

Technical Information

FAG

Rolling Bearings

TI No. WL 43-1190 EA

October 1999

FAG Rolling Bearings Fundamentals · Types · Designs



Contents · Introduction

Contents

The FAG rolling bearing programme	3
Rolling bearing types	4
Rolling bearing components	5
Rolling elements	5
Bearing rings	6
Cages	6
Load ratings	8
Combined load	8
Dimensioning	9
Statically stressed bearings	9
Service life	9
Wear	9
Dynamically stressed bearings	10
Nominal rating life	11
Adjusted rating life calculation	12
Lubrication	17
Grease lubrication	17
Oil lubrication	17
Important rolling bearing lubrication terms	17
Seals	21
Speed suitability	22
High temperature suitability	23
Bearing clearance	24
Tolerances	26
Alignment	27
Fits	28
Bearing arrangement	29
Symbols for load carrying capacity, alignment and speed suitability	32
Deep groove ball bearings	33
Angular contact ball bearings, single row	34
Angular contact ball bearings, double row	35
Four-point bearings	36
Self-aligning ball bearings	37
Cylindrical roller bearings	38
Tapered roller bearings	40
Barrel roller bearings	42
Spherical roller bearings	43
Thrust ball bearings	45
Angular contact thrust ball bearings	46
Cylindrical roller thrust bearings	47
Spherical roller thrust bearings	48
Matched rolling bearings	49
Bearing units	50
Checklist for rolling bearing determination	52
Index	53

Introduction

This Technical Information contains a summary of fundamental knowledge of FAG rolling bearings and should serve as an introduction to rolling bearing engineering. It is intended for those who have little or no knowledge of rolling bearings.

If you should like to enlarge your fundamental knowledge at your PC, we recommend you to use our **rolling bearing learning system W.L.S.** (cp. also Publ. No. WL 00106).

The FAG catalogue WL 41520 "FAG Rolling Bearings" is frequently referred to in this publication. It provides all the essential data designers need to safely and economically design all standard rolling bearings.

The **FAG rolling bearing catalogue on CD-ROM** outshines the usual software catalogues, being a comfortable, electronic consulting system. In a dialogue with WINDOWS you can quickly select the right FAG rolling bearing for your application and accurately calculate its life, speed, friction, temperature and cycling frequencies. This will save you a lot of money and time.

A large number of technical publications is available for specific applications which you can order from us indicating the publication number.

Rolling bearing codes are explained in detail in our Technical Information WL 43-1191.

Key rolling bearing engineering terms appear in boldface and will be explained in more detail (see also index at the end of this TI).

The FAG rolling bearing programme

The FAG rolling bearing programme

The FAG rolling bearing programme offers rolling bearings within outside diameters ranging from 3 millimetres to 4.25 metres, housings and accessories. The catalogue WL 41 520 "FAG Rolling Bearings" contains excerpts from this programme for the industrial original equipment manufacture (OEM), distribution, and replacement demand. With the products from this catalogue, most of which are produced in series, almost any application problem can be solved. To ensure quick availability of rolling bearings, housings and accessories, our stock-keeping programmes are constantly adapted to the requirements in your markets.

FAG standardized rolling bearing programme

In the catalogue WL 41 520, priority is given to rolling bearings in DIN/ISO dimensions. This allows the designer to solve almost any application problem quickly and cost-effectively.

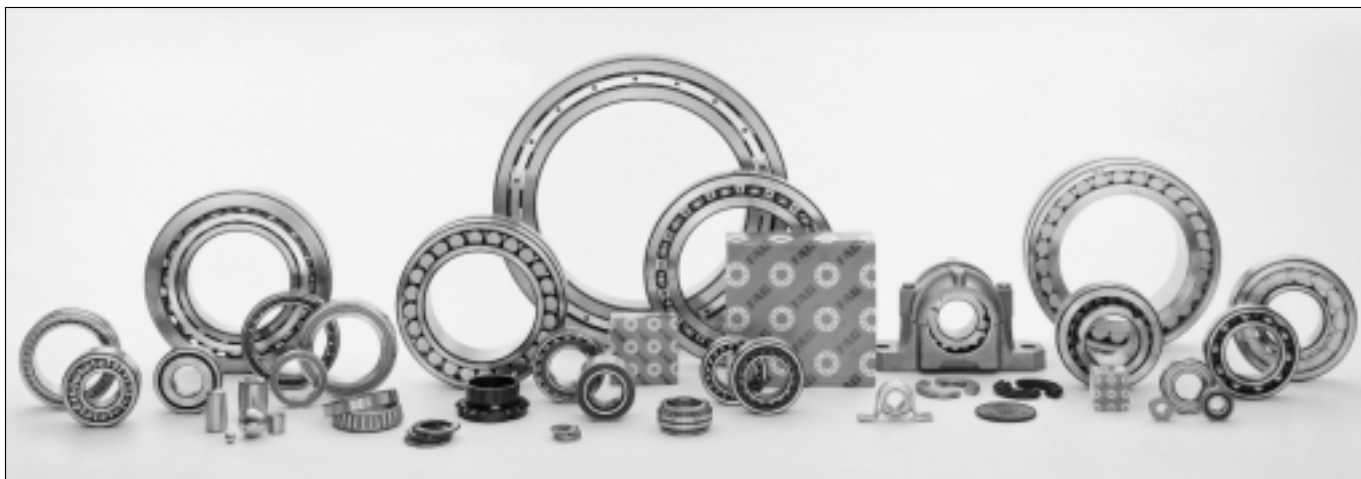
FAG target industry programmes

FAG have compiled special programmes for certain branches of industry. In addition to the standardized rolling bearings, these programmes contain numerous special designs which offer efficient, cost-effective solutions for more complicated bearing applications.

For-row cylindrical roller bearing for rolling mills (upper)

Self-aligning cylindrical roller bearings for paper-making machines (middle)

FAG standardized rolling bearings, housings and accessories (lower)



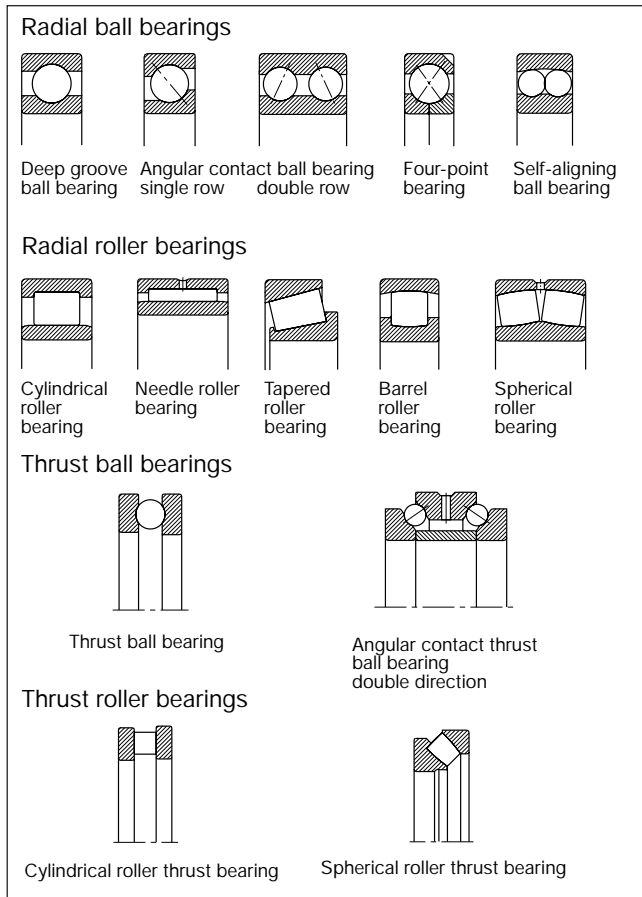
Rolling bearing types

Rolling bearing types

Numerous rolling bearing types with standardized main dimensions are available for the various requirements.

Rolling bearings are differentiated according to:

- the direction of main load: **radial bearings** and **thrust bearings**. Radial bearings have a nominal *contact angle* α_0 of 0° to 45° . Thrust bearings have a nominal contact angle α_0 of over 45° to 90° .
- the type of *rolling elements*: **ball bearings** and **roller bearings**.



The essential differences between ball bearings and roller bearings are:

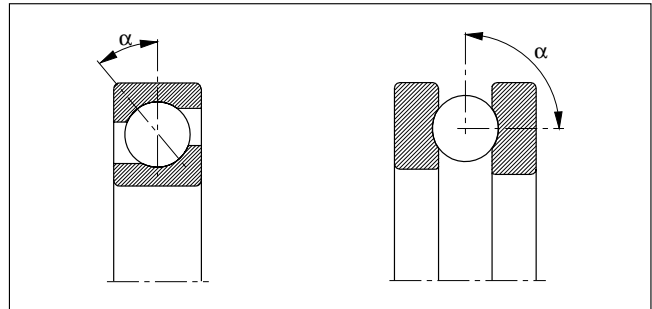
- Ball bearings: lower load carrying capacity, higher *speeds*
- Roller bearings: higher load carrying capacity, lower *speeds*

Other distinctive characteristics:

- *separable* or *non-separable*
- axial displaceability of the bearing rings relative to each other (ideal *floating bearings*)
- *self-aligning capability* of the bearing

Contact angle

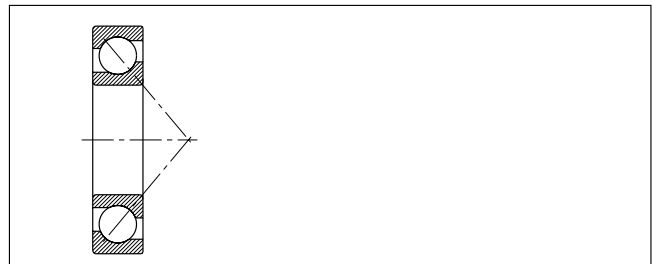
The *rolling elements* transmit loads from one *bearing ring* to the other in the direction of the **contact lines**. The contact angle α is the angle formed by the contact lines and the radial plane of the bearing. α_0 refers to the nominal contact angle, i.e. the contact angle of the load-free bearing. Under axial loads the contact angle of deep groove ball bearings, angular contact ball bearings etc. increases. Under a *combined load* it changes from one *rolling element* to the next. These changing contact angles are taken into account when calculating the pressure distribution within the bearing.



Ball bearings and *roller bearings* with symmetrical rolling elements have identical contact angles at their inner rings and outer rings. In roller bearings with asymmetrical rollers the contact angles at the inner rings and outer rings are not identical. The equilibrium of forces in these bearings is maintained by a force component which is directed towards the lip.

Pressure cone apex

The pressure cone apex is that point on the bearing axis where the *contact lines* of an **angular contact bearing**, i.e. an angular contact ball bearing, a tapered roller bearing or a spherical roller thrust bearing, intersect. The *contact lines* are the generatrices of the pressure cone apex.



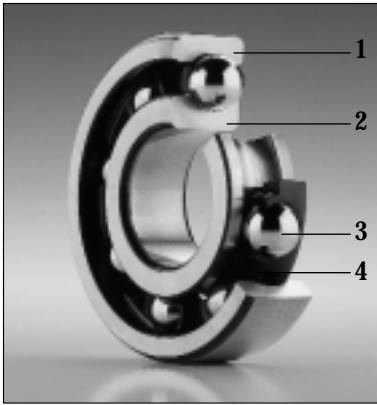
In *angular contact bearings* the external forces F act, not at the bearing centre, but at the pressure cone apex. This fact has to be taken into account when calculating the *equivalent dynamic load* P and the *equivalent static load* P_0 .

Rolling bearing components

Rolling elements

Rolling bearing components

Rolling bearings generally consist of *bearing rings* (inner ring and outer ring), *rolling elements* which roll on the raceways of the rings, and a *cage* which surrounds the rolling elements.



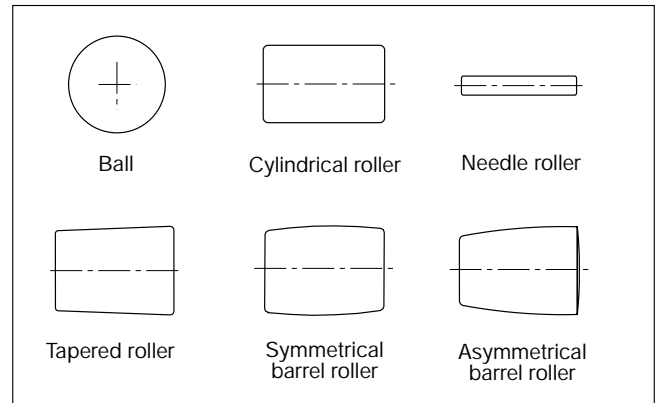
1 Outer ring, 2 Inner ring, 3 Rolling element, 4 Cage

The lubricant (usually *lubricating grease* or *lubricating oil*) also has to be regarded as a rolling bearing component as a bearing can hardly operate without a lubricant. *Seals* are also increasingly being integrated into the bearings.

The material of which rings and rolling elements for FAG rolling bearings are made is normally a low-alloyed, through-hardening chromium steel which is identified by the material number 1.3505, DIN designation 100 Cr 6.

Rolling elements

Rolling elements are classified, according to their shape, into balls, cylindrical rollers, needle rollers, tapered rollers and barrel rollers.



The rolling elements' function is to transmit the force acting on the bearing from one ring to the other. For a high load carrying capacity it is important that as many rolling elements as possible, which are as large as possible, are accommodated between the bearing rings. Their number and size depend on the cross section of the bearing.

It is just as important for loadability that the rolling elements within the bearing are of identical size. Therefore they are sorted according to grades. The tolerance of one grade is very slight.

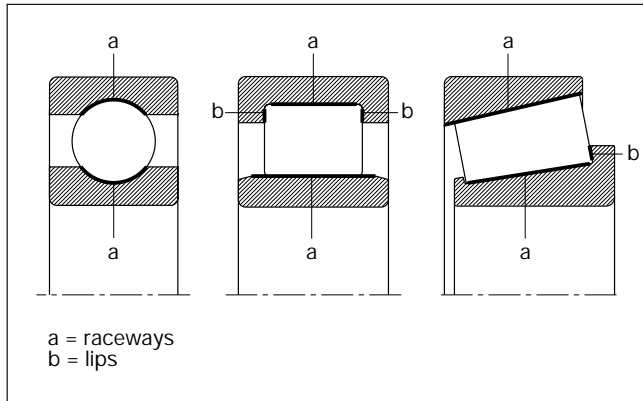
The generatrices of cylindrical rollers and tapered rollers have a logarithmic profile. This profile prevents, under normal load conditions, life-reducing edge stresses at a tilting angle of up to 4' between inner ring and outer ring.

Rolling bearing components

Bearing rings · Cages

Bearing rings

The bearing rings – inner ring and outer ring – guide the *rolling elements* in the direction of rotation. Raceway grooves, lips and inclined running areas guide the rolling elements and transmit axial loads in transverse direction. Design NU and N cylindrical roller bearings have lips only on one bearing ring; they can, therefore, accommodate shaft expansions as *floating bearings*.



The two rings of **separable** rolling bearings can be mounted separately. This is of advantage if both bearing rings have to be mounted with a tight *fit* (see page 28).

Separable bearings include, e.g. four-point bearings, double-row angular contact ball bearings with a split ring, cylindrical roller bearings, tapered roller bearings, thrust ball bearings, cylindrical roller thrust bearings and spherical roller thrust bearings.

Non-separable bearings include, e.g. deep groove ball bearings, single-row angular contact ball bearings, self-aligning ball bearings, barrel roller bearings and spherical roller bearings.

Cages

Functions of a cage:

- to keep the *rolling elements* apart so that they do not rub against each other
- to keep the rolling elements evenly spaced for uniform load distribution
- to prevent rolling elements from falling out of *separable bearings* and bearings which are swiveled out
- to guide the rolling elements in the unloaded zone of the bearing.

The transmission of forces is not one of the cage's functions.

Cages are classified into *pressed cages*, *machined cages* and *moulded cages*.

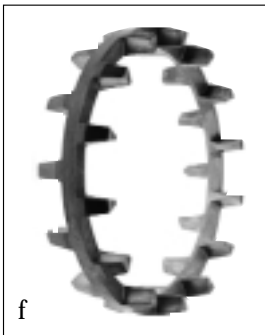
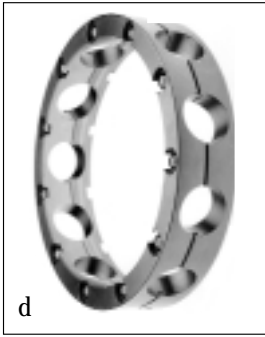
Pressed cages are usually made of steel, but sometimes of brass, too. They are lighter than machined metal cages. Since a pressed cage barely closes the gap between inner ring and outer ring, lubricant can easily penetrate into the bearing. It is stored at the cage.



Pressed steel cages: prong-type cage (a) and rivet cage (b) for deep groove ball bearings, window-type cage (c) for spherical roller bearings

Rolling bearing components

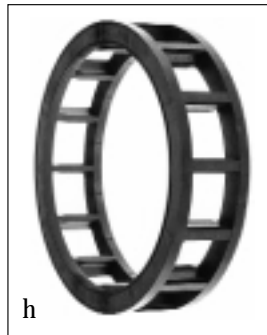
Cages



Machined brass cages: riveted machined cage (d) for deep groove ball bearings, window-type cage (e) for angular contact ball bearings, double prong type cage (f) for spherical roller bearings.

Moulded cages of polyamide 66 are produced by injection moulding and are used in many large-series bearings.

Injection moulding has made it possible to realize cage designs with an especially high load carrying capacity. The elasticity and low weight of the cages are of advantage where shock-type bearing loads, great accelerations and decelerations as well as tilting of the bearing rings relative to each other have to be accommodated. Polyamide cages feature very good sliding and dry running properties.

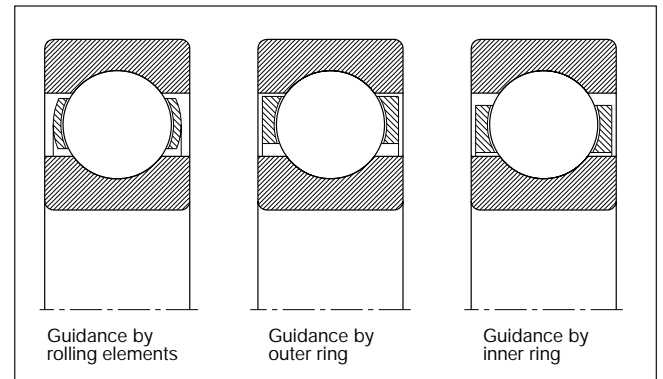


Moulded cages of glass fibre reinforced polyamide: window-type cage (g) for single-row angular contact ball bearings, window-type cage (h) for cylindrical roller bearings, double prong type cage (i) for self-aligning ball bearings

Cages of glass fibre reinforced polyamide PA66 are suitable for steady-state operating temperatures of up to +120 °C. In oil-lubricated bearings, *additives* contained in the oil may reduce the cage life. At increased temperatures, aged oil may also have an impact on the cage life so that it is important to observe the oil change intervals. The limits of application for rolling bearings with polyamide PA66-GF25 cages are indicated in the FAG catalogue WL 41 520EA, page 85. TI No. WL 95-4 contains a list of these cages.

Another distinctive feature of a cage is its **type of guiding**.

- The most frequent one: guidance by the *rolling elements* (no suffix)
- Guidance by the outer ring (suffix A)
- Guidance by the inner ring (suffix B)



Under normal operating conditions, the cage design specified as the standard design is usually suitable. Within a single bearing series the standard cages may differ depending on the bearing size, cp. section on "Spherical roller bearings". Where specific operating conditions have to be accommodated, a cage custom-tailored to these conditions has to be selected.

Rules determining the **cage code** within the bearing code:

- If a pressed cage is the standard cage: no code for the cage
- If the cage is a machined cage: code number for the cage whether normal or special cage
- If a pressed cage is not standard design: code numbers for cage

There are a number of special rolling bearing designs and some series of cylindrical roller bearings – so-called full complement bearings – without cages. By omitting the cage the bearing can accommodate more *rolling elements*. This yields an increased *load rating*, but, due to the increased friction, the bearing is *suitable for lower speeds* only.

Load ratings · Combined load

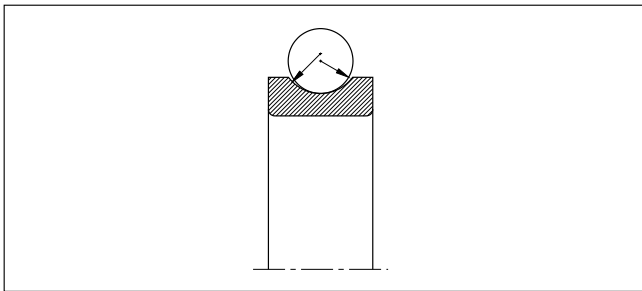
Load ratings

The load rating of a bearing reflects its load carrying capacity and is an important factor in the *dimensioning* of rolling bearings. It is determined by the number and size of the *rolling elements*, the *curvature ratio*, the *contact angle* and the pitch circle diameter of the bearing. Due to the larger contact area between rollers and raceways the load ratings of *roller bearings* are higher than those of *ball bearings*.

The load rating of a *radial bearing* is defined for radial loads whereas that of a *thrust bearing* is defined for axial loads. Every rolling bearing has a dynamic load rating and a static load rating. The terms "dynamic" and "static" refer to the movement of the bearing but not to the type of load.

