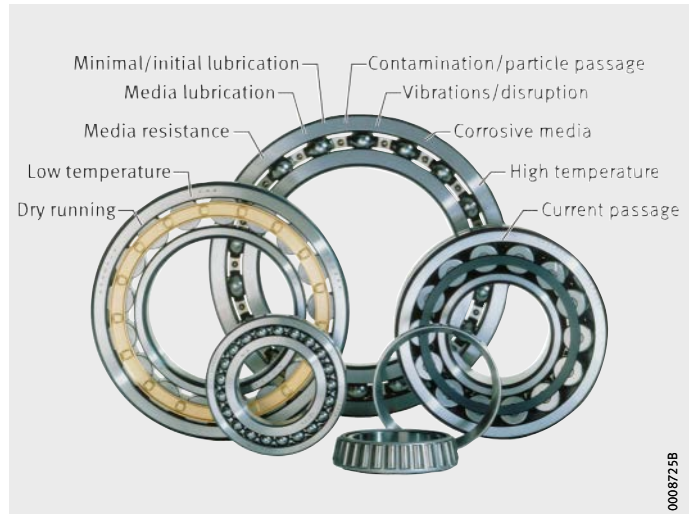


Figure 1
Challenges for rolling bearings

The prerequisite for media lubrication is a consistent material concept that ensures the resistance of all components to the relevant media. In the use of unsealed rolling bearings, material concepts must be taken into consideration that exhibit sufficient corrosion resistance to the ambient medium over the operating period. In addition, these concepts must be robust in relation to particles carried into the contact by the medium. The selection criteria for the correct ring material are therefore not only classic overrolling resistance but also and principally media resistance, wear resistance and resistance to particle overrolling. The combination of these characteristics gives the correct ring material.

Media lubricated bearings

The cage is a further important component. This must be compatible with the medium, which means that it must not undergo swelling, embrittlement or corrosion. In many cases, this combination of requirements can only be optimally fulfilled by special materials, for example high performance plastics such as PAI, PI, PEEK or austenitic steels. In addition to the possible high performance materials for cages, the products are rounded out by ceramic rolling elements and an optimised internal bearing design. A further element in the modular solution concept is coatings for protection against wear and corrosion. However, the combined requirements placed on coatings for the raceway area are extremely high, so there is still potential for development in these applications of dedicated coatings which must then be adapted individually.

Influences on the rating life

With the change in the lubricant medium from oil or grease to an ambient medium, principally in the case of media without lubricating action, the classic model of the fatigue life theory is no longer appropriate. In place of the fatigue life, the operating life comes to the forefront. This is based not only on parameters such as speed, contact pressure and the fatigue strength of materials but also includes phenomena such as wear (adhesive and abrasive), hot running and corrosion which act as criteria limiting the operating life. For example, a rolling bearing running in water is subjected principally to factors such as wear and corrosion. In addition, the bearing components in contact are also subjected to mechanical and chemical factors and may therefore undergo fatigue.

Friction mechanisms and typical types of wear symptoms

Friction mechanism	Wear mechanism	Types of wear symptoms
Abrasion (cleavage)	Abrasion	Scouring, scratch formation, scaling
Adhesion	Adhesion	Fretting, thermal cracks, material transfer, scaling
Deformation (elastic hysteresis and damping)	Deformation	Indentation, scoring, waves, scratch formation
	Surface fatigue	Pitting, grey staining (large number of smaller chips), cracks
Tribochemical reaction	Tribochemical reaction	Reaction layer, friction martensite

Areas of application engineering use

Areas of application for media lubricated rolling bearings can be found in industry, petrochemicals, drinking water supply, waste water disposal, drainage, energy generation and building technology.

Further information

- Further information on the relevant materials and a presentation of their media compatibilities can be found in TPI 64, Corrosion-resistant Products.
- An overview of rolling bearing materials including their suitability for media lubrication can be found in TPI 226, Materials for Rolling Bearing Technology.
- For joint development or the agreement of new products, please contact Schaeffler External Sales or the technical department.

Coatings for rolling bearings

Features

Bearings and precision components from Schaeffler offer high performance capacity and a long operating life. They provide the user with thoroughly developed and economical solutions for the large majority of 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 a solution to the task of increasing the operating life of a component.

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 give a significant increase in 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, *Figure 1*.