In all rolling bearings with a curved raceway profile the radius of the raceway is slightly larger than that of the rolling *elements*. This curvature difference in the axial plane is defined by the **curvature ratio** κ . The curvature ratio is the curvature difference between the rolling element radius and the slightly larger groove radius.

$$\text{curvature ratio } \kappa = \frac{\text{groove radius} - \text{rolling element radius}}{\text{rolling element radius}}$$



Dynamic load rating

Load rating comparison of a few rolling bearing types with a bore diameter of $d = 25 \text{ mm}$

Rolling bearing	Dyn. load rating C kN
Deep groove ball bearing 6205	14
Cylindrical roller bearing NU205E	29
Tapered roller bearing 30205A	32.5
Spherical roller bearing 22205E	43

The dynamic load rating C is a factor for the load carrying capacity of a rolling bearing under dynamic load at which the bearing rings rotate relative to each other. It is defined as the load, constant in magnitude and direction, a rolling bearing can theoretically accommodate for a *nominal rating life* of 1 million revolutions (DIN ISO 281).

Static load rating

In statically stressed bearings there is no relative motion between the *bearing rings* or only a very slow one. A load equalling the static load rating C_0 in magnitude generates in the middle of the *rolling element* /raceway contact area, which is the most heavily loaded, a Hertzian contact pressure of approximately

4600 N/mm² in self-aligning ball bearings,
4200 N/mm² in all other ball bearings,
4000 N/mm² in all roller bearings

Under the C_0 load a total plastic deformation of rolling element and raceway of about 0.01% of the rolling element diameter at the most heavily loaded contact area arises (DIN ISO 76).

Combined load

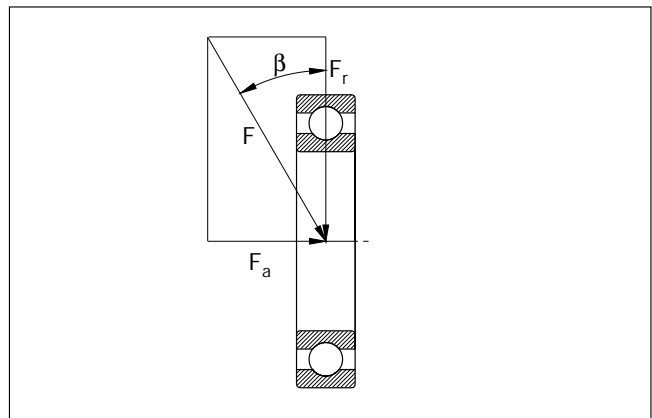
This applies when a bearing is loaded both radially and axially, and the resulting load acts, therefore, at the *load angle* β .

Depending on the type of load, the *equivalent static load* P_0 , (page 9) or the *equivalent dynamic load* P (page 10) is determined in the bearing calculation with the radial component F_r and the axial component F_a of the combined load.

Load angle

The load angle β is the angle between the resultant applied load F and the radial plane of the bearing. It is the resultant of the radial component F_r and the axial component F_a :

$$\tan \beta = F_a / F_r$$



Dimensioning

Statically stressed bearings · Service life · Wear

Dimensioning

A dimension calculation is carried out to check whether requirements on *life*, static safety and cost efficiency of a bearing have been fulfilled. This calculation involves the comparison of a bearing's load with its load carrying capacity. In rolling bearing engineering a differentiation is made between *dynamic* and *static* stress.

The dimensions calculation is considerably facilitated by the electronic FAG rolling bearing catalogue on CD-ROM, cp. also "Introduction" on page 2.

Statically stressed rolling bearings

Static stress refers to bearings carrying a load when stationary (no relative movement between the *bearing rings*). The term "static", therefore, relates to the operation of the bearing but not to the effects of the load. The magnitude and direction of load may change.

Bearings which perform slow slewing motions or rotate at a low speed ($n < 10 \text{ min}^{-1}$) are calculated like statically stressed bearings (cp. *dynamically stressed rolling bearings*, page 10).

For static stress conditions the safety against excessive plastic deformations of the raceways and *rolling elements* is checked.

Equivalent static load P_0

Statically stressed rolling bearings which operate under a *combined load* are calculated with the equivalent static load. It is a radial load for *radial bearings* and an axial load for *thrust bearings*, having the same effect with regard to permanent deformation as the *combined load*. The equivalent static load P_0 is calculated with the formula:

$$P_0 = X_0 \cdot F_r + Y_0 \cdot F_a$$

- F_r radial load
- F_a axial load
- X_0 radial factor (see FAG catalogues)
- Y_0 axial factor (see FAG catalogues)

Index of static stressing f_s

The index of static stressing f_s for statically loaded bearings is calculated to ensure that an adequately dimensioned bearing has been selected. It is calculated from the *static load rating* C_0 (see page 8) and the *equivalent static load* P_0 .

$$f_s = \frac{C_0}{P_0}$$

The index f_s is a safety factor against excessively great total plastic deformation in the contact area of the raceway and the most highly loaded *rolling element*.

A high f_s value is necessary for bearings which must run smoothly and particularly quietly. Smaller values satisfy modest demands on the quietness of running. Commonly applicable values are:

- $f_s = 1.5 \dots 2.5$ for high demands
- $f_s = 1 \dots 1.2$ for normal demands
- $f_s = 0.7 \dots 1$ for modest demands

Service life

This is the life during which the bearing operates reliably.

The *fatigue life* of a bearing (cp. section on "Bearing life", page 10) is the upper limit of the service life. Often this limit is not reached due to *wear* or lubrication breakdown.

Wear

The *life* of rolling bearings can be terminated, apart from *fatigue*, as a result of wear. The clearance of a worn bearing gets too large.

One frequent cause of wear are foreign particles which penetrate into a bearing due to insufficient *sealing* and have an abrasive effect. Wear is also caused by starved lubrication and when the lubricant is used up.

Therefore, wear can be considerably reduced by providing good lubrication conditions (*viscosity ratio* $\kappa > 2$ if possible) and a good degree of cleanliness in the rolling bearing. Where $\kappa \leq 0.4$ wear will dominate in the bearing if it is not prevented by suitable *additives* (*EP additives*).

Dimensioning

Dynamically stressed bearings · Bearing life

Dynamically stressed rolling bearings

Rolling bearings are dynamically stressed when one ring rotates relative to the other under load. The term "dynamic" does not refer, therefore, to the effect of the load but rather to the operating condition of the bearing. The magnitude and direction of the load can remain constant.

When calculating the bearings, a dynamic stress is assumed when the speed n amounts to at least 10 min^{-1} (see *static stressing*).

Equivalent dynamic load P

For dynamically loaded rolling bearings operating under *combined load*, the calculation is based on the equivalent dynamic load. This is a radial load for *radial bearings* and an axial and central load for *axial bearings*, having the same effect on *fatigue* as the *combined load*. The equivalent dynamic load P is calculated by means of the following equation:

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

- F_r radial load
- F_a axial load
- X radial factor
- Y axial factor

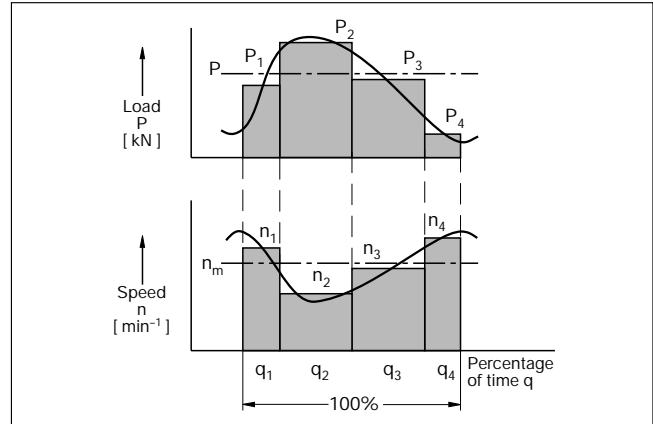
Variable load and speed

If loads and speeds vary over time this has to be taken into account when calculating the equivalent dynamic load. The curve is approximated by a series of individual loads and speeds of a certain duration q [%]. In this case, the equivalent dynamic load P is obtained from

$$P = \sqrt[3]{P_1^3 \cdot \frac{n_1}{n_m} \cdot \frac{q_1}{100} + P_2^3 \cdot \frac{n_2}{n_m} \cdot \frac{q_2}{100} + \dots} \text{ [kN]}$$

and the mean rotational speed n_m from:

$$n_m = n_1 \cdot \frac{q_1}{100} + n_2 \cdot \frac{q_2}{100} + \dots \text{ [min}^{-1}\text{]}$$

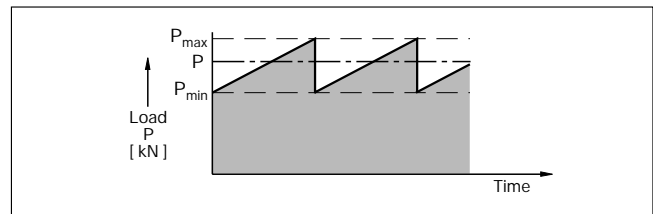


If the load is variable but the speed constant:

$$P = \sqrt[3]{P_1^3 \cdot \frac{q_1}{100} + P_2^3 \cdot \frac{q_2}{100} + \dots} \text{ [kN]}$$

If the load increases linearly from a minimum value P_{\min} to a maximum value P_{\max} at a constant speed:

$$P = \frac{P_{\min} + 2P_{\max}}{3} \text{ [kN]}$$



The mean value of the equivalent dynamic load may **not** be used for the *adjusted rating life calculation* (page 12ff). Rather, the *attainable life* under constant conditions has to be determined for every operating time.

Bearing life

The life of *dynamically stressed rolling bearings*, as defined by DIN ISO 281, is the operating time until failure due to material fatigue (**fatigue life**).

By means of the classical calculation method, a comparison calculation, the *nominal rating life* L or L_h of a bearing is determined; by means of the refined FAG calculation process, the *attainable life* L_{na} or L_{hna} is determined (see also a_{23} factor).

Dimensioning

Dynamically stressed bearings · Nominal rating life

Nominal rating life

The standardized calculation method (DIN ISO 281) for dynamically stressed rolling bearings is based on material fatigue (formation of pitting) as the cause of failure. The life formula is:

$$L_{10} = L = \left(\frac{C}{P}\right)^p \cdot 10^6 \text{ revolutions}$$

L_{10} is the nominal rating life in millions of revolutions which is reached or exceeded by at least 90% of a large group of identical bearings.

In the formula,

- C *dynamic load rating* (see page 8)
- P *equivalent dynamic load* (see page 10)
- p **life exponent**
 - p = 3 for ball bearings
 - p = $\frac{10}{3}$ for roller bearings

Where the bearing speed is constant, the life can be expressed in hours.

$$L_{h10} = L_h = \frac{L \cdot 10^6}{n \cdot 60} [\text{h}]$$

- L nominal rating life [10^6 revolutions]
- n speed [min^{-1}]

L_h can also be determined by means of the *index of dynamic stressing*, f_L .

The nominal rating life L or L_h applies to bearings made of conventional rolling bearing steel and the usual operating conditions (good lubrication, no extreme temperatures, normal cleanliness).

The nominal rating life deviates more or less from the really *attainable life* of rolling bearings. Influences like the lubricating film thickness, the cleanliness in the lubricating gap, lubricant *additives* and bearing type are taken into account in the *adjusted rating life calculation* by the *factor* a_{23} .

Index of dynamic stressing f_L

It is convenient to express the **value recommended** for dimensioning not in hours but as the index of dynamic stressing, f_L . It is calculated from the *dynamic load rating* C , the *equivalent dynamic load* P and the *speed factor* f_n .

$$f_L = \frac{C}{P} \cdot f_n$$

The f_L value is an empirical value obtained from field-proven identical or similar bearing mountings. The f_L values help to select the right bearing size. The values indicated in various FAG publications take into account not only an adequate *fatigue life* but also other requirements such as low weight for light-weight constructions, adaptation to given mating parts, higher-than-usual peak loads, etc. The f_L values conform with the latest standards resulting from technical progress. For comparison with a field-proven bearing mounting the calculation of stressing must, of course, be based on the same former method.

The **speed factor** f_n is an auxiliary quantity which is used, instead of the speed n , to determine the *index of dynamic stressing*, f_L .

$$f_n = \sqrt[p]{\frac{33^{1/3}}{n}}$$

$$p = 3 \quad \text{for ball bearings}$$

$$p = \frac{10}{3} \quad \text{for roller bearings}$$

Based on the calculated value of f_L , the nominal rating life in hours can be determined.

$$L_h = 500 \cdot f_L^p$$

Dimensioning

Dynamically stressed bearings · Adjusted rating life calculation

Adjusted rating life calculation

The *nominal rating life* L or L_h deviates more or less from the really *attainable life* of rolling bearings.

Therefore, additional important operating conditions besides the load have to be taken into account in the adjusted rating life calculation.

Modified life

The standard DIN ISO 281 introduced, in addition to the *nominal rating life* L_{10} , the modified life L_{na} to take into account, apart from the load, the influence of the failure probability (*factor* a_1), of the material (factor a_2) and of the operating conditions (factor a_3).

DIN ISO 281 indicates no figures for the *factor* a_{23} ($a_{23} = a_2 \cdot a_3$). With the FAG calculation process for the *attainable life* (L_{na} , L_{hna}), however, operating conditions can be expressed in terms of figures by the *factor* a_{23} .

Factor a_1

Generally (*nominal rating life* L_{10}), 10% failure probability is taken. The factor a_1 is also used for failure probabilities between 10% and 1% for the calculation of the *attainable life*, see following table.

Failure probability %	10	5	4	3	2	1
Fatigue life	L_{10}	L_5	L_4	L_3	L_2	L_1
Factor a_1	1	0.62	0.53	0.44	0.33	0.21

Attainable life L_{na} , L_{hna} according to the FAG method

The FAG calculation method for determining the attainable life (L_{na} , L_{hna}) is based on DIN ISO 281 (cp. *Modified Life*). It takes into account the influences of the operating conditions on the rolling bearing life.

$$L_{na} = a_1 \cdot a_{23} \cdot L \quad [10^6 \text{ revolutions}]$$

and

$$L_{hna} = a_1 \cdot a_{23} \cdot L_h \quad [\text{h}]$$

- a_1 *factor* a_1 for failure probability; usually, $a = 1$ is assumed for a 10% failure probability
- a_{23} *factor* a_{23} (*life adjustment factor*)
- L *nominal rating life* [10^6 revolutions]
- L_h *nominal rating life* [h]

Changing operating conditions

If the quantities influencing the bearing life (e.g. load, speed, temperature, cleanliness, type and condition of the lubricant) are variable, the attainable life (L_{hna1} , L_{hna2} , ...) under constant conditions has to be determined for every operating time q [%]. The attainable life is calculated for the total operating time using the formula

$$L_{hna} = \frac{100}{\frac{q_1}{L_{hna1}} + \frac{q_2}{L_{hna2}} + \frac{q_3}{L_{hna3}} + \dots}$$

Factor a_{23} (life adjustment factor)

The a_{23} factor (= $a_2 \cdot a_3$, cp. "Modified Life") takes into account not only the influence of material and lubrication but also the amount of load acting on the bearing and the bearing type as well as the influence of the cleanliness in the lubricating gap.

The a_{23} factor is determined by the lubricant film formation within the bearing, i.e. by the **viscosity ratio** $\lambda = \nu/\nu_1$.

Dimensioning

Dynamically stressed bearings · Adjusted rating life calculation

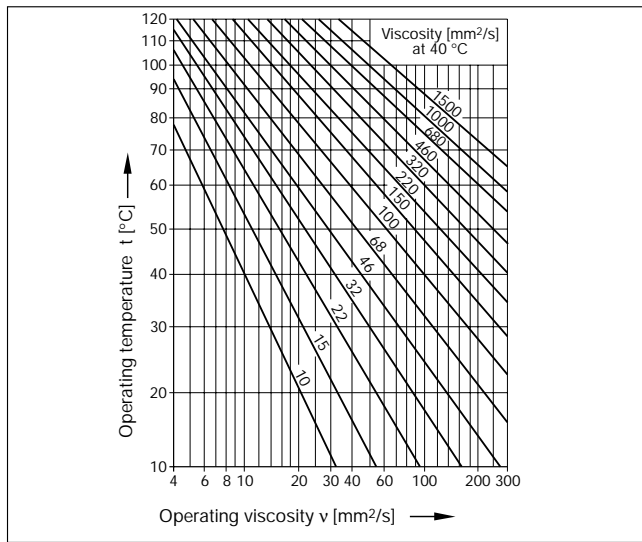
ν *operating viscosity* of the lubricant, depending on the nominal *viscosity* (at 40 °C) and the operating temperature (fig. 1). In the case of lubricating greases, ν is the *operating viscosity of the base oil*.

ν_1 *rated viscosity*, depending on the mean bearing diameter and the operating speed (fig. 2).

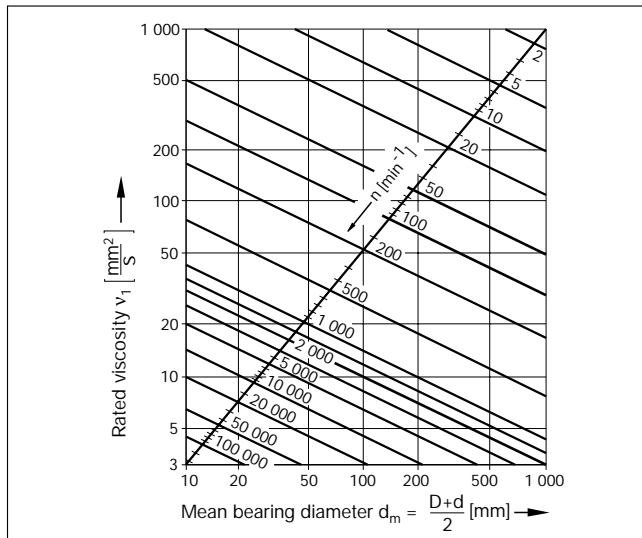
Fig. 3 for determining the a_{23} factor is subdivided into zones I, II and III.

Most applications in rolling bearing engineering are covered by zone II. It applies to normal cleanliness (*contamination factor* $V = 1$).

1: Average viscosity-temperature behaviour of mineral oils



2: Rated viscosity ν_1

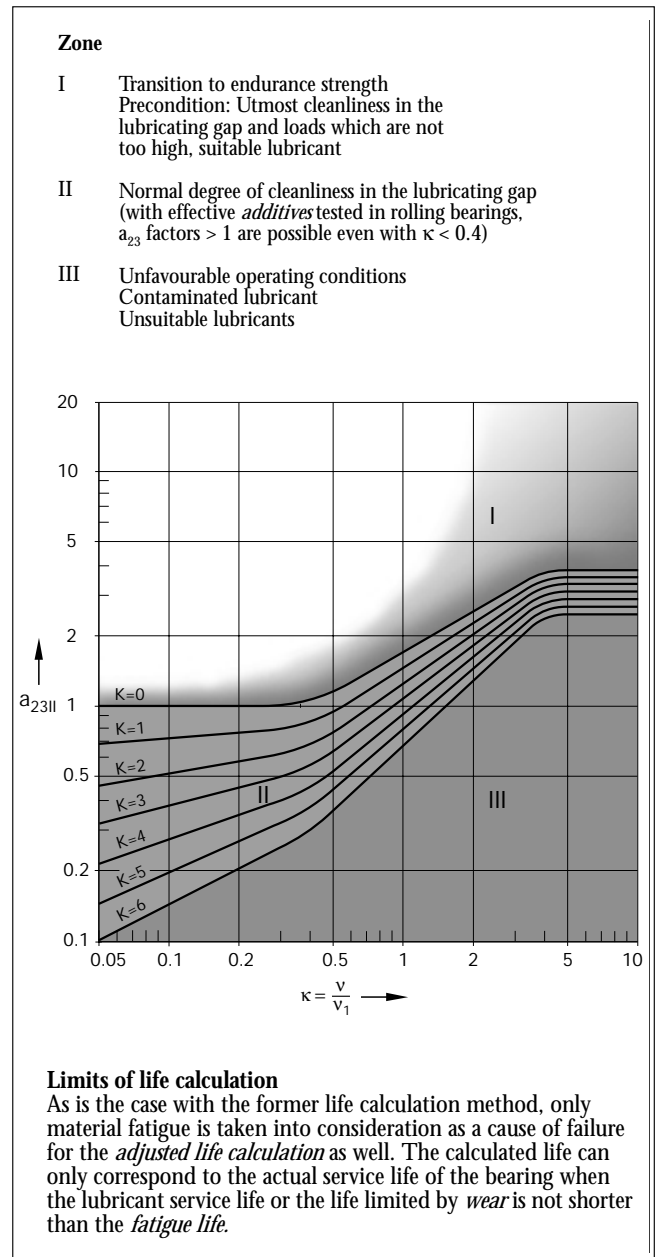


The **basic** a_{23II} factor can be determined as a function of K on one of the curves in zone II by means of the **value** K ($K = 0$ to 6).

If $K > 6$, a_{23} must be expected to be in zone III. In such a case, conditions should be improved so that zone II can be reached.

The a_{23} factor is obtained as the product of the **basic** a_{23II} factor and the **cleanliness factor** s (see page 16).