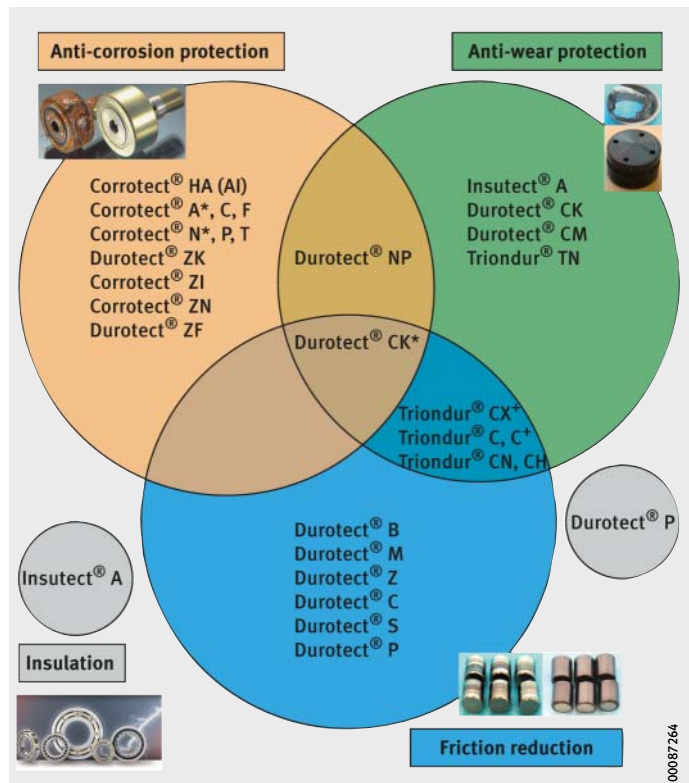


Figure 1
Coatings

Coatings for rolling bearings

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 can be achieved by the use of rolling bearings with the 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.

Further information

- TPI 67, Special Coating Corroprotect®
- TPI 133, Special Coatings
- TPI 186, Higher Performance Capacity Through the Use of Coatings
- TPI 206, Current-insulating Bearings
- PEC, Increased Efficiency for Electric Motors
- For joint development or the agreement of new products, please contact Schaeffler External Sales or the technical department.

Mechatronics and sensors

Features

Mechatronics is becoming increasingly important in the development of innovative rolling bearing solutions. Through the use of additional functionalities, it facilitates further increases in the productivity, cost-effectiveness and reliability of machinery. As new rolling bearings are developed with integrated sensors for the measurement of speed, direction of rotation, temperature and force as well as an integrated or adjacent power supply, Schaeffler is available as a development partner for new solution approaches in the field of fluid pumps.

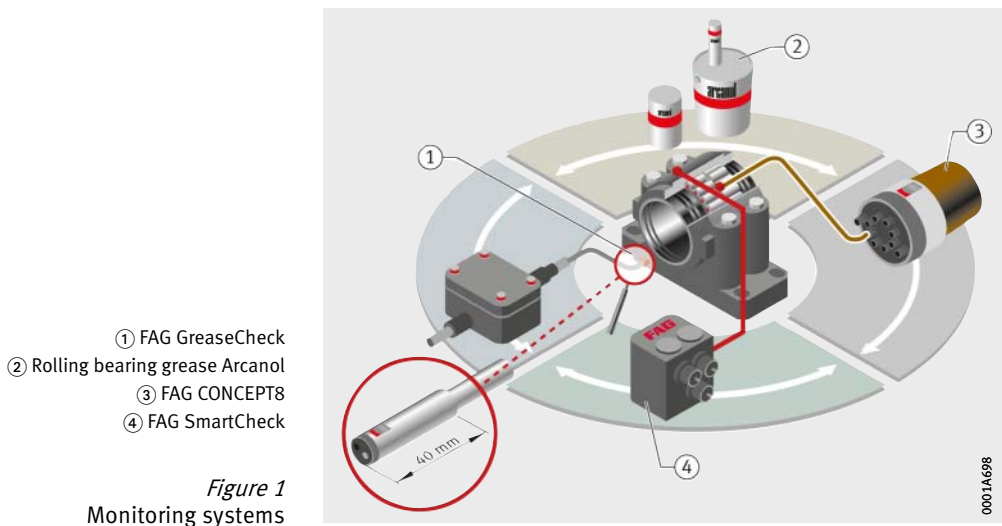
Monitoring systems

Increasing competition leads to increased cost pressures and drives companies to reduce their maintenance costs. It is therefore vital to avoid unplanned downtime and maximise machine lifetime. Special monitoring systems detect machinery damage at a very early stage. As a result, unplanned downtime can be prevented and bearing replacement can be scheduled on a forward-looking basis.