3: Basic a_{23II} factor for determining the a_{23} factor



Dimensioning

Dynamically stressed bearings · Adjusted rating life calculation

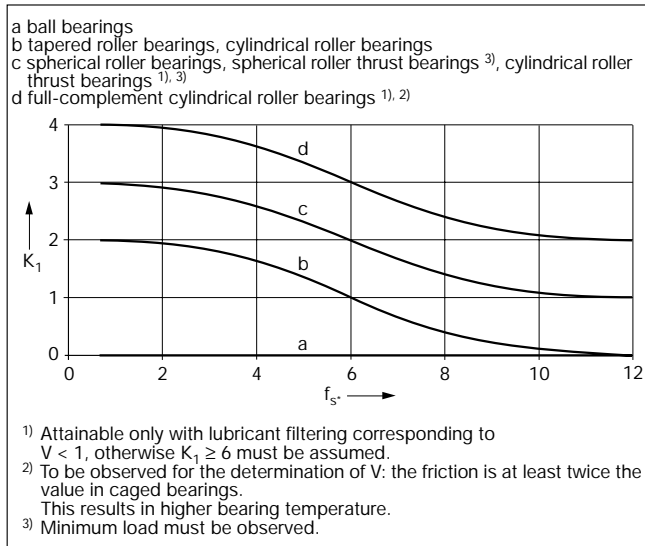
Value K

The value K is an auxiliary quantity needed to determine the *basic a_{23II} factor* when calculating the *attainable life* of a bearing.

$$K = K_1 + K_2$$

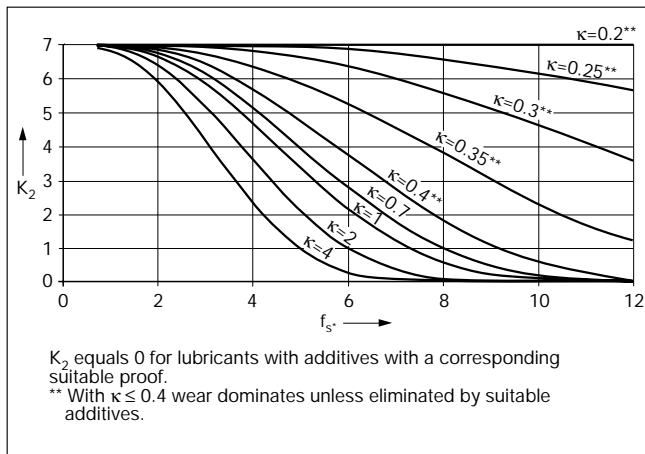
K_1 depends on the bearing type and the *stress index* f_{s^*} , see diagram.

Value K_1



K_2 depends on the *stress index* f_{s^*} and the *viscosity ratio* κ . The values in the diagram (below) apply to lubricants without additives and lubricants with *additives* whose effect in rolling bearings was not tested.

Value K_2



Stress index f_{s^*}

When calculating the *attainable life* of a bearing, the stress index f_{s^*} is taken into account as a measure of the maximum compressive stresses generated in the rolling contact areas.

$$f_{s^*} = C_0 / P_{0^*}$$

C_0 static load rating (see page 8)

P_{0^*} equivalent bearing load

$$P_{0^*} = X_0 \cdot F_r + Y_0 \cdot F_a$$

F_r dynamic radial force

F_a dynamic axial force

X_0 radial factor (see catalogue)

Y_0 thrust factor (see catalogue)

Contamination factor V

The contamination factor V indicates the degree of cleanliness in the lubricating gap of rolling bearings based on the *oil cleanliness classes* defined in ISO 4406.

When determining the *attainable life*, V is used, together with the *stress index* f_{s^*} and the *viscosity ratio* κ , to determine the *cleanliness factors* (see page 16).

V depends on the bearing cross section, the type of contact between the mating surfaces and especially the *cleanliness level of the oil*. If hard particles from a defined size on are cycled in the most heavily stressed contact area of a rolling bearing, the resulting indentations in the contact surfaces lead to premature material *fatigue*. The smaller the contact area, the more damaging the effect of a particle above a certain size when being cycled. Small bearings with point contact are especially vulnerable.

According to today's knowledge the following cleanliness scale is useful (the most important values are in boldface):

- V = 0.3 **utmost cleanliness**
- V = 0.5 improved cleanliness
- V = 1 **normal cleanliness**
- V = 2 moderately contaminated lubricant
- V = 3 **heavily contaminated lubricant**

Preconditions for utmost cleanliness (V = 0.3):

- bearings are greased and protected by seals or shields against dust by the manufacturer
- grease lubrication by the user who fits the bearings into clean housings under top cleanliness conditions, lubricates them with clean grease and takes care that dirt cannot enter the bearings during operation

Dimensioning

Dynamically stressed bearings · Adjusted rating life calculation

- flushing the oil circulation system prior to the first operation of the cleanly fitted bearings and taking care that the oil cleanliness class is ensured during the entire operating time

Preconditions for normal cleanliness (V = 1):

- good *sealing* adapted to the environment
- cleanliness during mounting
- oil cleanliness according to V = 1
- observing the recommended oil change intervals

Possible causes of heavy lubricant contamination (V = 3):

- the cast housing was inadequately cleaned
- abraded particles from components which are subject to wear enter the circulating oil system of the machine
- foreign matter penetrates into the bearing due to an unsatisfactory *sealing*

- water which entered the bearing, also condensation water, caused standstill corrosion or deterioration of the lubricant properties

The necessary **oil cleanliness class** according to ISO 4406 is an objectively measurable level of the contamination of a lubricant.

In accordance with the particle-counting method, the numbers of all particles > 5 µm and all particles > 15 µm are allocated to a certain ISO oil cleanliness class. An oil cleanliness 15/12 according to ISO 4406 means, for example, that between 16000 and 32000 particles > 5 µm and between 2000 and 4000 particles > 15 µm are present per 100 ml of a fluid. The step from one class to the next is by doubling or halving the particle number.

Guide values for the contamination factor V

(D - d)/2 mm	V	Point contact	guide values for	Line contact	guide values for
		required oil cleanliness class according to ISO 4406 ¹⁾	a suitable filtration ratio according to ISO 4572	required oil cleanliness class according to ISO 4406 ¹⁾	a suitable filtration ratio according to ISO 4572
≤ 12.5	0.3	11/8	$\beta_3 \geq 200$	12/9	$\beta_3 \geq 200$
	0.5	12/9	$\beta_3 \geq 200$	13/10	$\beta_3 \geq 75$
	1	14/11	$\beta_6 \geq 75$	15/12	$\beta_6 \geq 75$
	2	15/12	$\beta_6 \geq 75$	16/13	$\beta_{12} \geq 75$
	3	16/13	$\beta_{12} \geq 75$	17/14	$\beta_{25} \geq 75$
> 12.5...20	0.3	12/9	$\beta_3 \geq 200$	13/10	$\beta_3 \geq 75$
	0.5	13/10	$\beta_3 \geq 75$	14/11	$\beta_6 \geq 75$
	1	15/12	$\beta_6 \geq 75$	16/13	$\beta_{12} \geq 75$
	2	16/13	$\beta_{12} \geq 75$	17/14	$\beta_{25} \geq 75$
	3	18/14	$\beta_{25} \geq 75$	19/15	$\beta_{25} \geq 75$
> 20...35	0.3	13/10	$\beta_3 \geq 75$	14/11	$\beta_6 \geq 75$
	0.5	14/11	$\beta_6 \geq 75$	15/12	$\beta_6 \geq 75$
	1	16/13	$\beta_{12} \geq 75$	17/14	$\beta_{12} \geq 75$
	2	17/14	$\beta_{25} \geq 75$	18/15	$\beta_{25} \geq 75$
	3	19/15	$\beta_{25} \geq 75$	20/16	$\beta_{25} \geq 75$
> 35	0.3	14/11	$\beta_6 \geq 75$	14/11	$\beta_6 \geq 75$
	0.5	15/12	$\beta_6 \geq 75$	15/12	$\beta_{12} \geq 75$
	1	17/14	$\beta_{12} \geq 75$	18/14	$\beta_{25} \geq 75$
	2	18/15	$\beta_{25} \geq 75$	19/16	$\beta_{25} \geq 75$
	3	20/16	$\beta_{25} \geq 75$	21/17	$\beta_{25} \geq 75$

The oil cleanliness class can be determined by means of oil samples by filter manufacturers and institutes. It is a measure of the probability of life-reducing particles being cycled in a bearing. Suitable sampling should be observed (see e.g. DIN 51570). Today, on-line measuring instruments are available. The cleanliness classes are reached if the entire oil volume flows through the filter within a few minutes. To ensure a high degree of cleanliness flushing is required **prior** to bearing operation.

For example, a filtration ratio $\beta_3 \geq 200$ (ISO 4572) means that in the so-called multi-pass test only one of 200 particles $\geq 3 \mu\text{m}$ passes the filter. Filters with coarser filtration ratios than $\beta_{25} \geq 75$ should not be used due to the ill effect on the other components within the circulation system.

¹⁾ Only particles with a hardness > 50 HRC have to be taken into account.

Dimensioning

Dynamically stressed bearings · Adjusted rating life calculation

Specially particles with a hardness > 50 HRC reduce the life of rolling bearings. These are particles of hardened steel, sand and abrasive particles. Abrasive particles are particularly harmful. If the major part of foreign particles in the oil samples is in the life-reducing hardness range, which is the case in many technical applications, the cleanliness class determined with a particle counter can be compared directly with the values of the table on page 15.

If however, the filtered out contaminants are found, after counting, to be almost exclusively mineral matter as, for example, the particularly harmful moulding sand or abrasive grains, the measured values must be increased by one or two cleanliness classes before determining the contamination factor V . On the other hand, if the greater part of the particles found in the lubricant are soft materials such as wood, fibres or paint, the measured value of the particle counter should be reduced correspondingly.

A defined **filtration ratio** β_x should exist in order to reach the oil cleanliness required. The filtration ratio is a measure of the separation capability of a filter at defined particle sizes. Filtration ratio β_x is the ratio of all particles > $x \mu\text{m}$ before passing through the filter to the particles > $x \mu\text{m}$ which have passed through the filter.

A filter of a certain filtration ratio is not automatically indicative of an *oil cleanliness class*.

Cleanliness factor s

The cleanliness factor s quantifies the effect of contamination on the *attainable life*. The product of s and the *basic a_{23II} factor* is the *a_{23} factor*.

Contamination factor V is required to determine s . $s = 1$ always applies to normal cleanliness ($V = 1$).

With improved cleanliness ($V = 0.5$) and utmost cleanliness ($V = 0.3$) a cleanliness factor $s \geq 1$ is obtained from the right diagram (a) below, based on the *stress index f_s^** and depending on the *viscosity ratio κ* .

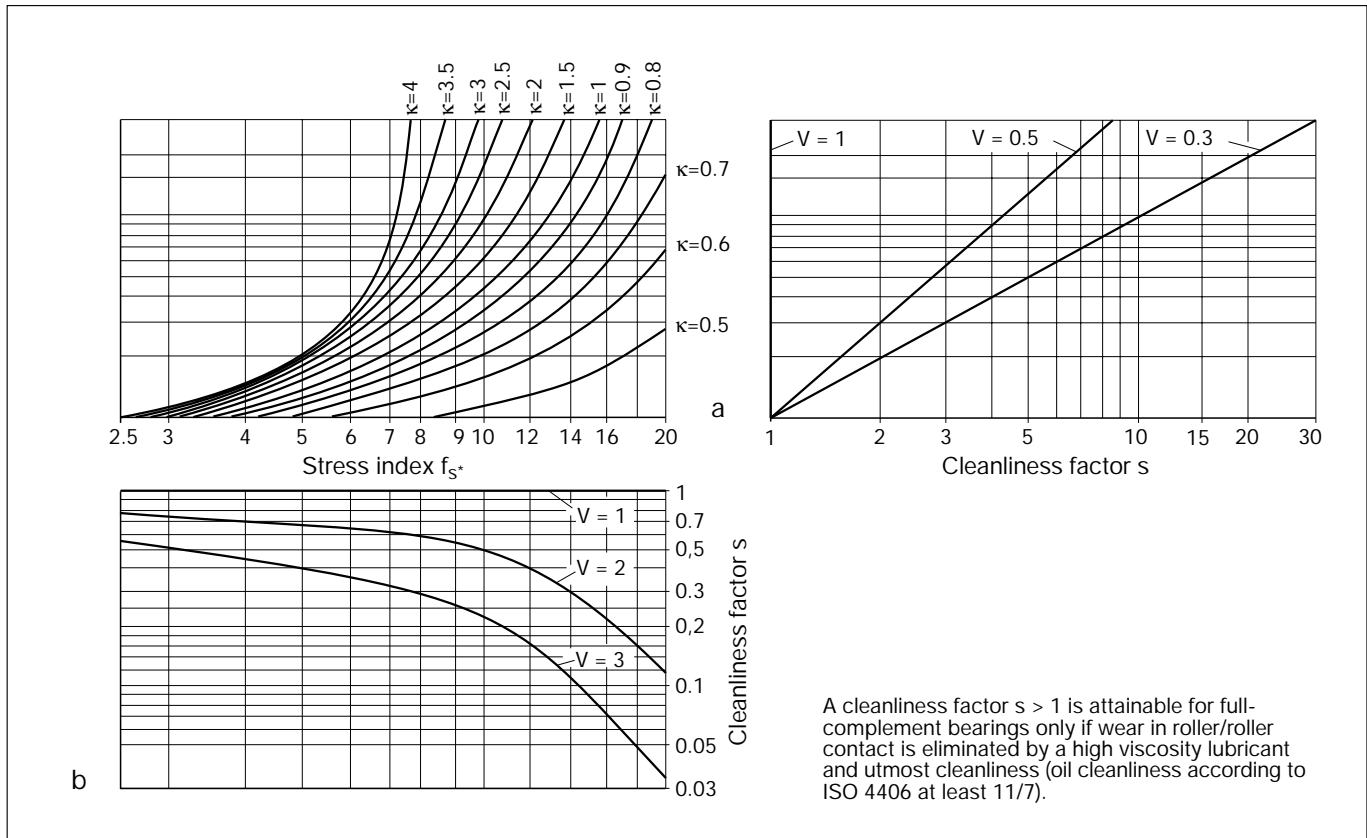
$s = 1$ applies to $\kappa \leq 0.4$.

With $V = 2$ (moderately contaminated lubricant) to $V = 3$ (heavily contaminated lubricant), $s < 1$ is obtained from diagram (b) below.

Diagram for determining the cleanliness factor s

a Diagram for improved ($V = 0.5$) to utmost ($V = 0.3$) cleanliness

b Diagram for moderately contaminated lubricant ($V = 2$) and heavily contaminated lubricant ($V = 3$)



Lubrication

Grease lubrication · Oil lubrication · Important rolling bearing lubrication terms

Lubrication

The main objective of lubrication is to prevent metal-to-metal contact between the *bearing rings* and the *rolling elements* by means of a lubricant film. In this way, *wear* and premature rolling bearing *fatigue* are avoided. In addition, lubrication reduces the development of noise and friction, thus improving the operating characteristics of a bearing. Additional functions may include protection against corrosion and heat dissipation from the bearing.

Usually, bearings are lubricated with grease or oil; in rare cases, e.g. where very high temperatures are involved, dry lubricants are also used.

Rolling bearing lubrication is discussed in detail in the FAG publication No. WL 81115/4EA.

Grease lubrication

Grease lubrication is used for about 90% of all rolling bearings. The main advantages of grease lubrication are:

- a very simple design
- it enhances the *sealing effect*
- long *service life* but little maintenance is required

With normal operating and environmental conditions, for-life grease lubrication is often possible.

If a bearing is heavily stressed (load, speed, temperature), suitable *relubrication intervals* must be scheduled.

Oil lubrication

Oil lubrication is the obvious solution for applications where adjacent machine elements are already supplied with oil or where heat has to be removed by means of the lubricant.

Heat can be removed by circulating substantial oil volumes. It may be required where high loads and/or high speeds have to be accommodated or where the bearings are exposed to external heating.

With oil throwaway lubrication, e.g. oil mist lubrication or oil-air lubrication, the bearing friction is kept low.

Important rolling bearing lubrication terms (in alphabetical order)

Additives

Additives are oil soluble substances which are added to *mineral oils* or mineral oil products. By chemical and/or physical action, they change or improve the lubricant properties (oxidation stability, EP properties, *viscosity-temperature behaviour*, setting point, flow property, etc.). Additives are also an important factor in calculating the *attainable bearing life*.

Ageing

is the undesirable chemical alteration of mineral and synthetic products (e.g. lubricants, fuels) during their application and storage; triggered by reactions with oxygen (development of peroxides, hydrocarbon radicals); heat, light as well as catalytic influences of metals and other contaminants accelerate oxidation. Formation of acids and sludge. Agents inhibiting deterioration (anti-oxidants) retard the deterioration process.

Arcanol (FAG rolling bearing greases)

FAG rolling bearing greases Arcanol are field-proven *lubricating greases* whose application ranges were determined with bearings of all types under diverse operating conditions. A selection of the main Arcanol rolling bearing greases is shown in the table on page 18. It also contains directions for use.

Base oil

is the oil contained in a *lubricating grease*. The amount of oil varies with the type of *thickener* and the grease application. The penetration number (see *Consistency*) and the frictional behaviour of the grease vary with the amount of base oil and its *viscosity*.

Consistency

A measure of the resistance of a *lubricating grease* to being deformed. The so-called worked penetration at 25 °C is indicated for the greases available on the market. There are several penetration classes (NLGI classes).

Dry lubricants

Substances, such as graphite and molybdenum disulphide, suspended in *lubricating oils* and *greases* or applied directly.

EP additives

Additives which reduce *wear* in *lubricating oils* and *lubricating greases*, also referred to as extreme pressure additives.

Lubrication

Important rolling bearing lubrication terms

Arcanol rolling bearing greases · Chemo-physical data and directions for use

Arcanol	Thickener Base oil	Base oil viscosity at 40 °C mm ² /s	Consistency NLGI-class DIN 51818	Temperature range °C	Main characteristics Typical applications
L12V	Calcium/ polyurea PAO	130	2	-40...+160	Special grease for high temperatures Couplings, electric machines (motors, generators)
L71V	Lithium soap Mineral oil	ISO VG 100	3	-30...+140	Standard grease for bearings with O.D.s > 62 mm large electric motors, wheel bearings for motor vehicles, ventilators
L74V	Special soap Synthetic oil	ISO VG 22	2	-40...+100	Special grease for high speeds and low temperatures Machine tools, spindle bearings, instruments
L78V	Lithium soap Mineral oil	ISO VG 100	2	-30...+140	Standard grease for bearings with O.D.s ≤ 62 mm Small electric motors, agricultural and construction machinery, household appliances
L79V	PTFE Synthetic oil	400	2	-40...+260	Special grease for extremely high temperatures and chemically aggressive environment Track rollers in bakery machines, piston pins in compressors, kiln trucks, chemical plants
L135V	Lithium soap with EP additives Mineral oil + Ester	85	2	-40...+150	Special grease for high loads, high speeds, high temperatures Rolling mills, construction machinery, motor vehicles, rail vehicles, spinning and grinding spindles
L166V	Lithium soap with EP additives Mineral oil	170	3	-30...+150	Special grease for high temperatures, high loads, oscillating movements Rotor blade adjusting mechanisms for wind power stations, packaging machinery
L186V	Lithium soap with EP additives Mineral oil	ISO VG 460	2	-20...+140	Special grease for extremely high loads, medium speeds, medium temperatures Heavily stressed mining machinery, construction machinery, machines with oscillating movements
L195V	Polyurea with EP additives Synthetic oil	ISO VG 460	2	-35...+180	Special grease for high temperatures, high loads Continuous casting plants
L215V	Lithium-/ Calcium soap with EP additives Mineral oil	ISO VG 220	2	-20...+140	Special grease for high loads, with speed range, high humidity Rolling mill bearings, rail vehicles
L223V	Lithium-/ Calcium soap with EP additives Mineral oil	ISO VG 1000	2	-20...+140	Special grease for extremely high loads, low speeds Heavily stressed mining machinery, construction machinery, particularly for impact loads and large bearings

Lubrication

Important rolling bearing lubrication terms

Grease life

The grease life F_{10} is the period from start-up of a bearing until its failure due to lubrication breakdown. The grease life depends on the

- amount of grease,
- grease type (*thickener*, *base oil*, *additives*),
- bearing type and size,
- type and amount of loading,
- *speed index*,
- bearing temperature.

Lithium soap base greases

have definite performance merits in terms of water resistance and width of temperature range. Frequently, they incorporate oxidation inhibitors, corrosion inhibitors and *EP additives*. Due to their favourable properties, lithium soap base greases are widely used as rolling bearing greases. Standard lithium soap base greases can be used at temperatures ranging from -35 °C to $+130\text{ °C}$.

Lubricating conditions

The following lubricating conditions exist in a rolling bearing (see illustration on page 20):

- **Full fluid film lubrication:** The surfaces of the components in relative motion are separated by a lubricant film. For continuous operation this type of lubrication, which is also referred to as fluid lubrication, should always be aimed at.
- **Mixed lubrication:** Where the lubricant film gets too thin, local metal-to-metal contact occurs, resulting in mixed friction.
- **Boundary lubrication:** If the lubricant contains suitable *additives*, reactions between the additives and the metal surfaces are triggered at the high pressures and temperatures in the contact areas. The resulting reaction products have a lubricating effect and form a thin boundary layer.

Lubricating greases

Greases are consistent mixtures of *thickeners* and *base oils*. The following grease types are distinguished:

- Metal soap base greases consisting of metal soaps as *thickeners* and *lubricating oils*,
- Non-soap greases comprising inorganic gelling agents or organic *thickeners* and *lubricating oils*,
- Synthetic greases consisting of organic or inorganic *thickeners* and *synthetic oils*.

Lubricating oils

Rolling bearings can be lubricated either with *mineral oils* or *synthetic oils*. Today, mineral oils are most frequently used.

Lubrication interval

The lubrication interval corresponds to the minimum *grease life* F_{10} of standard greases in accordance with DIN 51 825, see lubrication interval curve in the FAG publication No. WL 81 115. This value is assumed if the *grease life* F_{10} of the grease used is not known.

Influences which reduce the lubrication interval are taken into account by reduction factors.

Mineral oils

Crude oils and/or their liquid derivatives. Mineral oils used to lubricate rolling bearings must at least meet the requirements defined in DIN 51501.

Cp. also *Synthetic lubricants*.

Operating viscosity ν

Kinematic *viscosity* of an oil at operating temperature. Cp. also *Viscosity ratio* \times and *Attainable life*.

Rated viscosity ν_1

The rated viscosity is the kinematic *viscosity* attributed to a defined lubrication condition. Cp. also *Viscosity ratio* \times and *Attainable life*.

Relubrication interval

Period after which lubricant is replenished. The relubrication interval should be shorter than the lubricant *renewal* interval.

Speed index $n \cdot d_m$

Product from the operating speed n [min^{-1}] and the mean bearing diameter d_m [mm]

$$d_m = (D + d)/2$$

D = bearing outside diameter [mm], d = bearing bore [mm]

The speed index is predominantly used when selecting suitable lubrication modes and lubricants.

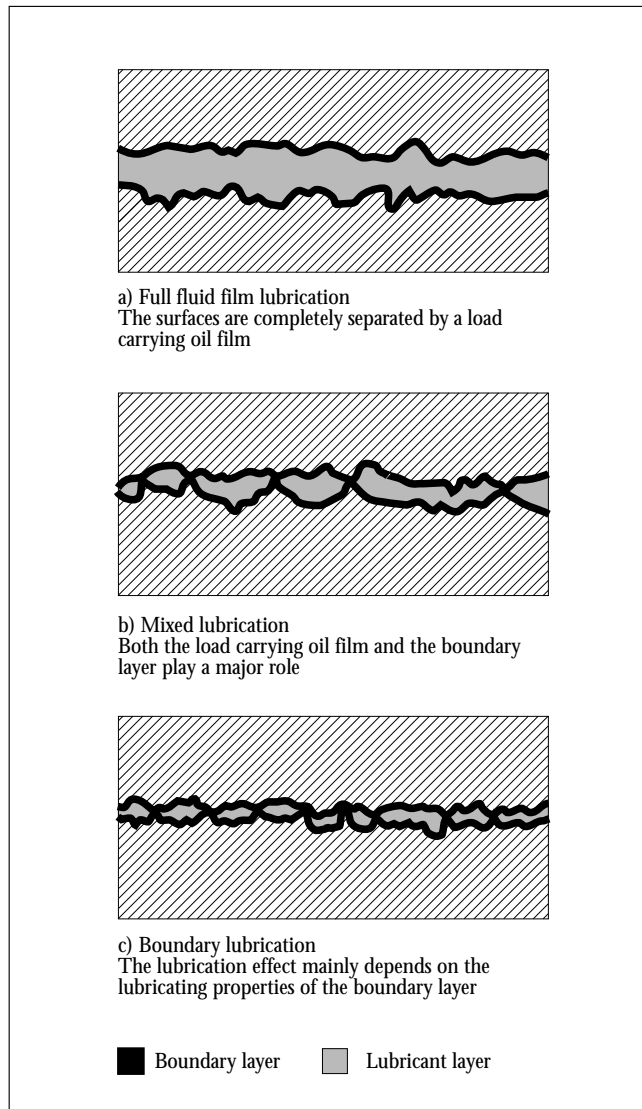
Synthetic lubricants/synthetic oils

Lubricating oils produced by chemical synthesis; their properties can be adapted to meet special requirements: very low setting point, good *V-T behaviour*, small evaporation losses, long life, high oxidation stability.

Lubrication

Important rolling bearing lubrication terms

The different lubricating conditions



Thickener

Thickener and *base oil* are the constituents of *lubricating greases*. The most commonly used thickeners are metal soaps and compounds, e.g. of the polyurea type.

Viscosity

Physically, viscosity is the resistance which contiguous fluid strata oppose to mutual displacement. Distinction is made between the **dynamic viscosity** η and the **kinematic viscosity** ν . The dynamic viscosity is the product of the kinematic viscosity and the density of a fluid (density of *mineral oils*: 0.9 g/cm^3 at $15 \text{ }^\circ\text{C}$).

SI Units (internationally agreed coherent system of units)

- for the dynamic viscosity: Pa s or mPa s.
- for the kinematic viscosity m^2/s and mm^2/s .

The viscosity of *lubricating oils* determines the load carrying capacity of the oil film in the bearing under elastohydrodynamic lubricating conditions. It decreases with climbing temperatures and increases with falling temperatures (see *V-T behaviour*).

For this reason the temperature to which any viscosity value applies must always be indicated. The **nominal viscosity** is the kinematic viscosity at $40 \text{ }^\circ\text{C}$.

Viscosity classification

The standards ISO 3448 and DIN 51 519 specify 18 viscosity classes ranging from 2 to $1500 \text{ mm}^2/\text{s}$ at $40 \text{ }^\circ\text{C}$ for industrial liquid lubricants.

Viscosity ratio α

The viscosity ratio, being the quotient of the *operating viscosity* ν and the *rated viscosity* ν_1 , is a measure of the lubricating film development in the bearing, cp. *factor* a_{23} .

Viscosity-temperature behaviour (V-T behaviour)

The term V-T behaviour refers to the viscosity variations in *lubricating oils* with temperatures. The V-T behaviour is good if the *viscosity* varies little with changing temperatures (see fig. 1 on page 13).

Seals

Seals

The seal should, on the one hand, prevent the *lubricating grease* or *oil* from escaping from the bearing and, on the other hand, prevent contaminants from entering the bearing. The effectiveness of a seal has a considerable influence on the *service life* of a bearing arrangement.

Non-rubbing seals

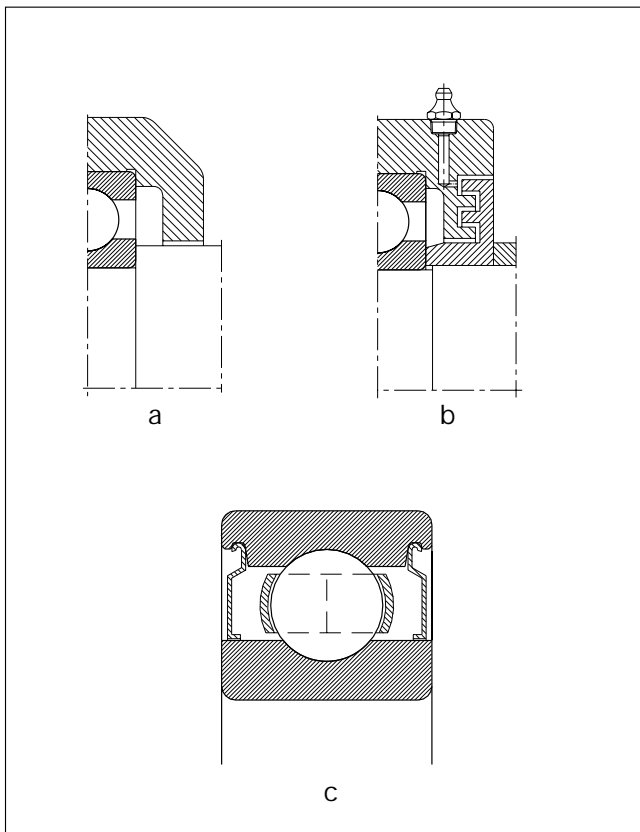
The only friction arising with non-rubbing seals is the lubricant friction in the lubricating gap. These seals can function for a long time and are suitable even for very high speeds.

Outside the bearing, gap-type seals or labyrinth seals may, for instance, be used.

Space-saving sealing elements are dust shields mounted in the bearing. Bearings with two dust shields are supplied with a grease filling.

Non-rubbing seals (examples)

a = gap-type seal, b = labyrinth seal, c = bearing with dust shields



Rubbing seals

Rubbing seals contact their metallic running surfaces under a certain force. The intensity of the resulting friction depends on the magnitude of this force, the lubricating condition and the roughness of the running surface, as well as on the sliding velocity.

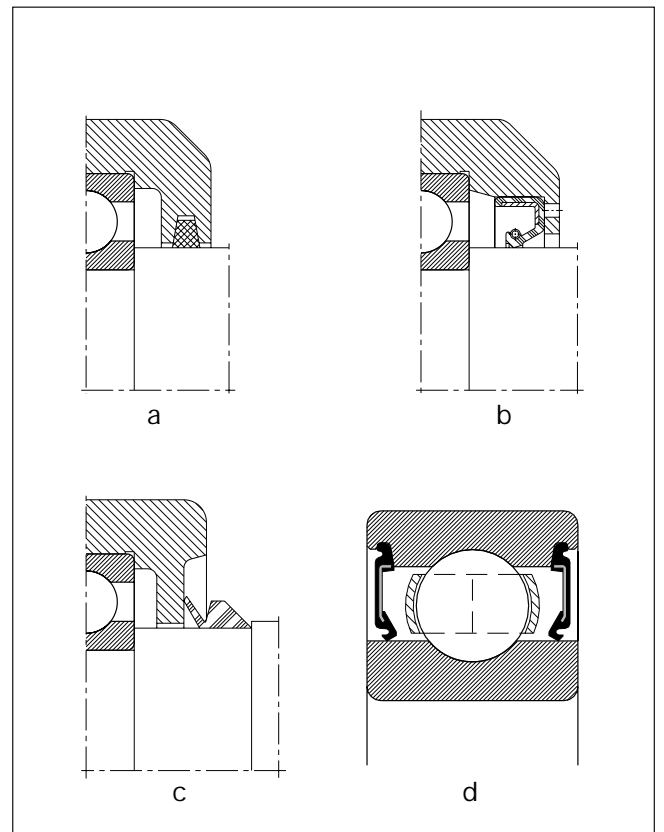
Felt rings prove particularly successful with grease lubrication. Radial shaft seals are above all used at oil lubrication.

V-rings are lip seals with axial effect which are frequently used as pre-seals in order to keep dirt away from a radial shaft seal.

Bearings with integrated sealing washers allow the construction of plain designs. FAG offer maintenance-free bearings with two sealing washers and a grease filling.

Rubbing seals (examples)

a = felt seal, b = radial shaft seal, c = V-ring, d = bearing with sealing washers



Speed suitability

Speed suitability

Generally, the maximum attainable speed of rolling bearings is dictated by the permissible operating temperatures. This limiting criterion takes into account the (thermal) *reference speed*.

The *limiting speed* may be higher or lower than the *reference speed*. It is indicated in the FAG catalogues also for bearings for which – according to DIN 732 – no reference speed is defined. The *limiting speed* may only be exceeded on consultation with FAG.

In the catalogue WL 41 520 EA "FAG Rolling Bearings" a reference is made to a method based on DIN 732, Part 2, for determining the *thermally permissible operating speed* on the basis of the *reference speed* for cases where the operating conditions (load, oil viscosity or permissible temperature) deviate from the reference conditions.

Limiting speed

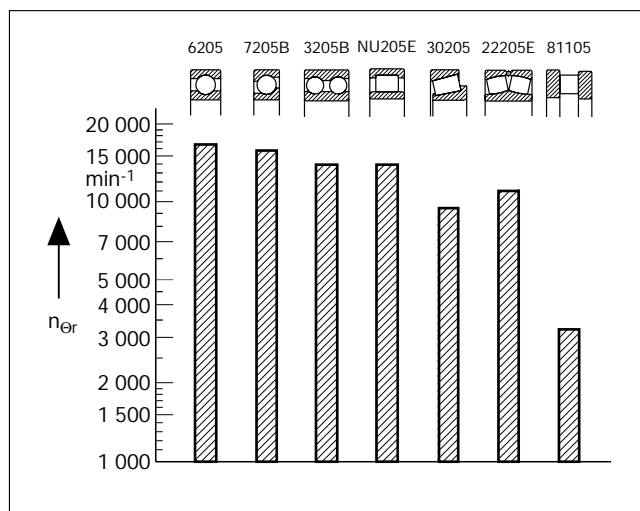
Decisive criteria for the limiting speed are e.g. the strength limit of the bearing parts or the permissible sliding velocity of rubbing *seals*. Limiting speeds which are higher than the *reference speeds* can be reached, for example, with

- specially designed lubrication
- bearing clearance adapted to the operating conditions
- accurate machining of the bearing seats
- special regard to heat dissipation

Reference speed

The reference speed is a new index of the *speed suitability* of rolling bearings. It is defined in the draft of DIN 732, Part 1, as the speed at which the reference temperature of 70 °C is established. In the FAG catalogue WL 41 520 the standardized reference conditions are indicated which are similar to the normal operating conditions of the current rolling bearings (exceptions are, for example, spindle bearings, four point bearings, barrel roller bearings, thrust ball bearings). Contrary to the past, the reference speed values now apply equally to *oil lubrication* and *grease lubrication*.

Reference speeds n_{0r} of various bearing types with a bore of $d = 25 \text{ mm}$



Thermally permissible operating speed

For applications where the loads, the oil *viscosity* or the permissible temperature deviate from the reference conditions for the *reference speed* the thermally permissible operating speed can be determined by means of diagrams. The method is described in the FAG catalogue WL 41 520.

High temperature suitability

High temperature suitability

(over +150 °C)

The rolling bearing steel used for *bearing rings* and *rolling elements* is generally heat-treated so that it can be used at operating temperatures of up to +150 °C. At higher temperatures, dimensional changes and hardness reductions result. Therefore, operating temperatures over +150 °C require special heat treatment. Such bearings are identified by the suffixes S1...S4 (DIN 623).

Suffix	without	S1	S2	S3	S4
Maximum operating temperature	150 °C	200 °C	250 °C	300 °C	350 °C

Bearings with an outside diameter of more than 240 mm are generally dimensionally stable up to 200 °C. Bearings of normal design which are heat-treated in accordance with S1 have no heat-treatment suffix. Details of the heat treatment process are provided in the catalogue.

For all applications involving operating temperatures over +100 °C, the limiting temperatures of the other bearing components have to be observed, e.g.:

- *cages* of glass fibre reinforced polyamide PA66 +120 °C (+100 °C)
- *cages* of textile laminated phenolic resin +100 °C
- common sealing washers of synthetic caoutchouc NBR +110 °C
- common *lithium soap base greases* approx. +130 °C

When using these greases, one should remember that, at constant temperatures of +70°C and higher, any increase in temperature reduces the *grease life*. This has also to be taken into account with those double seal bearings which were filled with such greases by the manufacturer.

Where higher temperatures have to be accommodated metal *cages*, heat-resistant *sealings* and special greases are used.

The temperature limit of application for rolling bearings made of standard steels is approx. +300 °C. Where even higher temperatures have to be accommodated, the hardness of these steels would be so heavily reduced that high-temperature materials must be used.

If high-temperature synthetic materials are used it has to be taken into account that the very efficient fluorinated materials, when heated above +300 °C, can release gases and vapours which are detrimental to health. This has to be remembered especially if bearing parts are dismantled with a welding torch. FAG uses fluorinated materials for *seals* made of fluoro-caoutchouc (FKM, FPM, e.g. Viton®) or for fluorinated greases, e.g. *Arcanol/L79V*, an FAG rolling bearing grease. Where high temperatures cannot be avoided, the safety data sheet for the fluorinated material in question should be observed. The data sheet is available on request.

Examples of operating temperatures:

Bench drill	+40 °C	Vibration motor	+70 °C
Mandrel	+50 °C	Vibrating screen	+80 °C
Jaw crusher	+60 °C	Vibratory roller	+90 °C

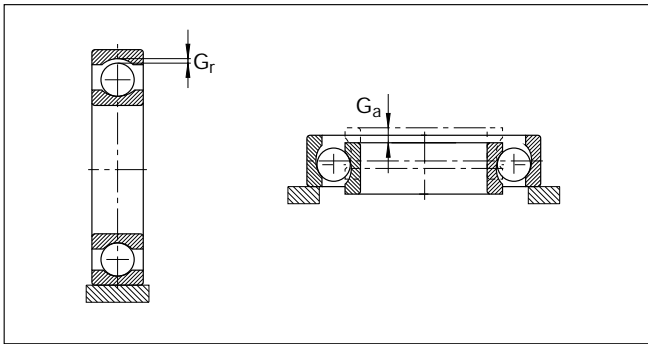
Examples of bearings which are used at higher temperatures:

Bearings for sand-lime brick autoclave trucks, Publ. No. WL 07 137 EA

Bearing clearance

Bearing clearance

The bearing clearance is the distance by which one *bearing ring* can be freely displaced in relation to the other one. With axial clearance the bearing is displaced along its axis, with radial clearance vertically to the bearing axis.



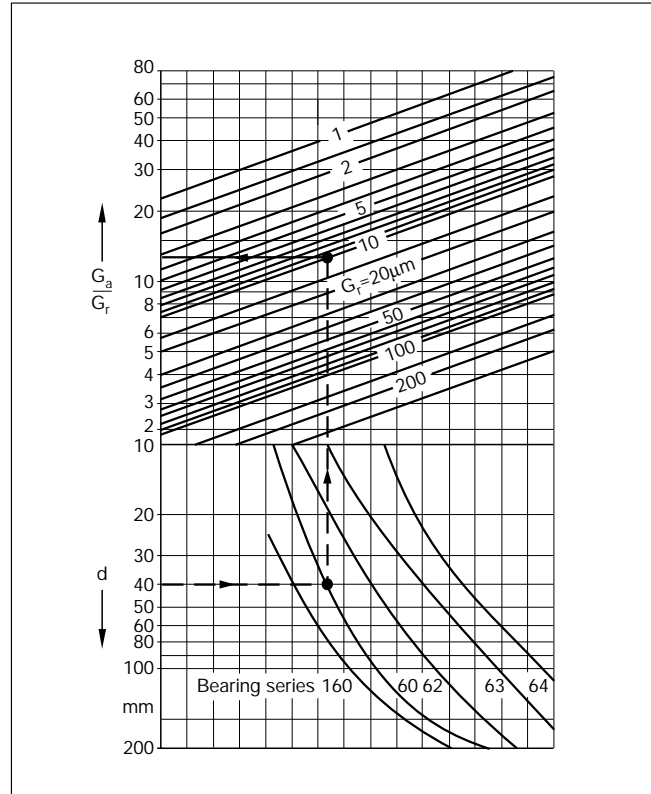
G_r radial bearing clearance
 G_a axial bearing clearance

Depending on the bearing type, either the radial or the axial bearing clearance is decisive. It is standardized in DIN 620 for most bearing types and sizes and classified in bearing clearance groups designated C1...C4.

Clearance group Suffix	Bearing clearance
C1	smaller than C2
C2	smaller than normal
-	normal
C3	larger than normal
C4	larger than C3

The suffix identifying the clearance group is added to the bearing code; no suffix is used for the clearance group "normal" (CN).

Relation between radial and axial clearances with deep groove ball bearings



d = bearing bore [mm]
 G_r = radial bearing clearance [μm]
 G_a = axial bearing clearance [μm]

Example:

Deep groove ball bearing 6008.C3 with $d = 40$ mm
 Radial clearance before mounting: 15...33 μm
 Actual radial clearance: $G_r = 24$ μm

Mounting tolerances: Shaft k5
 Housing J6

Radial clearance reduction during mounting: 14 μm
 Radial clearance after mounting: 24 $\mu\text{m} - 14$ $\mu\text{m} = 10$ μm

According to this diagram, $\frac{G_a}{G_r} = 13$

Axial clearance: $G_a = 13 \cdot 10$ $\mu\text{m} = 130$ μm

Bearing clearance

Relation between radial and axial clearance with other bearing types

Bearing type	G_a/G_r
Self-aligning ball bearings	$2.3 \cdot Y_0^*$
Spherical roller bearings	$2.3 \cdot Y_0^*$
Tapered roller bearings, single row, arranged in pairs	$4.6 \cdot Y_0^*$
Tapered roller bearings, matched (N11CA)	$2.3 \cdot Y_0^*$
Angular contact ball bearings, double row series 32 and 33 series 32B and 33B	1.4 2
Angular contact ball bearings, single row series 72B and 73B arranged in pairs	1.2
Four-point bearings	1.4

*) Y_0 value from catalogue

The clearance of the installed bearing at operating temperature (**operating clearance**) should be as small as possible for accurate guidance of the shaft but the bearing should nevertheless be able to rotate easily. It should be remembered that during mounting the original bearing clearance usually decreases:

- when the inner ring is expanded or the outer ring is compressed due to a tight *fit* of the bearing;
- when the inner ring expands even more due to the operating temperature, which is often the case.

Both of these have to be taken into consideration by selecting the right bearing clearance. The classification into clearance groups (C) allows the determination of the required bearing clearance for the wide range of fits and operating conditions.

The normal bearing clearance (CN) is calculated to ensure that, in the medium diameter range, with normal *fits* and normal operating conditions (max. temperature difference between inner and outer ring 10 K), the mounted bearings have the right clearance. The following fits are considered normal:

	Shaft	Housing
Ball bearings	j5 to k5	H7 to J7
Roller bearings	k5 to m5	H7 to M7

However, the respective operating conditions are ultimately decisive for the selection of the fit (see section on fits).

A larger-than-normal bearing clearance is selected for tighter fits and/or a great temperature difference between inner ring and outer ring.

Bearing clearance C2 or C1 is used where a very rigid shaft guidance is required, e.g. in machine tools, where bearings often run under preload.

Any bearing clearance not covered by the C-classification is written uncoded, e.g.:

6210.R10.30 = radial clearance 10 to 30 μm
 QJ210MPA.A100.150 = axial clearance 100 to 150 μm

Please note: bearing clearance tables differentiate between bearings with a cylindrical bore and those with a tapered bore.

Tolerances

Tolerances

The tolerances of rolling bearings are standardized according to DIN 620 Part 2 (radial bearings) and DIN 620 Part 3 (thrust bearings). The tolerances are laid down for the dimensional and running accuracy of the bearings or bearing rings.

Beginning with PN (normal tolerance), there are **tolerance classes** P6, P6X, P5, P4 and P2 for **precision bearings**, the precision of which is the greater the lower the number. In addition, there are the (non-standardized) FAG tolerance classes SP (Super Precision) and UP (Ultra Precision) for double-row cylindrical roller bearings and P4S for spindle bearings. These bearings are mainly used in machine tools.

The suffix for the tolerance class is always added to the bearing code, with the exception of PN for the normal clearance, which is omitted.

Please remember that bearings in inch dimensions have different tolerance systems (ABMA tolerances).