Possible monitoring systems are:

- FAG SmartCheck
- FAG DTECT X1_s
- FAG GreaseCheck.

Through networking of the FAG products FAG CONCEPT8, FAG DTECT X1_s, FAG GreaseCheck and FAG SmartCheck, it is possible to monitor systems on a continuous basis, *Figure 1*.



Mechatronics and sensors

FAG SmartCheck

FAG SmartCheck is a cost-effective, innovative online measuring system for the continuous monitoring of machine and process parameters on a decentralised basis, *Figure 2*.

It offers the performance features of expensive systems but is compact in design, easy to fit and simple to use. The system can be expanded on a modular basis and can thus be adapted at any time to meet changing requirements.

FAG SmartCheck facilitates:

- increased plant availability
- condition-based maintenance
- contributions to low Total Cost of Ownership (TCO)
- correlation of machine and process parameters.



Figure 2
FAG SmartCheck

FAG SmartCheck is ready for immediate use as soon as it is delivered. The integrated characteristic value set allows general, reliable monitoring.

For more precise monitoring, a component template for pumps stored in the device can be selected and the corresponding parameters can be inputted by means of component data.

The device has an integrated rolling bearing database containing data for FAG and INA standard bearings. The user can add data on further rolling bearings to the database at any time.

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

FAG DTECT X1_s FAG DTECT X1_s is a flexible online system for the monitoring of rotating components and elements in the machinery and plant industry, *Figure 3*.

The system gives early, reliable detection of possible damage and thus helps to prevent unplanned and expensive downtime. This reduces the risk of possible production shutdowns, increasing the utilisation of machinery and plant.

The advantages of FAG DTECT X1_s are:

- reliable machinery protection by means of vibration diagnosis
- space saving due to compact construction
- suitable for harsh environments (–20 °C to +70 °C)
- diverse monitoring tasks due to the large number of measurement channels
- increased reliability through the combination of various process parameters
- versatile communication interfaces and connection options
- increased operational security due to breakdown protection
- flexible and simple installation at the location due to standardised connection systems.



Figure 3
FAG DTECT X1_s

FAG GreaseCheck

Many rolling bearings are lubricated using grease. The grease forms a lubricant film on the contact surfaces that is sufficiently capable of supporting loads and thus preventing wear and premature fatigue of the bearing. Reliable knowledge of the condition of the grease in the rolling bearing is therefore of enormous importance. Approximately three quarters of all rolling bearing failures are related to the lubricant, through lubricant starvation, contamination or ageing.

In order to prevent rolling bearing failure as a result of lubricant ageing, the grease operating life can be calculated, see Catalogue HR 1, Rolling Bearings.

In order to prevent damage to rolling bearings and thus expensive downtime and failures of machinery or plant, greases are normally replaced as part of preventive maintenance long before the end of their operating life. Alternatively, there is a tendency to carry out overgreasing as a result of an incorrect safety philosophy, which has a negative effect on the function and operating life of the bearing.

The lubricant sensor FAG GreaseCheck can analyse the condition of the grease in the rolling bearing during ongoing operation, *Figure 4*. The lubricant sensor can be used to detect changes in the condition of the grease long before damage occurs in the rolling bearing. As a result, the replacement of grease is oriented only towards the actual need.

Considerable savings are possible due to:

- a reduction in failure times that can be attributed to operational malfunctions related to lubrication
- a reduction in lubricant costs
- a reduction in the costs of maintenance and replacement parts
- a reduction in plant costs through increased efficiency levels.



Figure 4
FAG GreaseCheck

Further information

- TPI 214, FAG SmartCheck or at www.FAG-SmartCheck.com
- TPI 170, FAG DTECT X1_s
- SSD 21, Condition Monitoring of Greases in Rolling Bearings (FAG GreaseCheck).



Services

Technical advice
Calculation using BEARINX[®]
Failure analysis
Schaeffler Industrial Aftermarket

Technical advice

Features

Schaeffler offers you technical advice relating to the life cycle of rolling bearings under the philosophy of Total Cost of Ownership (TCO). The experts have excellent knowledge in bearing technology as well as comprehensive know-how in the field of pumps. As a result, customers receive competent advice and support in bearing design and the selection of products.