Bore diameter

$\Delta_{dmp} =$	$d_{mp} - d$ Mean bore diameter deviation from nominal dimension
$\Delta_{d1mp} =$	$d_{1mp} - d_1$ Deviation of mean large diameter from nominal dimension (tapered bore)
V_{dp}	Bore diameter variation; difference between maximum and minimum bore diameter in a single radial plane
$V_{dmp} =$	$d_{mpmax} - d_{mpmin}$ Mean bore diameter variation; difference between maximum and minimum mean bore diameter

Outside diameter

$\Delta_{Dmp} =$	$D_{mp} - D$ Mean O.D. deviation from nominal dimension
V_{Dp}	O.D. variation; difference between maximum and minimum O.D. in a single radial plane
$V_{Dmp} =$	$D_{mpmax} - D_{mpmin}$ Mean O.D. variation; difference between maximum and minimum mean O.D.

Width and height

$\Delta_{Bs} =$	$B_s - B$, $\Delta_{Cs} = C_s - C$ Deviation of a single ring width (inner or outer ring) from nominal dimension
$V_{Bs} =$	$B_{smax} - B_{smin}$, $V_{Cs} = C_{smax} - C_{smin}$ Variation of inner ring width or outer ring width; difference between maximum and minimum measured ring width
$\Delta_{Ts} =$	$T_s - T$, $\Delta_{T1s} = T_{1s} - T_1$, $\Delta_{T2s} = T_{2s} - T_2$ Deviation of a single overall tapered roller bearing height from nominal dimension
*) $\Delta_{Hs} =$	$H_s - H$, $\Delta_{H1s} = H_{1s} - H_1$, $\Delta_{H2s} = H_{2s} - H_2$, ... Deviation of a single overall thrust bearing height from nominal dimension

Running accuracy

K_{ia}	Radial runout of inner ring of assembled bearing
K_{ea}	Radial runout of outer ring of assembled bearing
S_i	Washer raceway to back face thickness variation (thrust bearing shaft washer)
S_e	Washer raceway to back face thickness variation (thrust bearing housing washer)

*) In the standard, the overall height of thrust bearings is designated T.

Alignment

Alignment

The machining of the bearing seats on a shaft or in a housing can lead to misalignment, particularly when the seats are not machined in one setting. Misalignment can also be expected to occur where single housings such as flanged housings or plummer block housings are used. Tilting of bearing rings relative to each other as a result of shaft inflections brought about by operating loads has similar effects.

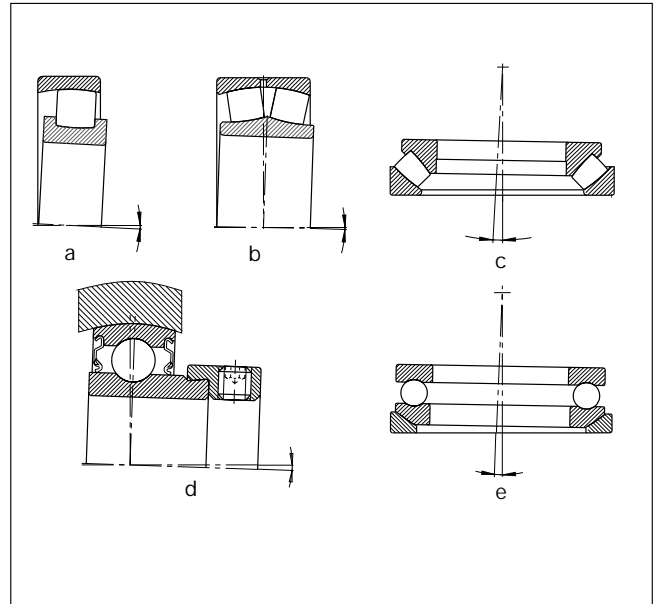
Self-aligning bearings – self-aligning ball bearings, barrel roller bearings, radial spherical roller bearings and spherical roller thrust bearings – compensate for misalignment and tilting during operation. These bearings have a spherical outer ring raceway, which enables the inner ring and the rolling element set to make angular motions. The angle of alignment of these bearings depends on the bearing type and size as well as on the load.

S-type bearings and thrust ball bearings with a seating ring have a spherical support surface; during mounting they can align themselves on the spherical mating surface.

The bearing types not listed above have only a very limited self-aligning capability, some in fact have none at all.

Self-aligning rolling bearings:

Barrel roller bearings (a), spherical roller bearings (b), spherical roller thrust bearings (c); S-type bearings (d) and thrust ball bearings with a seating ring (e) have a spherical support surface.



Fits

Fits

The fit of a rolling bearing determines how tightly or loosely the bearing sits on the shaft and in the housing.

As a rule, both *bearing rings* should be tightly fitted for the following reasons:

- easiest and safest means of ring retention in circumferential direction
- complete support of the rings over their entire circumference; in this way full utilization of the bearing's load carrying capacity is possible.


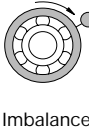

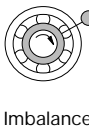
On the other hand, a loose fit is often necessary in practice:

- it facilitates mounting of non-*separable* bearings
- it permits displacement of non-*separable* bearings in longitudinal direction as *floating bearings*.

Based on a compromise of the above requirements, the following rule applies:

- a tight fit is necessary for the ring with **circumferential load**,
- a loose fit is permitted for the ring with **point load**.

The different load and motion conditions are shown in the following diagram.

Bearing kinematics	Example	Illustration	Loading conditions	Fits
Rotating inner ring Stationary outer ring Constant load direction	Weight suspended by shaft		Circumferential load on inner ring	Inner ring: tight fit mandatory
Stationary inner ring Rotating outer ring Direction of load rotating with outer ring	Hub bearing mounting with large imbalance		Point load on outer ring	Outer ring: loose fit permissible
Bearing kinematics	Example	Illustration	Loading conditions	Fits
Stationary inner ring Rotating outer ring Constant load direction	Automotive front wheel Track roller (hub bearing mounting)		Point load on inner ring	Inner ring: loose fit permissible
Rotating inner ring Stationary outer ring Direction of load rotating with inner ring	Centrifuge Vibrating screen		Circumferential load on outer ring	Outer ring: tight fit mandatory

When selecting the fit, the following should also be taken into account:

- The greater the load, the tighter the fit should be, particularly where shock-type loads are expected.
- Possible varying heat expansion of bearing rings and mating parts.
- The radial clearance is reduced by tight fits, and a correspondingly higher clearance group must therefore be selected.

Principle fits for rolling bearings

The type of fit is described by the terms interference fit (tight fit), transition fit and sliding fit (loose fit). These seats or fits are the result of the combined effects of the bearing tolerances for the bore (Δ_{dmp}), for the outside diameter (Δ_{Dmp}), and the ISO tolerances for shaft and housing.

The ISO tolerances are classified in the form of tolerance zones. They are determined by their position relative to the zero line (= tolerance position) and by their size (= tolerance quality). The tolerance position is indicated by letters (capital letters for housings, small letters for shafts) and the tolerance quality by numbers.

The bearing tolerance tables and the tables for shaft and housing tolerances as well as recommendations for fits under certain mounting conditions are contained in the catalogue WL 41 520EA "FAG Rolling Bearings".

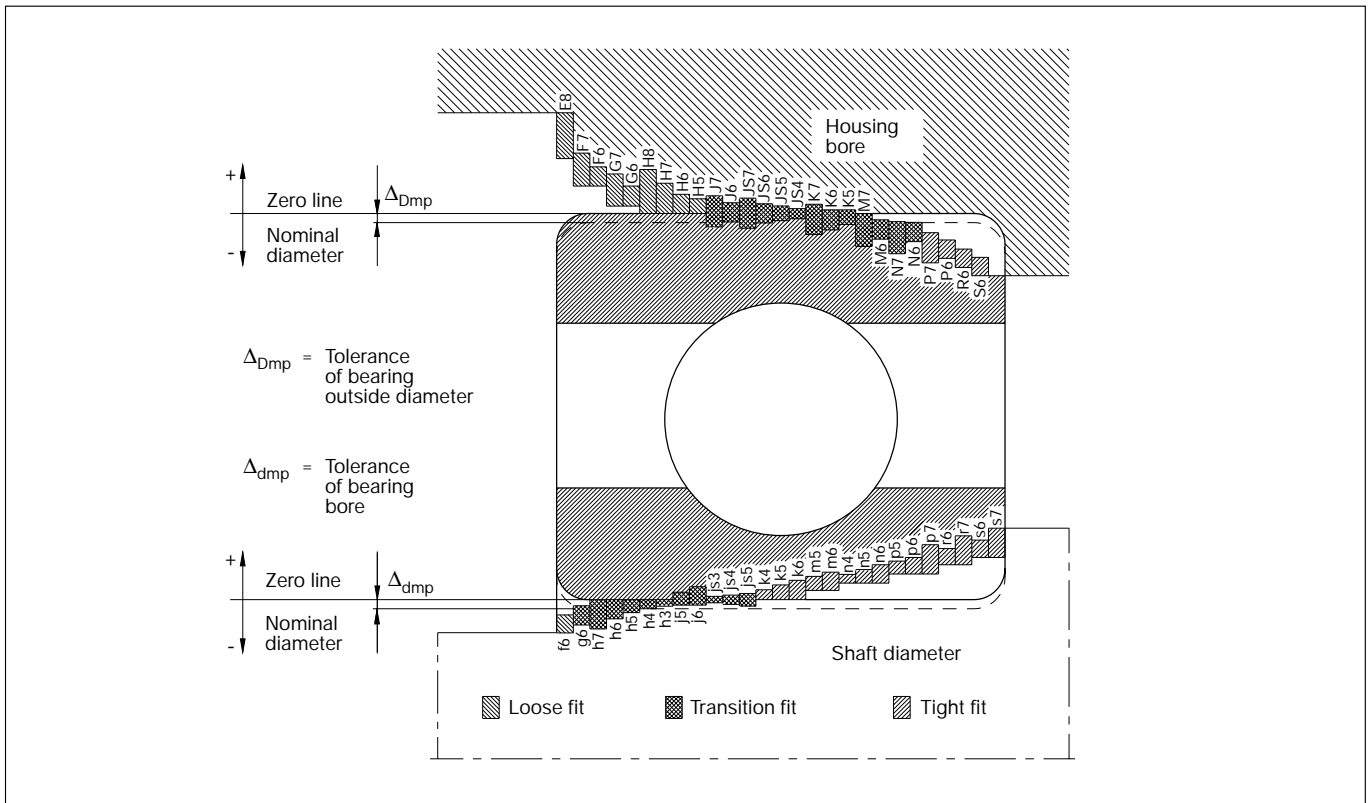
Mounting and dismounting of rolling bearings

The fits of the *bearing rings*, the bearing type and the bearing size have considerable influence on how (mechanical, thermal or hydraulic method), and in which order, the rings are mounted and dismounted. Detailed information on the mounting of rolling bearings is given in FAG Publ. No. WL 80 100EA.

Fits · Bearing arrangement

Locating bearing/floating bearing arrangement

Principle fits for rolling bearings



Bearing arrangement

In order to guide and support a rotating shaft, at least two bearings are required which are arranged at a certain distance from each other. Depending on the application, a bearing arrangement with locating and floating bearings, with adjusted bearings or with floating bearings can be selected.

Locating-floating bearing arrangement

Due to machining tolerances the centre distances between the shaft seats and the housing seats are often not exactly the same with a shaft which is supported by two *radial bearings*. Warming-up during operation also causes the distances to change. These differences in distance are compensated for in the **floating bearing**. Cylindrical roller bearings of N and NU designs are ideal floating bearings. These bearings allow the roller and cage assembly to shift on the raceway of the lipless *bearing ring*. Both rings can be fitted tightly.

All other bearing types, e.g. deep groove ball bearings and spherical roller bearings, only function as floating bearings when one bearing ring is provided with a loose fit. The ring under *point load* is therefore given a loose fit; this is generally the outer ring.

The **locating bearing**, on the other hand, guides the shaft axially and transmits external axial forces. For shafts with more than two radial bearings, only one bearing is designed as a locating bearing in order to avoid detrimental axial preload.

The bearing to be designed as a locating bearing depends on how high the axial load is and how accurately the shaft must be axially guided.

Closer axial guidance is achieved for example with a double row angular contact ball bearing than with a deep groove ball bearing or a spherical roller bearing. A pair of symmetrically arranged angular contact ball bearings or tapered roller bearings provide extremely close axial guidance when designed as locating bearings.

With angular contact ball bearings of universal design, mounted in *X* or *O* arrangement, or matched tapered roller bearings (design N11) neither setting nor adjusting jobs are required.

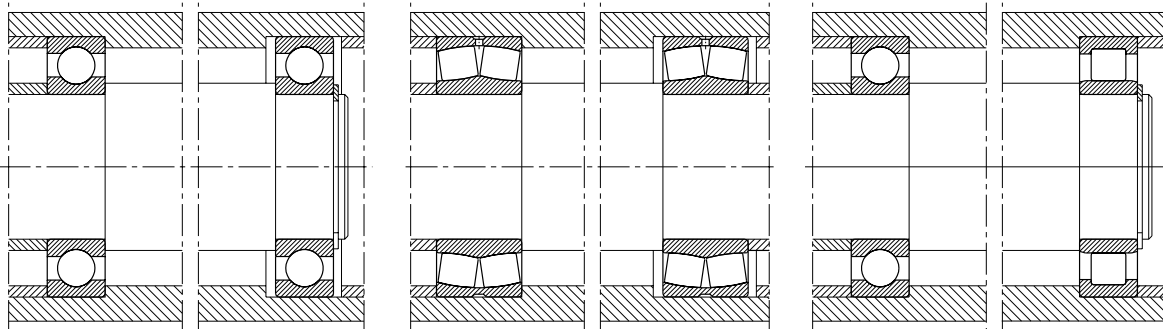
In the case of transmissions, a four-point bearing is sometimes mounted directly next to a cylindrical roller bearing in such a way that a locating bearing results. A four-point bearing whose outer ring is not supported radially can only transfer axial forces. The cylindrical roller bearing takes on the radial load.

Examples of locating-floating bearing arrangements are shown on page 30.

Bearing arrangement

Locating bearing/floating bearing arrangement

Examples of a locating-floating bearing arrangement



a. Locating bearing: deep groove ball bearing

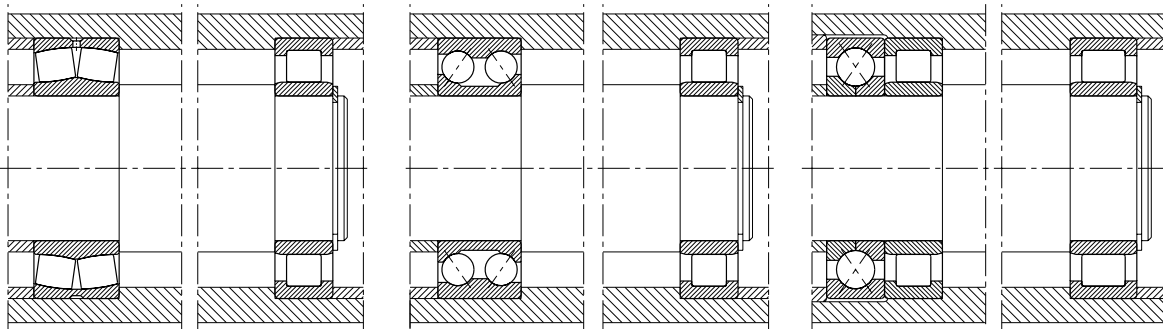
Floating bearing: deep groove ball bearing

b. Locating bearing: spherical roller bearing

Floating bearing: spherical roller bearing

c. Locating bearing: deep groove ball bearing

Floating bearing: cylindrical roller bearing NU



d. Locating bearing: spherical roller bearing

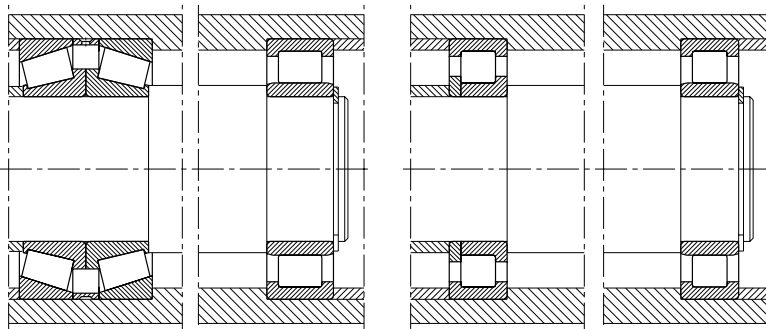
Floating bearing: cylindrical roller bearing NU

e. Locating bearing: double row angular contact ball bearing

Floating bearing: cylindrical roller bearing NU

f. Locating bearing: four-point bearing and cylindrical roller bearing NU

Floating bearing: cylindrical roller bearing NU



g. Locating bearing: two tapered roller bearings

Floating bearing: cylindrical roller bearing NU

h. Locating bearing: cylindrical roller bearing NUP

Floating bearing: cylindrical roller bearing NU

Bearing arrangement

Adjusted bearing arrangement · Floating bearing arrangement

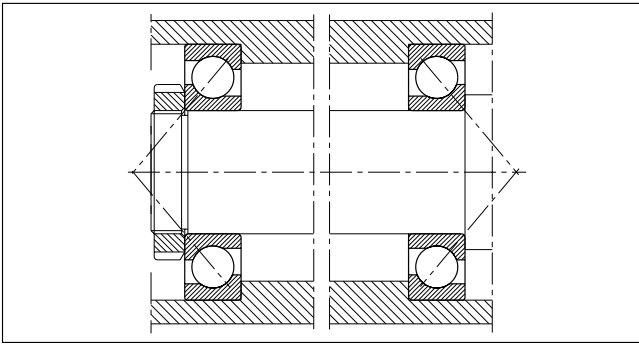
Adjusted bearing arrangement

As a rule, an adjusted bearing arrangement consists of two symmetrically arranged angular contact ball bearings or tapered roller bearings. During mounting, the required *bearing clearance* (see also page 24) or the preload is set.

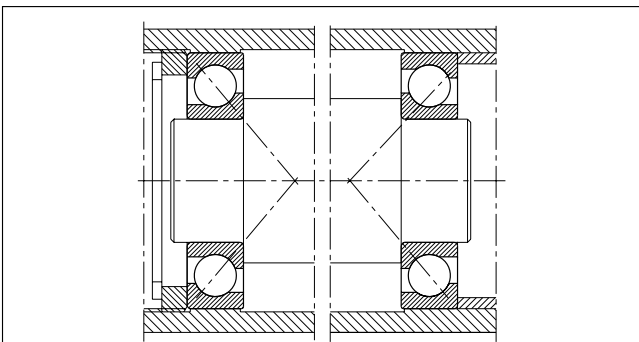
For this purpose, one ring is axially displaced on its seat until the required clearance or preload is achieved (in the case of an *O arrangement*, the inner ring; in the case of an *X arrangement*, the outer ring). This procedure is referred to in rolling bearing engineering as "adjusting" (adjusted bearing arrangement). This means that the adjusted bearing arrangement is particularly suitable for those cases in which close axial guidance is required, for example, for pinion bearing arrangements with spiral toothed bevel gears and spindle bearing arrangements in machine tools.

In the *O arrangement*, the apexes of the cone formed by the *contact lines* point outward while those of the *X arrangement* point inward. The **spread**, i.e. the distance between the *pressure cone apexes*, is larger in the *O arrangement* than in the *X arrangement*. The *O arrangement* therefore provides a smaller tilting clearance.

Adjusted bearing arrangement in O arrangement



Adjusted bearing arrangement in X arrangement



Floating bearing arrangement

The floating bearing arrangement is an economical solution where close axial guidance of the shaft is not required. Its design is similar to that of the *adjusted bearing arrangement*. In a floating bearing arrangement, the shaft, however, can shift by the axial clearance s relative to the housing. The value s is determined depending on the guiding accuracy in such a way that detrimental axial preloading of the bearings is prevented even under unfavourable thermal conditions.

In floating bearing arrangements with NJ cylindrical roller bearings, length is compensated for in the bearings. Inner and outer rings can be fitted tightly.

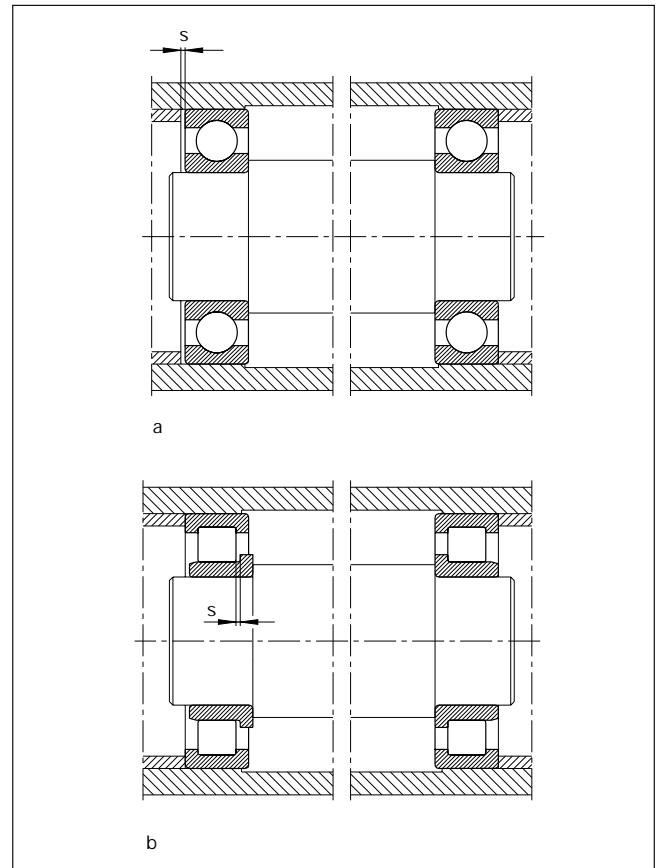
Non-separable radial bearings such as deep groove ball bearings, self-aligning ball bearings and spherical roller bearings are also suitable for the floating bearing arrangement. One ring of both bearings – generally the outer ring – is *fitted* loosely to allow displacement.