The service portfolio comprises:

- soundly based advice from experienced engineers
- efficient product updating and development
- greater cost-effectiveness with X-life
- optimised combinations of bearings, materials and seals
- efficient matching to differing operating conditions (special solutions).

medias®

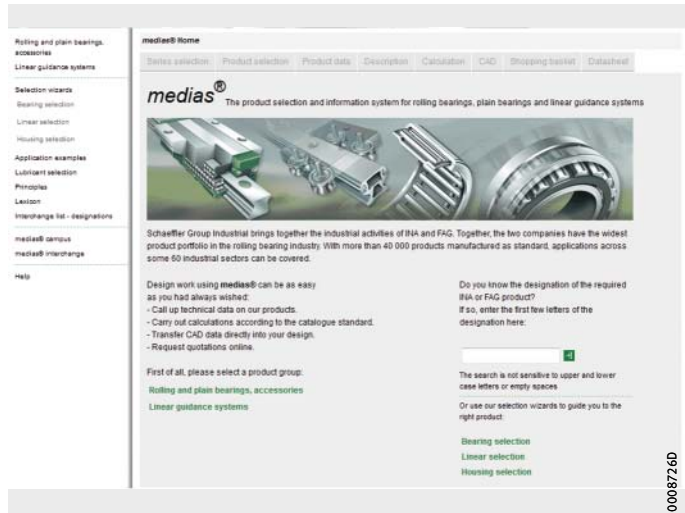
The electronic advice and selection system **medias®** gives information on more than 40 000 standard products for approximately 60 industrial market sectors. The selected bearings can be calculated and loaded into CAD drawings. In addition, selection of the correct lubrication is simplified by a comprehensive database. The entire Schaeffler service spectrum for industry can be accessed by just a few clicks of a mouse.

The **medias®** product catalogue can be found on the Internet at medias.schaeffler.de, *Figure 1*. This is also where you can also gain access to **medias®** campus and **medias®** interchange.

Our online training courses **medias®** campus give you the necessary rolling bearing knowledge in the form of short learning units.

With **medias®** interchange, you can determine appropriate INA and FAG bearings based on designations from other manufacturers.

Figure 1
Advice and selection system
medias®



Calculation using BEARINX®

Features

BEARINX® is one of the leading programs for the calculation of rolling bearings. It facilitates the detailed analysis of rolling bearing arrangements – from the individual bearing through complex shaft and linear guidance systems to complex applications. The complete calculation is carried out in a consistent calculation model. Even for extensive applications, the contact pressure at each individual rolling element is included in the calculation.

BEARINX® takes account of factors including the following:

- the non-linear elastic deflection behaviour of the bearings
- the elasticity of shafts and housings
- the influences of fit, temperature and speed on the operating clearance or preload of the bearings and on their contact angle
- the profiling of rollers and raceways as well as raceway oscillations
- the displacement of contact angles as a function of load in ball bearings
- the actual contact pressure taking account of the misalignment and profiling of rolling elements
- the influence of lubrication conditions, contamination and actual contact pressure on the fatigue life.

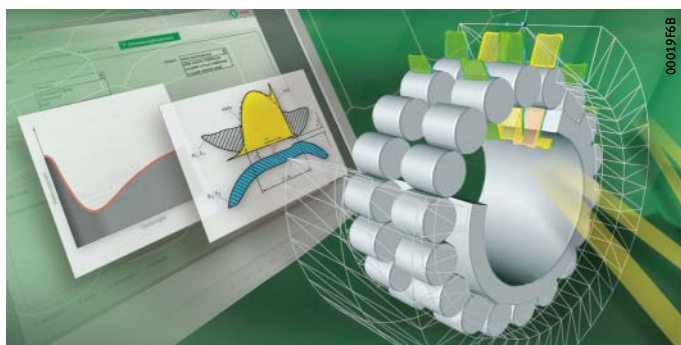


Figure 1
BEARINX®

The analysis of design variants is aided by the transparent documentation of results and the graphical representation of shaft reactions and the internal load distribution of bearings. Thanks to an online tutorial and a detailed help system, it is possible to easily utilise the full potential of BEARINX®-online Shaft Calculation.

The uniform calculation of the fatigue life using computer-aided calculation methods corresponding to the state of the art is defined in DIN 26281. This calculation method is of course also included in the online version.