Tapered roller bearings and angular contact ball bearings are not suitable for a floating bearing arrangement because they must be *adjusted* for flawless running.

Examples of a floating bearing arrangement (s = axial clearance)

a = two deep groove ball bearings

b = two cylindrical roller bearings NJ



Bearing arrangement · Symbols

More bearing arrangement terms

Counter guidance

Angular contact bearings and single direction *thrust bearings* accommodate axial forces only in one direction. A second, symmetrically arranged bearing must be used for "counter guidance", i.e. to accommodate the axial forces in the other direction (cp. also "Adjusted bearing arrangement", page 31).

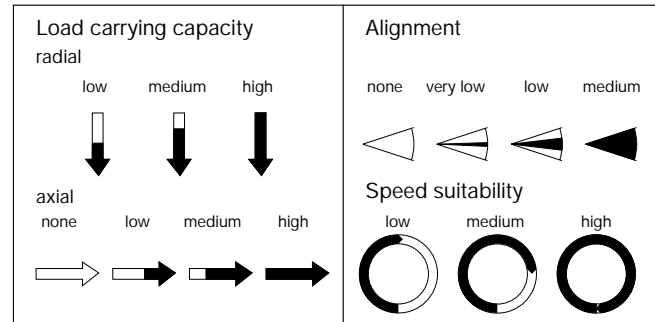
Tandem arrangement

A tandem arrangement consists of two or more *angular contact bearings* which are mounted adjacent to each other facing in the same direction, i.e. asymmetrically. In this way, the axial forces are distributed over all bearings. An even distribution is achieved with *universal-design angular contact bearings* (cp. "Matched Rolling Bearings", page 49).

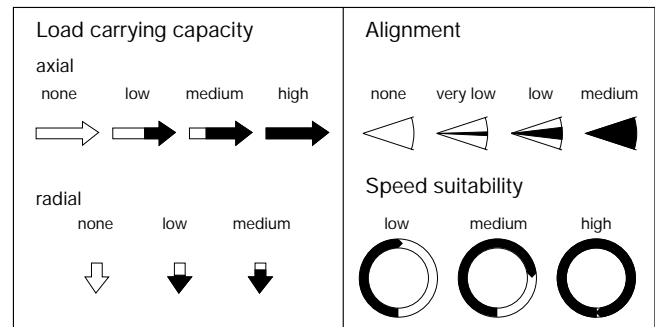
Symbols for load carrying capacity, alignment and speed suitability

The symbols allow a comparison between the different bearing types, but only within the categories "radial bearings" and "thrust bearings". The relative categories apply to bearings with identical bore diameters.

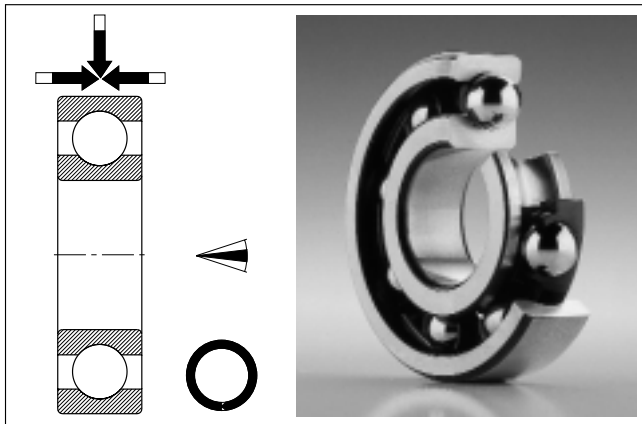
Radial bearings



Thrust bearings



Deep groove ball bearings



Single row: series 618, 160, 161, 60, 62, 622, 63, 623, 64
 Double row: series 42B, 43B

Single row deep groove ball bearings can accommodate both radial and axial forces and can be used at high speeds. Deep groove ball bearings are not separable. Thanks to their versatility and their competitive price, deep groove ball bearing are the most commonly used bearing type.

Standards

Single row deep groove ball bearings DIN 625, Part 1
 Double row deep groove ball bearings DIN 625, Part 3
 Dimension plan DIN 616

Tolerances, bearing clearance

Single row deep groove ball bearings of basic design have normal clearance and tolerances. Designs with an increased bearing clearance (suffix C3) or reduced tolerances are also available.

Alignment

Bearing series	Low loads	High loads
	in angular minutes	in angular minutes
62, 622, 63, 623, 64	5...10'	8...16'
618, 160, 60	2...6'	5...10'

Contact angle

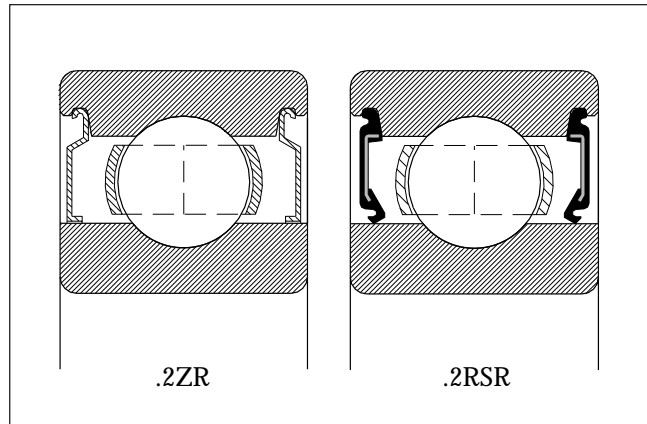
Nominal contact angle $\alpha_0 = 0^\circ$. Under axial load and with enlarged bearing clearance, the contact angle can increase to 20° .

Cages

Deep groove ball bearings without cage suffix are fitted with a pressed steel cage. The cage designs used in all other deep groove ball bearings are indicated in the bearing code.

Load carrying capacity

Radial and axial: good.



Speed suitability

High to very high.

High temperatures

FAG deep groove ball bearings are heat-treated in such a way that they are dimensionally stable up to 150°C . For application in sand-lime brick autoclave trucks, FAG offers deep groove ball bearings which were specially heat-treated, with an increased radial clearance (see Publ. No. WL 07 137). These bearings are lubricated with dry lubricants.

Sealed deep groove ball bearings

Deep groove ball bearings with ZR shields (non-rubbing sealings, Z shields for miniature bearings) or RSR seals (rubbing seals, RS seals for miniature bearings) make simple designs possible. The bearings can be sealed either on one side or on both sides. In the latter case the bearings are provided with a grease filling during production which, under normal operating conditions, is sufficient for life (for-life lubrication). Quality greases tested in accordance with FAG specification are used. The non-rubbing RSD seal combines the advantages of shields (no friction) with those of seals (efficient sealing). It makes high speeds possible, even with a rotating outer ring.

Stainless steel deep groove ball bearings

These bearings are used for applications where the effects of water or aggressive substances have to be accommodated; they are available both with and without seals.

Code:

Prefix S + suffix W203B.

Examples:

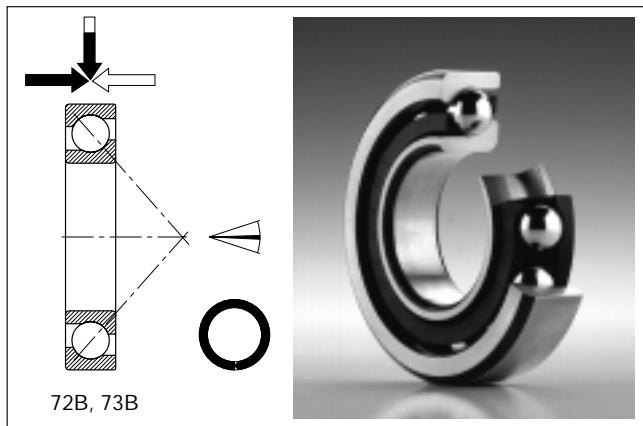
S6205.W203B

S6205.2RSR.W203B.

Double row deep groove ball bearings

Where higher loads have to be accommodated, double row deep groove ball bearings are used. The bearings of standard design without a filling slot (series 42B and 43B) have synthetic material cages and are already greased at the manufacturer's plant. Double row deep groove ball bearings have no self-aligning capacity. The basic-design bearings have normal bearing clearance and normal tolerances.

Angular contact ball bearings, single row



Angular contact ball bearings:

Series 72B, 73B

Spindle bearings:

Series B719, B70, B72, HSS719, HSS70, HCS719, HCS70

Single row angular contact ball bearings can accommodate axial loads in only one direction; usually, they are adjusted against another, symmetrically arranged bearing. Single row angular contact ball bearings are non-separable.

FAG spindle bearings are specially designed single row angular contact ball bearings; they were developed primarily for high-speed work spindles in machine tools. They differ from the normal angular contact ball bearings by their contact angle, accuracy and cage design.

In addition to open B-design spindle bearings, sealed high-speed spindle bearings (HSS) with small steel balls and sealed hybrid spindle bearings (HCS) with ceramic balls are available (cp. Publ. No. AC 41 130).

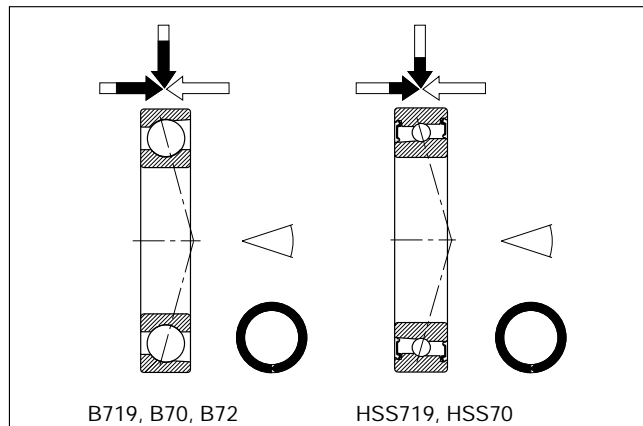
Standards

Single row angular contact ball bearings DIN 628, Part 1

Universal design

Where angular contact ball bearings with a specific axial clearance are required, bearings of universal design (suffix U) are used. Their bearing faces are machined, in relation to the raceways, in such a way that bearing pairs in X or O arrangement, or in a combination of X or O and tandem arrangement, have a specific axial clearance or preload prior to mounting (see also section on "Matched Rolling Bearings").

The most commonly used universal-design bearings have the following suffixes:



UA small axial clearance (angular contact ball bearings)

UO zero clearance (angular contact ball bearings)

UL light preload (spindle bearings)

With tight fits, the axial clearance is reduced or the preload of the bearing pair increased (fit recommendations for angular contact ball bearings, see catalogue WL 41 520EA, for spindle bearings, see FAG Publ. No. AC 41 130).

When ordering, please state the number of individual bearings, not the number of bearing groups.

Tolerances

Angular contact ball bearings of series 72B and 73B are machined to normal tolerances.

Spindle bearings are only available with narrow tolerances (tolerance class P4S with dimensional and form accuracies of tolerance class P4 and running precision of tolerance class P2).

Contact angle

Angular contact ball bearings of series 72B and 73B have a contact angle of 40°.

Spindle bearings are produced with contact angles of 15° (suffix C) and 25° (suffix E).

Cage

The smaller angular contact ball bearings are fitted with synthetic material cages (TVP), the larger ones with machined brass cages (MP).

The standard cage used in spindle bearings is an outer-ring riding machined cage of textile laminated phenolic (T).

Alignment

Very limited.

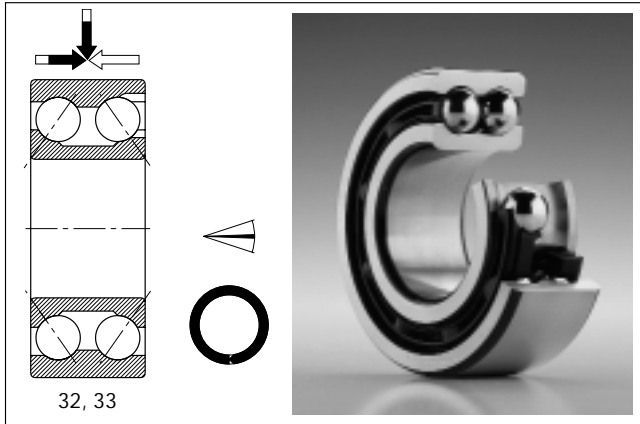
Load carrying capacity

Axial: high; radial: good.

Speed suitability

Angular contact ball bearings: high; spindle bearings: very high.

Angular contact ball bearings, double row



Series 32, 33
Contact angle 35°

The structure of a double row angular contact ball bearing corresponds to a pair of single row angular contact ball bearings in O arrangement. The bearing can accommodate high radial loads, and thrust loads in both directions. It is particularly suitable for bearing arrangements requiring a rigid axial guidance.

Double row angular contact ball bearings are available in 3 designs:

- with an unsplit inner ring and filling slots on one side (no suffix): series 32, 33
- with a split inner ring, no filling slots (suffix DA): series 33DA
- with an unsplit inner ring, no filling slots, greased (suffix B.TVH): series 32B, 33B

Standards

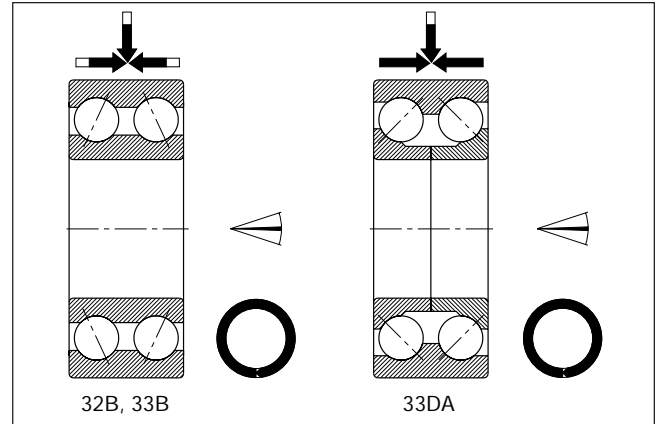
Double row angular contact ball bearings DIN 628, Part 3

Tolerances, bearing clearance

Basic double row angular contact ball bearings have normal tolerances and normal clearance. Bearings with larger than normal (C3) or smaller than normal (C2) axial clearance are also available.

Double row angular contact ball bearings with a split inner ring, which are designed for higher loads, are usually mounted with a tighter fit than unsplit bearings. Their normal clearance corresponds to the clearance group C3 of unsplit bearings.

The radial clearance for unsplit bearings with filling slots amounts to about 70% of their axial clearance, and for bearings without filling slots to about 50% of their axial clearance. For bearings with a split inner ring, the axial and radial clearances are the same.



Series 32B, 33B
Contact angle 25°

Series 33DA
Contact angle 45°

Cages

Double row angular contact ball bearings with pressed cages do not have a cage suffix. Bearings with machined brass cages are identified by the suffixes M or MA. Double row angular contact ball bearings with a moulded cage of glass-fibre reinforced polyamide cage are identified by the suffixes TVH or TVP.

Contact angle

The double row angular contact ball bearings without filling slots and an unsplit inner ring have a contact angle of 25°, bearings with filling slots have a contact angle of 35°. The high axial load carrying capacity of bearings with a split inner ring is due to the contact angle of 45°.

Sealed double row angular contact ball bearings

Bearings of series 32B and 33B are also available with ZR shields (non-rubbing seals) and RSR seals (rubbing seals) on both sides. These bearings are filled, at the manufacturer's plant, with a tested high-quality grease.

Alignment

Very limited.

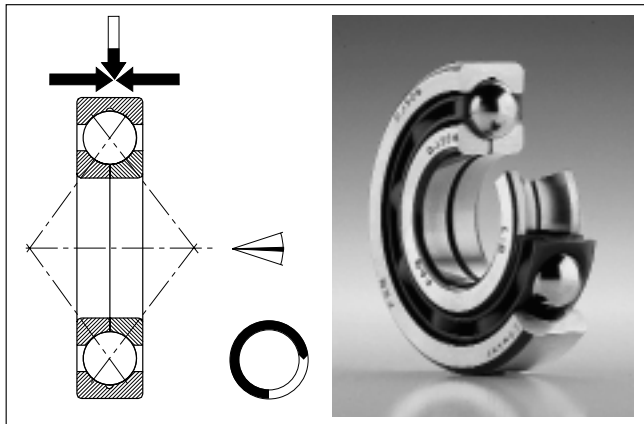
Load carrying capacity

The axial load carrying capacity of bearings with a filling slot is lower on the filling slot side than on the opposite side. Bearings without filling slots can accommodate axial loads of the same magnitude in both directions. Designs with a split inner ring can accommodate particularly high axial loads.

Speed suitability

Not as high as that of single row deep groove ball bearings or single row angular contact ball bearings.

Four-point bearings



Series QJ2, QJ3

Four-point bearings are single row angular contact ball bearings which can accommodate axial loads in both directions and low radial loads.

Four-point bearings feature a split inner ring; this allows a large complement of balls to be filled in. The outer ring with the ball and cage assembly and the inner ring halves can be mounted separately.

Standards

Angular contact ball bearings (four-point bearings) DIN 628, Part 4

Tolerances, bearing clearance, contact angle

Four-point bearings are usually manufactured to normal tolerances and normal clearance. The high load carrying capacity in axial direction is achieved with the large number of balls, the high raceway shoulders and the 35° contact angle.

Cages

Depending on the bearing series and size, four-point bearings have either moulded cages of glass-fibre reinforced polyamide (suffix TVP) or machined brass cages (MPA).

Retaining grooves

Four-point bearings which are mounted as thrust bearings have a loose fit in the housing to avoid radial loading. Large four-point bearings have two grooves (suffix N2) to retain the outer rings.

Alignment

Very limited.

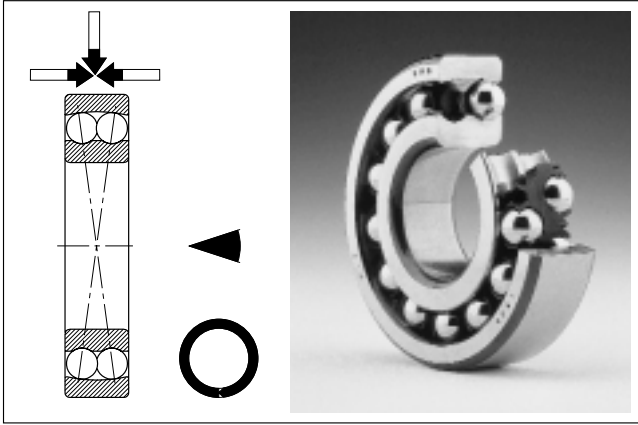
Load carrying capacity

High axial loads in both directions; low radial loads.

Speed suitability

Medium to high (if subjected to purely axial loads, cp. catalogue WL 41 520EA).

Self-aligning ball bearings



Series 12, 13, 22, 23
Series 112 with extended inner ring

Self-aligning ball bearings are of the double row type, with a spherical outer ring raceway. Their self-aligning capability allows them to compensate for misalignments, shaft deflections and housing deformations. Self-aligning ball bearings are not separable.

Standards

Self-aligning ball bearings	DIN 630
Adapter sleeves	DIN 5415

Tolerances, bearing clearance

The self-aligning ball bearings of basic design with a cylindrical bore are machined to normal tolerances and to "normal" clearance. Basic designs with a tapered bore have the larger-than-normal radial clearance C3.

Contact angle

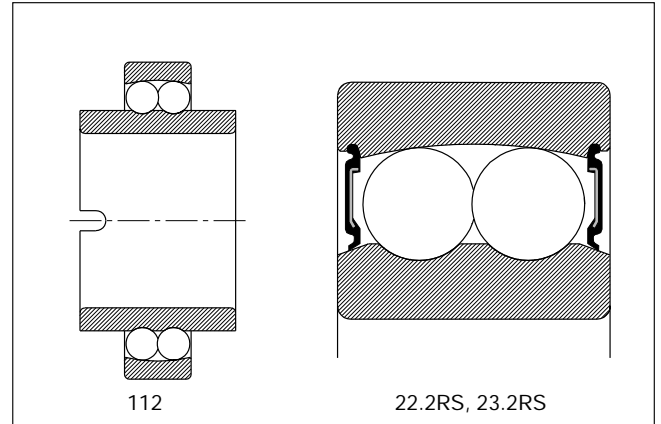
$\alpha_0 = 6 \dots 20^\circ$, depending on the bearing series.

Cages

Small self-aligning ball bearings have a ball riding moulded cage of glass-fibre reinforced polyamide (suffix TV); larger self-aligning ball bearings are fitted with a ball riding machined brass cage (suffix M).

Tapered bore

Self-aligning ball bearings with a bore taper 1:12 (suffix K) can be mounted either directly on a tapered shaft or on a cylindrical shaft using adapter sleeves.



Bearings with an extended inner ring

Self-aligning ball bearings of series 112 have an extended inner ring. They are located on the shaft by means of dowel pins which engage in a slot on one side of the inner ring. If a shaft is supported by a pair of self-aligning ball bearings the slots must be symmetrically arranged, either on the bearing sides facing each other or on the outboard sides. The bores of series 112 are machined to J7.

Sealed self-aligning ball bearings

Sealed self-aligning ball bearings have seals (rubbing seals) on both sides (series 22.2RS, 22K.2RS and 23.2RS). These bearings are filled with grease at the manufacturer's plant.

Alignment

Non-sealed self-aligning ball bearings can compensate for a misalignment of approx. 4° out of the centre position; sealed self-aligning ball bearings up to 1.5° .

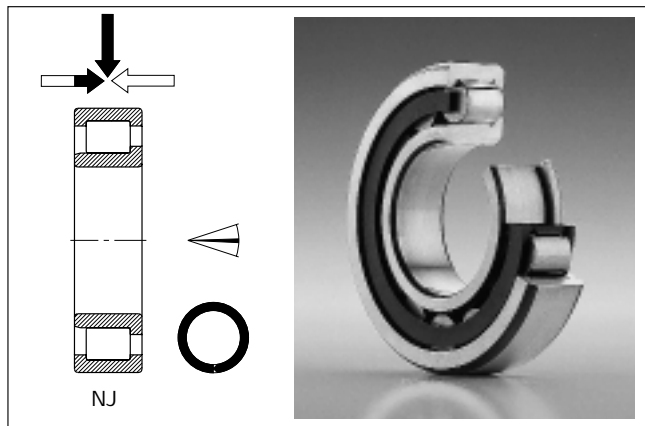
Load carrying capacity

Low radial and axial loads.

Speed suitability

High.

Cylindrical roller bearings, single row and double row



Series

single row: NU19, NU10, NU2, NU22, NU3, NU23, NU4, also with a different lip design
 double row: NNU49S(K), NN30ASK

Cylindrical roller bearings are separable. This facilitates mounting and dismounting. Both rings can be given a tight fit.

The various designs of single row cylindrical roller bearings are distinguished by the arrangement of their lips. Design NU has two lips on the outer ring, the inner ring being lipless. The inner ring of design N has two lips, the outer ring has none. Cylindrical roller bearings of design NU and N are used as floating bearings; they make length compensation within the bearing possible.

Cylindrical roller bearings NJ have two lips on the outer ring and one on the inner ring. They can transmit axial forces in one direction.

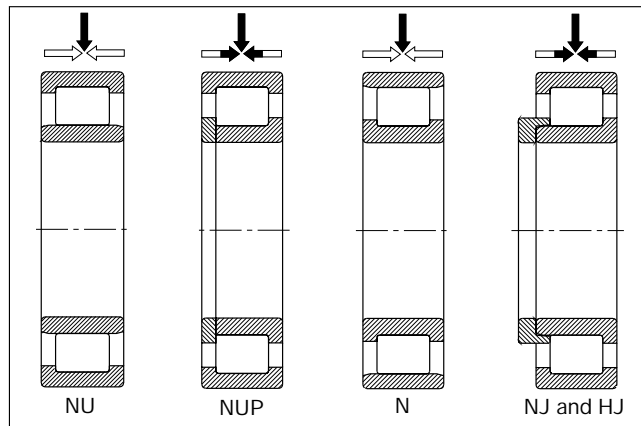
Cylindrical roller bearings NUP are installed as locating bearings to accommodate reversing axial forces. They have two lips on the outer ring and one fixed lip and one loose lip on the inner ring. A cylindrical roller bearing NJ with an angle ring HJ also forms a locating bearing.

Maximum capacity single row cylindrical roller bearings (suffix E, for larger bearings also EX) are available as basic designs in series 2E, 22E, 3E and 23E. Their roller set is designed for maximum load carrying capacity.

Double row FAG cylindrical roller bearings of series NN30ASK have a lipless outer ring and three lips on the inner ring. The suffix S identifies a lubricating groove and lubricating holes in the outer ring, K the tapered bearing bore (taper 1:12).

Double row bearings of series NNU49S have three lips on the outer ring, and the inner ring is lipless.

Double row cylindrical roller bearings are floating bearings. With them, arrangements are obtained which are radially rigid, have a high load carrying capacity and are of high precision.



Standards

Single row cylindrical roller bearings	DIN 5412, Part 1
Double row cylindrical roller bearings	DIN 5412, Part 4
Cylindrical roller bearings for electric machines in electric vehicles	DIN 43283
Angle rings	ISO 246 and DIN 5412, Part 1

Tolerances, bearing clearance

Single row FAG cylindrical roller bearings of basic design are available in the tolerance class "normal" and with normal radial clearance. Upon request, designs suffixed C3 (radial clearance larger than normal) and C4 (radial clearance larger than C3) are also available.

Double row cylindrical roller bearings are precision bearings with narrow tolerances according to tolerance class SP (FAG specification). These bearings have the reduced radial clearance C1NA (clearance group C1 according to FAG specification, bearing rings not interchangeable). C1NA is not indicated in the bearing code.

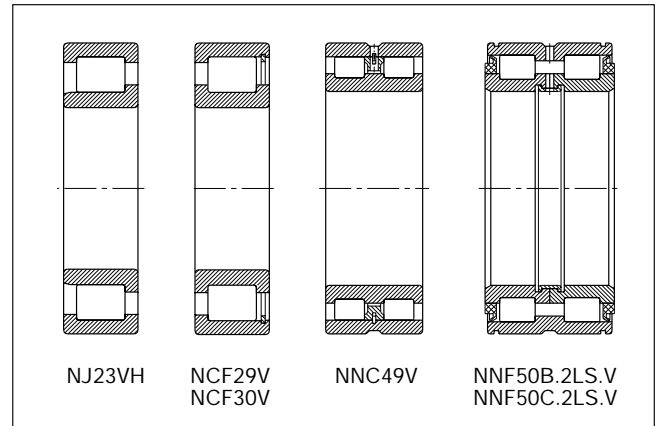
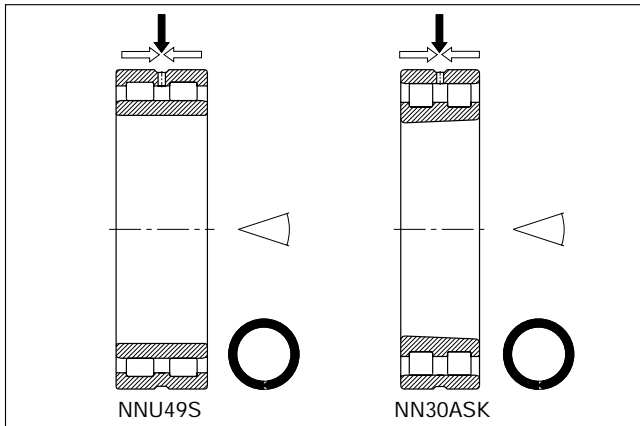
Boundary circle dimensions

The dimensions F and E are especially important where one adjacent component serves as a raceway instead of the separable ring.

- An NU bearing without inner ring becomes design RNU, whose rollers (dimension F) run directly on the shaft.
- An N bearing without outer ring becomes design RN, whose rollers (dimension E) run directly in the housing bore.

Due to the usually differing boundary circles, components of E design bearings are not interchangeable with those of non-reinforced bearings with the same basic code. This also applies for components of new EX designs and old E designs.

Cylindrical roller bearings, single row and double row · Full complement cylindrical roller bearings



Alignment

The modified line contact between rollers and raceways prevents edge stressing and allows a certain self-aligning capability of the single-row cylindrical roller bearings. With a load ratio of $P/C \leq 0.2$, the angle of alignment must not exceed 4 angular minutes.

P = equivalent dynamic load [kN]
 C = dynamic load rating [kN]

For applications where higher loads or greater misalignment have to be accommodated, please consult FAG.

Bearing locations designed for double row cylindrical roller bearings must be free from misalignment.

Cages

Single row cylindrical roller bearings without cage suffix have a pressed steel cage.

The suffixes M and M1 indicate bearings with roller-riding machined brass cages.

Small bearings of series 2E, 22E, 3E and 23E have cages of glass-fibre reinforced polyamide 66 (suffix TVP2).

Load carrying capacity

Very high radial loads. Axial loads can only be accommodated by designs NJ and NUP or if HJ angle rings are used (NJ + HJ).

Speed suitability

High to very high.

Full complement cylindrical roller bearings – series

single row: NCF29V, NCF30V,

NJ23VH

double row: NNC49V,

NNF50B.2LS.V,

NNF50C.2LS.V

Full complement cylindrical roller bearings are suitable for bearing locations where particularly high loads and low speeds have to be accommodated.

Single row full complement bearings can accommodate, in addition to very high radial loads, axial loads in one direction. Bearings of series NCF29V and NCF30V have two lips on the inner ring and are not separable. In the separable bearings of series NJ23VH the roller set is self-retained in the outer ring so that the rollers do not drop out even if the inner ring is removed.

Double row full complement cylindrical roller bearings can accommodate very high radial loads, axial loads in both directions and tilting moments. Bearings of series NNC49V have a lubricating groove and lubricating holes in the outer ring. The grease filling on both sides of sealed bearings NNF50B.2LS.V and NNF50C.2LS.V is sufficient for the entire bearing life.

Alignment

The self-aligning capability of full complement cylindrical roller bearings corresponds to that of caged bearings.

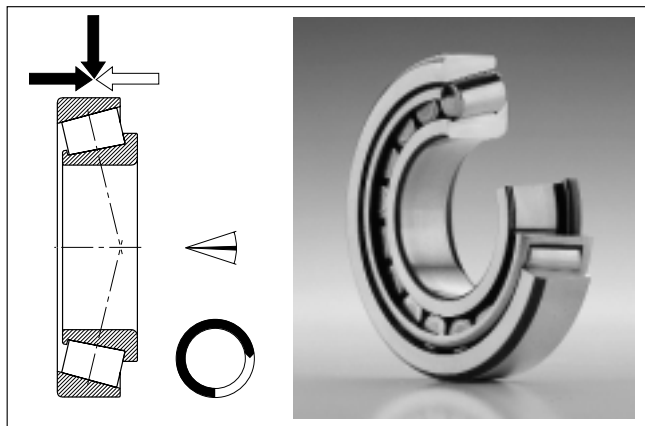
Tolerances, bearing clearance

Full complement cylindrical roller bearings of basic design have the normal clearance of radial bearings. Sealed double row bearings are available with normal radial clearance. Unsealed single row and double row cylindrical roller bearings have the increased bearing clearance C3.

Speed suitability

As the rollers rotate in opposite directions where they are in mutual contact, full complement cylindrical roller bearings have a considerably higher friction than caged bearings. Therefore, they are suitable only for low speeds.

Tapered roller bearings



Series 329, 320, 330, 331, 302, 322, 332, 303, 313, 323

Tapered roller bearings are separable; the cone and the cup can be mounted separately. As tapered roller bearings can accommodate axial loads only in one direction, a second, symmetrically arranged tapered roller bearing is usually needed for counter guidance. In this respect, they can be compared with angular contact ball bearings, but they have a higher load carrying capacity and are less suitable for high speeds.

Standards

Tapered roller bearings in metric dimensions DIN 720 and DIN ISO 355.

Tolerances, bearing clearance

Tapered roller bearings of basic design have a normal tolerance PN. Bearings of series 320X, 329, 330, 331 and 332 with bore diameters of up to 200 mm have the narrow width tolerances of tolerance class P6X (without suffix). Larger bearings of these series and bearings of the other series have width tolerances of tolerance class PN.

On request, tapered roller bearings are also available with an increased precision.

When mounting two symmetrically arranged tapered roller bearings, one bearing ring is displaced along its seat until the bearing arrangement has the required axial clearance or axial preload.

Contact angle

Due to their contact angle ($\alpha_0 = 5...28^\circ$), tapered roller bearings can accommodate both radial and axial loads. Larger contact angles, and consequently a greater axial load carrying capacity, are featured by bearings of series 323B (as compared to the normal design 323 and 323A) and especially bearings of series 313.

Cages

FAG tapered roller bearings, with the exception of integral tapered roller bearings (page 41), are fitted with pressed steel cages for which no suffix is used. The cages slightly project laterally; this must be taken into account for mounting.

Alignment

The modified line contact between the tapered rollers and the raceways (logarithmic profile) eliminates edge stressing and allows the tapered roller bearings to align. For single row tapered roller bearings with a load ratio of $P/C < 0.2$ a maximum angular alignment of 4 angular minutes is admissible. If higher loads or greater misalignments have to be accommodated, please consult FAG.

P = equivalent dynamic load [kN]

C = dynamic load rating [kN]

Load carrying capacity

Radial: very high loads; axial: high loads in one direction.

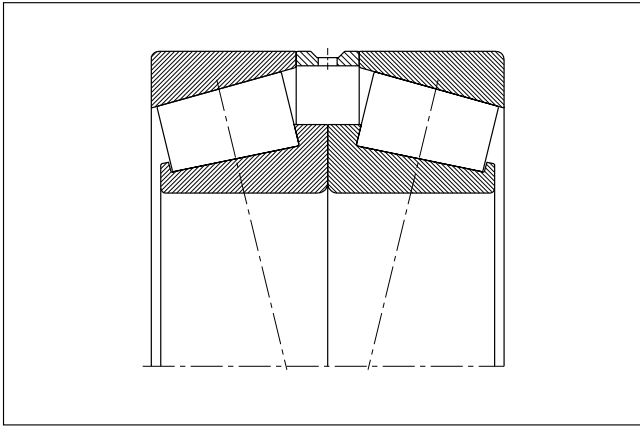
Speed suitability

Medium to high. The speeds reached by matched bearings are approx. 20% lower than those of single bearings.

Inch dimensions

Tapered roller bearings in metric dimensions should be preferred for new designs. In addition to the metric bearings, FAG also offers tapered roller bearings in inch dimensions.

Tapered roller bearings



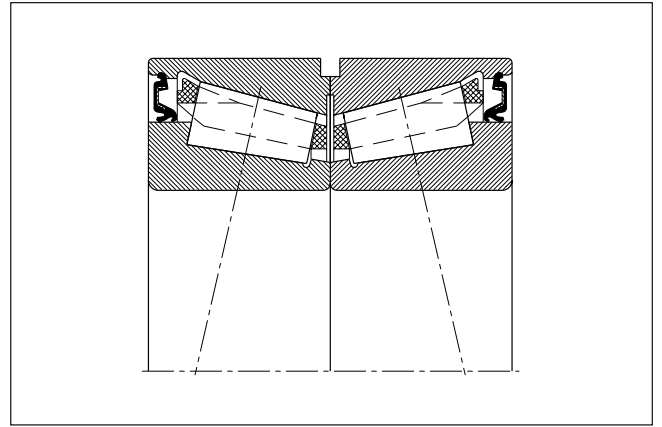
Design N11CA

Matched bearings

The suffix N11CA (formerly K11) identifies matched tapered roller bearing pairs with a defined axial clearance. The axial clearance is obtained by means of a matched spacer ring between the outer rings.

Example for ordering: 2 bearings 31306A.A50.90.N11CA

The spacer ring is part of the delivery scope. A50.90 means that the axial clearance of the bearing pair before mounting is between 50 and 90 μm .

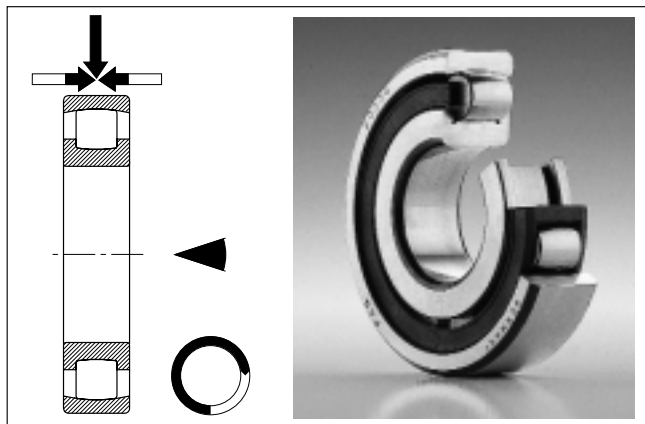


Series JK0S

Integral tapered roller bearings

Tapered roller bearings of series JK0S are self-retaining, sealed and greased. They are primarily intended for the mounting of pairs in O arrangement. The axial clearance need not be set. The bearings have cages of glass-fibre reinforced polyamide (no suffix).

Barrel roller bearings



Series 202, 203

FAG barrel roller bearings are single row, self-aligning roller bearings. They are particularly suitable for applications where a high radial load carrying capacity and the compensation of misalignments are required. Their sturdy design has proven its worth especially in cases where shock-type radial loads have to be accommodated. The axial load carrying capacity of the barrel roller bearings is limited. The bearings are not separable.

Standards

Barrel roller bearings DIN 635, Part 1

Tolerances, bearing clearance

The FAG barrel roller bearings of basic design have a normal tolerance. Bearings with a cylindrical bore have the clearance group "normal" (no suffix), bearings with a tapered bore have an increased radial clearance (suffix C3).

Contact angle

$\alpha_0 = 0^\circ$.

Cages

Barrel roller bearings are fitted with moulded window-type cages of glass-fibre reinforced polyamide 66 (suffix T) or with inner ring riding machined brass cages (suffix MB).

Tapered bore

Barrel roller bearings with a tapered bore (taper 1:12) are fastened either directly on a tapered shaft seat or, using an adapter sleeve, on a cylindrical shaft seat.

Alignment

Under normal loads and with rotating inner ring barrel roller bearings can compensate for misalignments of up to 4° .

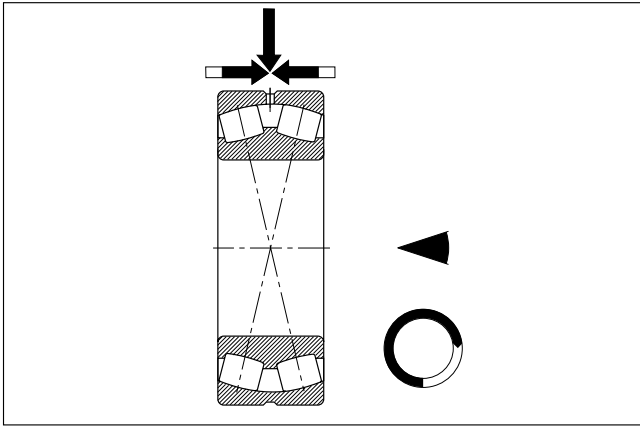
Load carrying capacity

Very high radial loads, low axial loads.

Speed suitability

Low to medium.

Spherical roller bearings



Series 222, 223, 230, 231, 232, 233, 239, 240, 241

FAG spherical roller bearings are made for heavy-duty applications. They feature two rows of symmetrical barrel rollers which can align freely in the spherical outer ring raceway, thus compensating for misalignments of the bearing seats and shaft deflections.

FAG spherical roller bearings have a maximum number of long rollers with a large diameter. The close contact between the rollers and raceways yields a uniform stress distribution and a high load carrying capacity.

Most FAG spherical roller bearings with an outside diameter of up to 320 mm are of the E design. Unlike the other spherical roller bearings, these bearings have no centre lip on the inner ring, and therefore their rollers are longer. This yields higher load ratings.

For particularly punishing applications, e.g. where vibratory stresses have to be accommodated, FAG offer special spherical roller bearings (suffix T41A) with narrow dimensional tolerances and an increased radial clearance (see also Publ. No. WL 21 100).

Examples: 22322E.T41A
22332A.MA.T41A

Another special design which is increasingly being used are the split spherical roller bearings. Their inner ring, outer ring and roller-and-cage assembly are divided into 2 halves which facilitates mounting, especially in the case of bearing replacement (cp. Publ. No. WL 43 165).

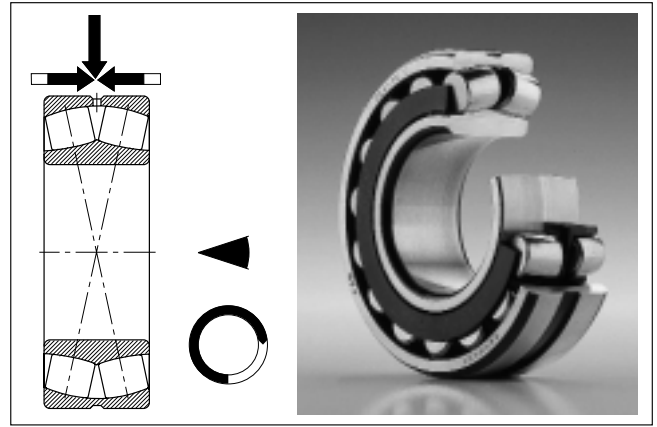
Standards

Spherical roller bearings

DIN 635, Part 2

Tolerances, bearing clearance

Spherical roller bearings of basic design are made with normal tolerances and the clearance group "normal". To account for varying operating and mounting conditions, bearings with an increased radial clearance (C3 and C4) are also available.



E-design (213E, 222E, 223E, 230E, 231E, 240E, 241E)

Contact angle

$\alpha_0 = 6...15^\circ$

Tapered bore

In addition to spherical roller bearings with a cylindrical bore, there are two designs with a tapered bore:

Taper 1:12 (suffix K) for standard width series

Taper 1:30 (suffix K30) for the wide series 240 and 241

Taper 1:12 means that the bore expands by 1 mm every 12 mm and in the case of taper 1:30 only every 30 mm.

Spherical roller bearings with a tapered bore are usually fastened on the shaft by means of adapter sleeves or withdrawal sleeves (see catalogue WL 41 520EA). As these bearings are mounted, their radial clearance is reduced.

Heat treatment

Spherical roller bearings are normally heat-treated in such a way that they can be used at operating temperatures of up to 200 °C (S1). If bearings with a polyamide cage are used, the temperature limits of application of the cage have to be observed.

Alignment

Under normal operating conditions and with rotating inner ring, spherical roller bearings can compensate for misalignments of up to 0.5° out of the centre position. If the loads are low, angular misalignments of up to 2° are admissible if there is a suitable surrounding structure.

Load carrying capacity

Radial: very high, axial: good.

Speed suitability

Low to medium.

Spherical roller bearings

Cages

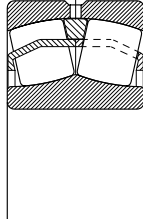
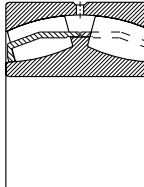
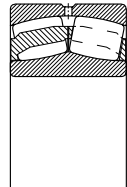
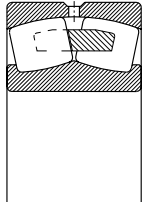
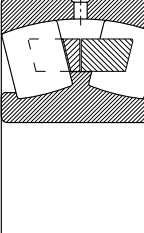
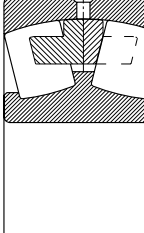
Spherical roller bearings of series 222E and 223E without cage suffix have pressed steel cages which are outer ring guided. All cage parts are surface-hardened for the basic bearing design of series 223E and the bearing according to specification T41A.

The other E-design bearings have cages of glass-fibre reinforced PA66 (suffix TVPB) or machined brass cages (suffix M).