BEARINX®-online Shaft Calculation – customer version

Commonly available calculation tools normally use heavily simplified calculation methods. In these cases, the misalignment of bearings as a result of shaft deflection and the different deflection behaviour of various bearing types is largely disregarded. In general, the internal load distribution of bearings – which is decisive for the fatigue life – is generally determined only by means of approximation methods.

Calculation using BEARINX®

It is possible using BEARINX®-online to determine the actual load taking account of shaft deflection and the deflection behaviour of the rolling bearings, *Figure 2*. The internal load distribution of the bearings is of course also calculated precisely – to the level of the contact pressure taking account of the actual rolling element profile.

The algorithms in BEARINX®-online Shaft Calculation are identical with those in BEARINX®, which is used at Schaeffler. BEARINX®-online Shaft Calculation facilitates calculation at the workstation of single axis shaft systems supported at several points. Input of data is supported by a Java-aided user interface. Checking of data is aided by graphical representation of the design.

An integrated database facilitates retrieval of data and the geometry of rolling bearings in the Schaeffler catalogue range.

The actual calculation is then performed by the powerful Schaeffler calculation servers. The input files created using BEARINX®-online Shaft Calculation are compatible with BEARINX® itself. As a result, further communication with Schaeffler advisory engineers is easier and duplicate work is avoided.

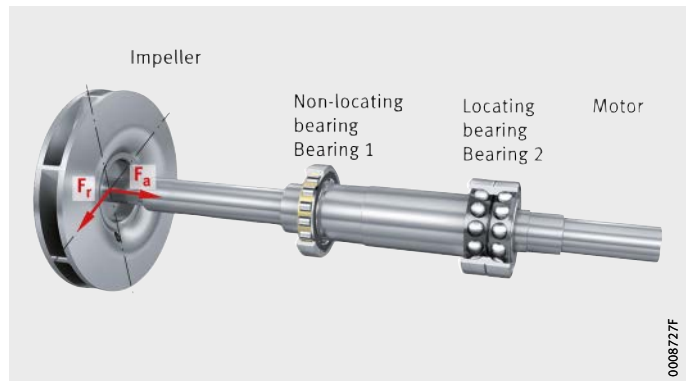


Figure 2
Shaft calculation

The software is not provided with the intention of transferring advice and calculation services from Schaeffler to customers. The reality is the opposite: with this arrangement, Schaeffler wishes to work even more closely with its customers. The objective is to make a suitable preliminary selection of rolling bearings in the early design phase, in order to reduce development times at the customer.

BEARINX®-online Shaft Calculation – an overview:

- calculation of bearing rigidity at the operating point taking account of all relevant influences
- graphical representation of shaft reactions (shaft deflection and shaft inclination)
- rigid and elastic adjustment of bearings in the relevant shaft system
- calculation of fatigue life in accordance with DIN 26281
- simple modelling of shaft systems by means of integrated wizards.

BEARINX®-online Easy Friction – customer version

The BEARINX®-online module Easy Friction can be used to determine the friction values of Schaeffler rolling bearings using a detailed method. The internal load distribution of the bearings and the contact pressures on the raceways and ribs together with the actual rolling element profile is of course taken into consideration. The new module is based on a theory of friction calculation that employs physical algorithms and have been confirmed by means of extensive test values. The bearing rating life is calculated in accordance with ISO/TS 16281.

The algorithms applied in BEARINX®-online Easy Friction take account in particular of the following parameters:

- losses in rolling and sliding contacts
- losses in the load-free zone
- splash losses
- seal friction.

Since it is seamlessly incorporated in the “parent software” BEARINX® used at Schaeffler, other typical influencing factors are also taken into consideration:

- radial and axial load
- tilting of bearing rings
- lubricant (viscosity class)
- temperature
- precise internal bearing geometry
- bearing clearance
- profiling of the bearing components
- rib geometry.

Since bearings can be exchanged, different bearing arrangement concepts can be quickly and easily compared with each other. This makes it possible to achieve a bearing arrangement that is efficient and has optimised friction. All input data can be stored locally. As a result, modifications can be quickly made to an existing application case without the need for duplicated input of data. Furthermore, the stored file can be exchanged with the Schaeffler engineering service in order to achieve an optimum bearing design. The most important results are displayed directly in a results window. In addition, the input data and the calculation results can be documented in a PDF file.

The calculation software is available only in an online format.

Further information

- www.schaeffler.com
- see PBO BEARINX®-online, Shaft Calculation
- see PBR BEARINX®-online, Easy Friction.

Failure analysis

Features

Rolling bearings are among the most important components of a pump in relation to high reliability and long life. Over time, the condition of rolling bearings is impaired by material fatigue, wear, thermal strain or changes in the lubricant, leading to premature loss of function.

Root causes of bearing damage

Most cases of bearing damage are induced by:

- inadequate cleanliness, caused by particles or undesirable fluids
- high operating temperature or large temperature differential
- incorrect mounting
- shock loads and vibrations
- material fatigue
- electrical current puncture
- defective bearing location in the housing or on the shaft
- overloading or insufficient load.

Types of bearing damage



Bearing damage occurring in fluid pumps can include the following:

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



In order to identify the cause of damage, assessment of the bearing is not generally sufficient. Furthermore, it is necessary to take account of the adjacent parts, the lubrication and sealing as well as the operating and environmental conditions. Identification of causes is assisted by the use of a planned procedure in examination.

Based on the results of damage analysis, remedial measures can be initiated with the corresponding technical department.

Rolling bearing damage due to contamination or current passage

Contamination	Current passage
	
Cause	
Dust, contamination or abrasive substances present in the air from contaminated working areas, contaminated hands or tools, foreign bodies in lubricants or cleaning solutions.	Continuously flowing alternating or direct current, marking possible even with small current values.
Remedy	
Filtration of the lubricant, cleaning of working areas and retention of the bearings in their original packaging until the time of mounting. In the case of contaminated operating environments, possibilities for sealing should be taken into consideration.	Prevention of current passage through the bearing (grounding, insulation), use of current-insulating bearings.

Rolling bearing damage due to failure of the lubricant or material fatigue

Failure of lubricant	Material fatigue
	
Cause	
Restricted lubricant flow or excessive temperatures, leading to deterioration of the lubricant.	Overloading, excessive preload, tight seating of the inner ring, bearings in operation beyond the calculated fatigue life.
Remedy	
Use of a suitable lubricant in the correct quantity, prevention of grease loss and compliance with suitable relubrication intervals, maintenance of the correct bearing seat and checking of the preload in order to reduce the bearing temperature.	Replacement of the bearing or modification of the design for use of a bearing with a longer calculated fatigue life.

Schaeffler Industrial Aftermarket

Features The Business Division Schaeffler Industrial Aftermarket (IAM) is responsible for replacement parts and service business for end customers and sales partners in all significant industrial sectors. On the basis of innovative solutions, products and services relating to rolling and plain bearings as well as intelligent implementation of the philosophy of Total Cost of Ownership (TCO), the Industrial Aftermarket service function offers a comprehensive portfolio that covers all phases in the lifecycle of the rolling bearing. The aim is to help customers save on maintenance costs, optimise plant availability and avoid unforeseen machine downtime, *Figure 1*.



Figure 1
Schaeffler Industrial Aftermarket

The portfolio in the area of maintenance and quality assurance extends from mounting, through plant monitoring, to the introduction and implementation of preventive maintenance measures. A wide range of mounting and alignment tools, measuring instruments and lubricants, as well as training courses makes maintenance work easier and work processes more efficient. Based on many years' experience and qualified experts, Schaeffler is the competent partner for customer-oriented solutions relating to the life cycle of rolling bearings. Service experts provide worldwide support using state of the art technology, for example by remote diagnosis via the Internet or GSM. Where personal intervention is required, support is available from highly qualified technicians and engineers. The highest levels of machinery availability are best achieved by means of service contracts. Their scope and structure is based on the individual customer and plant requirements.

Further information ■ Catalogue IS 1, Mounting and Maintenance of Rolling Bearings – Products, Services, Training.



FAG



Application examples

Submersible pump
Standardised chemical pump
Double flow pump

Submersible pump

Introduction

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

The area of applications lies principally in the removal and transport of water and contaminated water, for example in drainage of buildings or removal of water from rivers and containers.

Submersible pumps differ from the basic design of a centrifugal pump in that they are normally fitted with a vertical shaft on which the drive motor is mounted directly (block construction), *Figure 1*.



Figure 1
Submersible pump
© Flygt Xylem

Requirement

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, loads are generated by pressure generation and slight shocks may occur as a result of waste water containing solid particles.

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 $3\,600\text{ min}^{-1}$.

Design solution

In order to achieve an efficient, reliable and maintenance-free bearing arrangement of the shaft, 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 the contact angle of the angular contact ball bearing, it is highly suitable for the support of the axial loads.

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

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

Products used

The bearings used in submersible pumps are:

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

In addition to these rolling bearings, special solutions matched to the specific requirements are also possible. In this case, please contact the relevant specialists in Schaeffler Application Engineering.

Standardised chemical pump

Introduction

The designation “standardised chemical 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, standardised chemical pumps must in many cases additionally fulfil other standards such as ISO 5199 (EN 25199). Due to these specifications, pumps from different manufacturers can be replaced and fitted without problems 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, *Figure 1*.



Figure 1
Standardised chemical pump
© NKG
Factory image from Grundfoss

Requirements

The standardisation of these 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 where, for example, ISO 2858 specifies the diameter of the shaft end and thus the minimum bearing diameter as a function of the power rating.

In addition to the operating forces, no additional shocks or similar phenomena normally occur. Standardised chemical pumps are operated at speeds up to $3\,600\text{ min}^{-1}$. However, the speed can also be matched to the current requirements by means of an optional frequency inverter.

Design solution

As in the case of the submersible pump, a locating/non-locating bearing arrangement is normally used in the standardised chemical pump.

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 the NU design is used, which has no rib on the inner ring and thus ensures an axial displacement facility. 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 or, as shown in *Figure 1*, page 56, 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.

Products used

The bearings used in standardised chemical pumps are:

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

In addition to these rolling bearings, it is possible to use other bearing solutions, such as tapered or spherical roller bearings for high loads and moments. These are matched to the relevant requirements and are designed specially for these cases. In this case, please contact the relevant specialists in Schaeffler Application Engineering.

Double flow pump

Introduction

The double flow pump contains two single flow impellers arranged back to back an this symmetry improves the suction behaviour of the pump, *Figure 1*. The conveying height remains constant due to parallel switching but the volume flow is doubled.

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

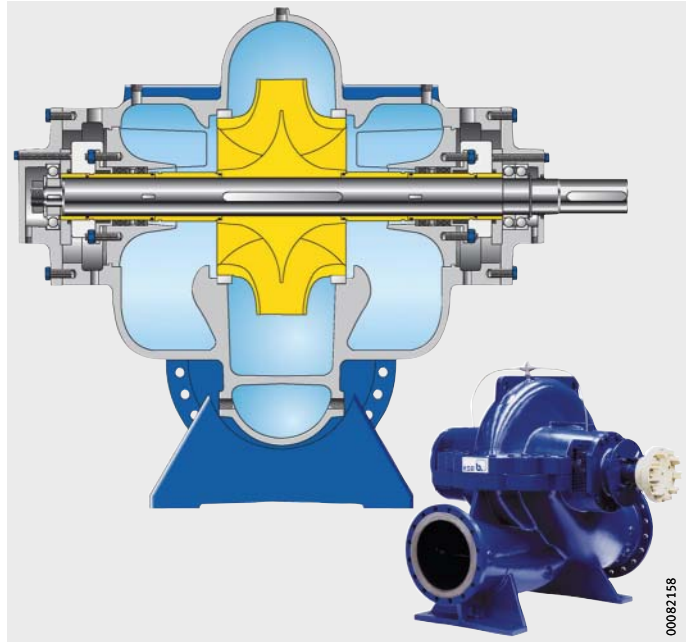


Figure 1
Volute casing pump and cross-section
© KSB Aktiengesellschaft RDLO

Requirements

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

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.

Design solution

In contrast to the flying bearing arrangement of submersible pump and standardised chemical pump, the impeller in the double flow pump is normally located between the two bearing positions.

The radial loads occurring are therefore 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.

The locating bearing can, due to the low axial load, be mounted on the drive side as well as on the pump side.

For lower loads, single row deep groove ball bearings can be used at both bearing positions. 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 or double row angular contact ball bearings are used as locating bearings. Both bearing positions can be lubricated with oil or grease.

Products used

The bearings used in double flow pumps are:

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

In addition to these rolling bearings, it is possible to use other bearing solutions, for example with split bearing rings to allow easier mounting in the case of large pumps. These are matched to the relevant requirements and are designed specially for these cases. In this case, please contact the relevant specialists in Schaeffler Application Engineering.

Notes

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Issued: 2014, October

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TPI 223 GB-D