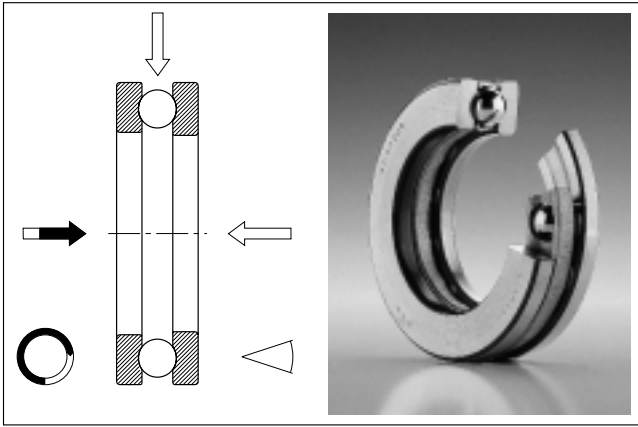
Spherical roller bearings with an integral centre lip on the inner ring have machined brass cages or pressed brass cages. Bearings with pressed cages have no cage suffix. The machined cages are inner ring guided (MB), cages for bearings of design T41A are outer ring guided (MA).

The table below shows the allocation of the standard cages to the series (designs) and sizes of the FAG spherical roller bearings.

Standard cages of FAG spherical roller bearings

Series (Design)	Pressed steel cage	Pressed brass cage	Moulded polyamide cage	Machined brass cage		
	outer ring guided	inner ring guided	inner ring guided	roller riding	inner ring guided	outer ring guided
						
Cage suffix	-	-	TVPB	M	MB	MA
	Bore reference number					
213E			up to 22			
222					from 38 on	
222E	up to 36					
223					from 32 on	
223A (T41A)						from 32 on
223E	up to 30					
223E (T41A)	up to 30					
230					from 44 on	
230E			up to 40			
230EA				up to 40		
231					from 40 on	
231E			up to 38			
231EA				up to 38		
232					from 38 on	
232E			up to 36			
232EA				up to 36		
233A (T41A)						from 20 on
239					from 36 on	
240					from 24 on	
240E						
241		up to 88	up to 32		from 92 on	
241E			up to 28			

Thrust ball bearings



single direction
series 511, 512, 513, 514, 532, 533

Thrust ball bearings are used where purely axial loads have to be accommodated. The single direction (= single row) design is designed for loads from one direction, the double direction one (= double row) for reversing loads. Besides the design with flat washers, designs with spherical housing washers and seating washers are also available which can compensate for misalignment.

Standards

Single direction thrust ball bearings DIN 711
Double direction thrust ball bearings DIN 715
Seating washers for thrust ball bearings DIN 711

Tolerances

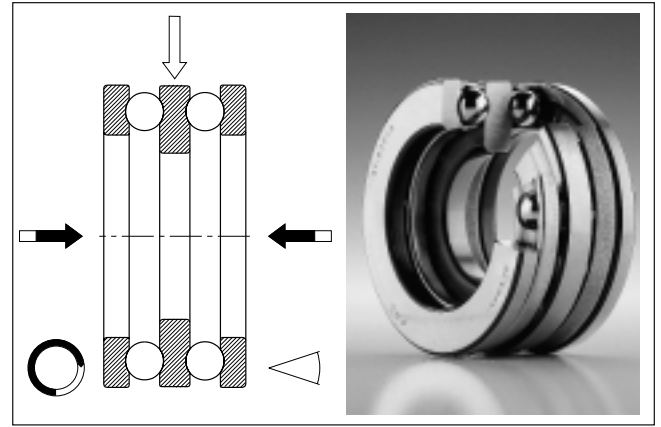
Thrust ball bearings of basic design are machined to normal tolerances. FAG bearings of series 511 are also available with narrow tolerances (suffixes P6 and P5).

Cages

Small bearings have pressed steel cages (no cage suffix), the larger ones have ball-riding machined window-type steel or brass cages (suffix FP or MP) or ball-riding machined brass cages (suffix M).

Minimum axial load

At high speeds bearing kinematics is affected by the inertia forces of the balls if the axial load does not reach a certain minimum value. For details on the minimum axial load F_{amin} , see catalogue WL 41 520EA. If the external load is too low, the bearings must be preloaded, e.g. by means of springs.



double direction
series 522, 523, 542, 543

Contact angle

$\alpha_0 = 90^\circ$.

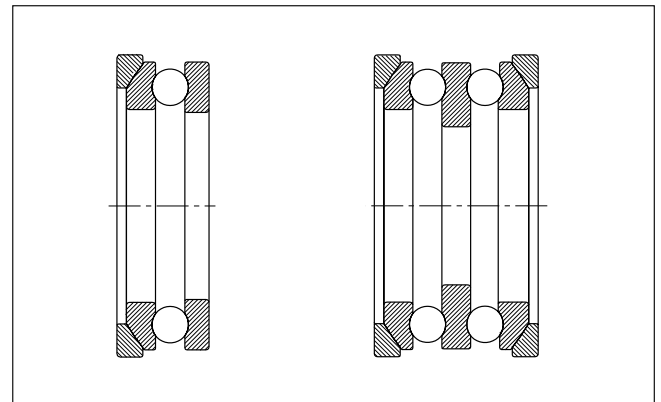
Alignment

None. The mating surfaces of the bearing washers must be parallel to each other. Misalignments can be compensated for by means of spherical housing washers and seating washers.

single direction with one seating washer	double direction with two seating washers
---	--

532.. + U2..
533.. + U3..

542.. + U2..
543.. + U3..



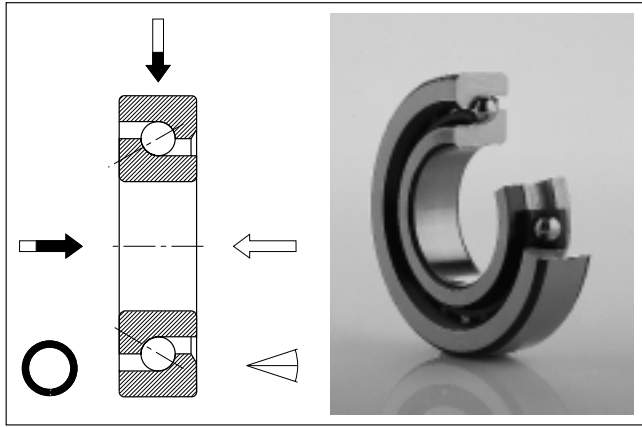
Load carrying capacity

No radial loads; high axial loads.

Speed suitability

Medium.

Angular contact thrust ball bearings



single direction
series 7602, 7603

Single direction angular contact thrust ball bearings are precision bearings for machine tools. These bearings are characterized by great rigidity, low friction and suitability for high speeds at fast changes of position. Like all angular contact ball bearings, they can accommodate axial loads in only one direction.

Tolerances

Dimensional tolerances (diameter): tolerance class P4 for radial bearings

Running tolerance (axial runout): tolerance class P4 for thrust bearings

Preload, rigidity

Single direction angular contact thrust ball bearings are preferably mounted in pairs or groups. The width tolerances of the bearing rings permit the matching of identically sized bearings directly side by side in pairs or groups. O and X arranged bearings have a defined preload. The preload and rigidity of the bearing arrangement are increased by lining up several bearings at one bearing location.

Cage

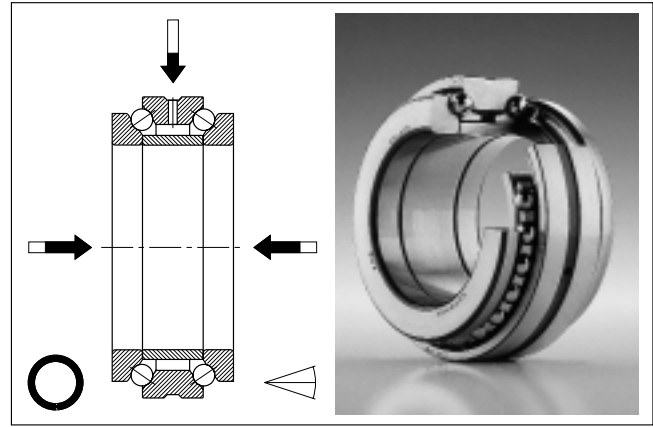
The ball-riding, moulded window-type cage of glass fibre reinforced polyamide (suffix TVP) allows a large number of balls to be fitted.

Lubrication, speed suitability

Single direction angular contact thrust ball bearings are usually lubricated with grease. If the bearings are mounted in groups of three or four the speeds reached by bearing pairs must be reduced accordingly.

Contact angle, load carrying capacity

Contact angle $\alpha_0 = 60^\circ$, and consequently a high axial load carrying capacity. Radial loads can also be accommodated.



double direction
series 2344, 2347

Double direction angular contact thrust ball bearings are mainly used, together with double row cylindrical roller bearings of series NN30ASK, in precision spindles of machine tools. Bearings of series 2347 are mounted at the wider end of the cylindrical roller bearing bore, whereas bearings of series 2344 are mounted at the narrower end. Double direction angular contact thrust ball bearings are separable; their components must not be interchanged with parts of other bearings of the same size.

Tolerances, preload

Double row angular contact thrust ball bearings have the same nominal outside diameter as cylindrical roller bearings NN30ASK. The tolerance of the outside diameter, however, is defined so that there is a loose fit if the seats of the angular contact thrust ball bearing and of the cylindrical roller bearing were machined together.

Angular contact thrust ball bearings are produced in the tolerance class SP. Tolerance class UP on request.

The preload is determined by means of the spacer ring between the two shaft washers.

Contact angle, cage

Due to the contact angle of 60° , the bearings have a great axial rigidity and load carrying capacity.

The machined brass cage is designed for high speeds. Every ball row has its own, ball-riding cage (suffix M).

Alignment

None, i.e. the mating surfaces of the bearing washers must be parallel.

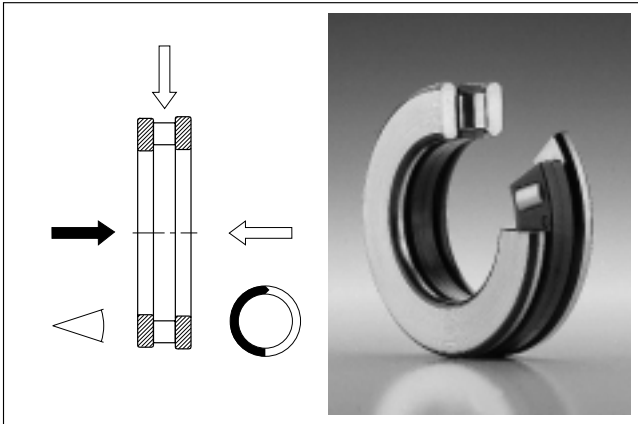
Load carrying capacity

Axial: good; radial: low.

Speed suitability

Very high.

Cylindrical roller thrust bearings



single direction
series 811, 812

FAG cylindrical roller thrust bearings provide rigid bearing arrangements which can accommodate high axial loads and shock loads without problems but no radial loads. They have no self-aligning capability.

Cylindrical roller thrust bearings can be separated into thrust cylindrical roller and cage assembly, shaft washer and housing washer.

Standards

Cylindrical roller thrust bearings DIN 722

Contact angle

$\alpha_0 = 90^\circ$.

Cages

FAG cylindrical roller thrust bearings have moulded cages of glass fibre reinforced polyamide (TVPB), machined cages of light metal (LPB) or brass (MPB, MB). The cage is guided on the shaft.

Alignment

None, i.e. the mating surfaces of the bearing washers must be parallel.

Minimum axial load

To prevent slippage between rollers and bearing washers, cylindrical roller thrust bearings must always be loaded axially (see catalogue WL 41 520EA). If the external load is too low the bearing must be preloaded, e.g. with springs.

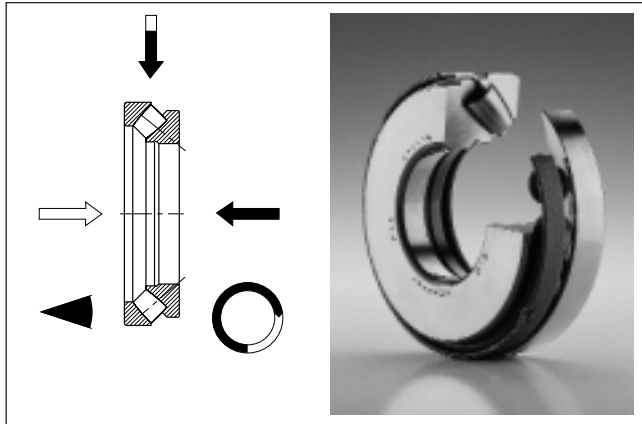
Load carrying capacity

Very high axial loads, no radial loads.

Speed suitability

Low.

Spherical roller thrust bearings



series 292E, 293E, 294E

Spherical roller thrust bearings can accommodate high axial loads. They are suitable for relatively high speeds. The raceways which are inclined towards the bearing axis allow the bearings to accommodate radial loads as well. The radial load must not exceed 55% of the axial load.

The bearings have asymmetrical barrel rollers and compensate for misalignment. As a rule, spherical roller thrust bearings have to be lubricated with oil.

FAG supply spherical roller thrust bearings of reinforced design (suffix E). The bearings are designed for maximum load carrying capacity.

Standards

Spherical roller thrust bearings ISO 104 and DIN 728

Tolerances

Spherical roller thrust bearings are made with normal tolerances.

Contact angle

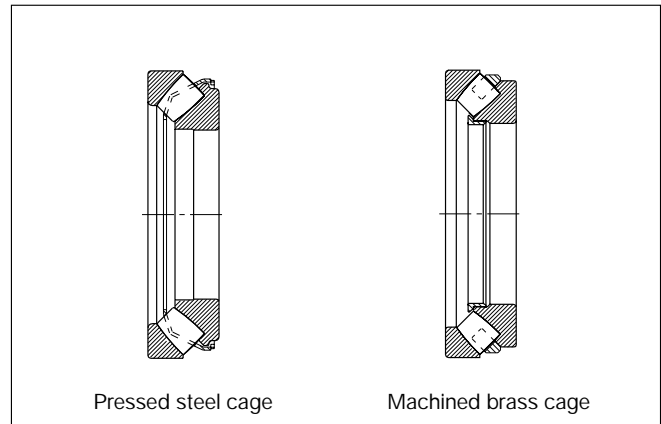
$\alpha_0 = 50^\circ$.

Cages

Spherical roller thrust bearings have either pressed steel cages (no cage suffix) or machined brass cages (suffix MB). The cages hold together the roller set and the shaft washer.

Alignment

Owing to their spherical housing washer, spherical roller thrust bearings are self-aligning and can compensate for misalignments and shaft deflections.



If P or $P_0 \leq 0.05 \cdot C_0$ [kN], the misalignment values indicated in the table are admissible provided the shaft washer rotates and the misalignment is constant.

Angular misalignment in degrees

Bearing series	Angular alignment
292E	1 ... 1.5°
293E	1.5 ... 2.5°
294E	2 ... 3°

The lower values apply to large bearings.

For details on the aligning capability at rotating housing washer or wobbling shaft motion (dynamic misalignment) please consult our Technical Service.

Minimum axial load

At high speeds bearing kinematics is impaired by the inertia forces of the rollers if the axial load does not reach a certain minimum. For details on this minimum axial load F_{amin} see catalogue WL 41 520.

If the external load and the weight of the supported machine elements are lower than the minimum load the bearings have to be preloaded, e.g. by means of springs.

If a radial load has to be accommodated in addition to the axial load, the requirement $F_r \leq 0.55 \cdot F_a$ must be fulfilled.

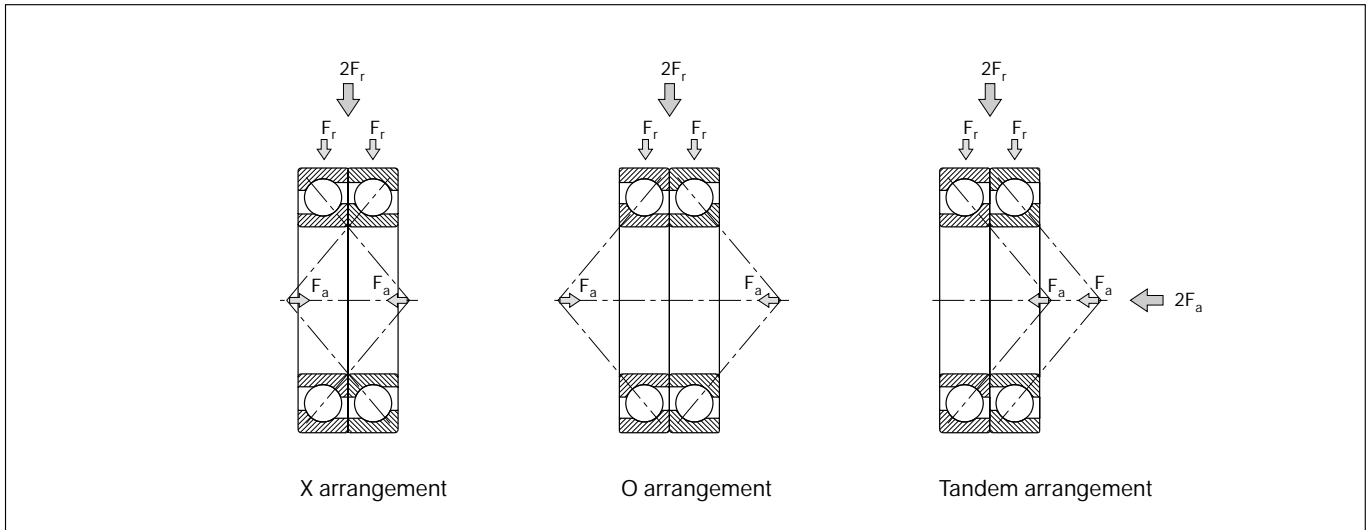
Load carrying capacity

Very high axial loads, medium radial loads.

Speed suitability

Medium to high.

Matched rolling bearings



If the load carrying capacity of one single bearing is not sufficient several bearings can be mounted adjacent to one another. In this case the bearings have to be matched in such a way that as uniform a load distribution as possible and a specific clearance in the bearing set can be achieved.

Rolling bearings are matched together within narrow tolerances in accordance with technical specifications. One example are matched tapered roller bearings of design N11CA (see also page 41).

Spindle bearings are also available as ready-to-mount sets, cp. Catalogue WL 41 520 and Publ. No. AC 41 130.

Furthermore, angular contact ball bearings, especially spindle bearings, that are intended for mounting in pairs or sets in X,

O or tandem arrangement (see drawing above) are also available in **universal design**. In bearings of universal design the bearing faces match the raceways in such a way that the bearing pairs, prior to mounting in X or O arrangement, or in a combination of X or O and tandem arrangement, have a certain axial clearance, zero clearance or preload. If they are fitted tightly, the axial clearance is reduced or the preload increased by mounting.

Suffixes:

- UA Universal design, small axial clearance
- UO Universal design, zero clearance
- UL Universal design, light preload
- UM Universal design, medium preload

Bearing units

Bearing units

A complete bearing mounting comprises not only the bearing itself but *sealing* and *lubrication* as well. Rolling bearings into which these elements are integrated are referred to as bearing units. These are cost-efficient bearing designs because, as a rule, they do not require any maintenance throughout their entire *service life*. The most commonly used bearing units incorporate deep groove ball bearings with seals or dust shields. Sealed designs offered by FAG also include self-aligning ball bearings, double-row full complement cylindrical roller bearings, JKOS tapered roller bearings and high-speed spindle bearings.

Apart from the sealing, other components adjacent to the rolling bearing can be integrated in the unit as well. For instance, clamping elements which are used to fasten the inner rings of S-type bearings on the shaft. The thick-walled cylindrical or spherical outer rings of track rollers can run directly on tracks. The function of the housing is completely or partly integrated in the unit with wheel bearing units for automobiles, journal roller bearing units for rail vehicles, VRE plummer block units for fans, flanged bearing units for electric machines and bottom bracket bearing units for bicycles (see also "FAG Target Industry Programmes" in catalogue WL 41 520).

S-Bearing Units

S-bearing units are used for highly contaminated environments, shaft deflection and misalignment, e.g. in agricultural machines, conveyor systems and construction machines.

The sealed deep groove ball bearings require no maintenance. They have a spherical outside diameter and are mounted into spherical housings so that they can compensate for misalignment. The inner ring is fastened on the shaft by means of an eccentric self-locking collar (series 162 and 362), by means of two threaded pins (series 562) or by the fit (series 762.2RSR).

S-bearing housings are plummer block housings or flanged housings. One can choose between the materials grey-cast iron and pressed steel. The cast housings are used for higher loads than the lower priced pressed housings.

For more details see catalogue WL 41 520 and Publ. No. WL 90 115.

S-type bearing units, S-type bearings and housings



Bearing units

FAG deep groove ball bearings with an integrated sensor

FAG deep groove ball bearings with an integrated sensor allow a precise and cost-effective speed measurement in an extremely limited space. Speed and sense of rotation are recorded and the data transmitted via a cable, for instance to a frequency converter. You will no longer need expensive rotary encoder systems in electric machines, mobile and stationary transmissions, conveying machines, as well as textile and packaging machinery.

The overall width of the sensor bearings is 8 mm greater than that of standard deep groove ball bearings of dimensional series 62. The sealed bearings are maintenance-free. The performance data correspond to those of the standard bearings.

For more detailed information, see TI No. WL 43-1206.

Sensor bearings



Mast guide rollers

Mast guide rollers transmit longitudinal and transverse forces from the fork carriage to the fork lift truck's lift mast. They have thick-walled outer rings with which the rollers run directly on the tracks. Mast guide rollers are sealed on both sides and lubricated for life.

Mast guide rollers



Plummer block units VRE3

These units, which were originally developed for fans, are especially suitable for applications where precise and easy-to-mount bearing units are required, e.g. in conveyor systems, test rigs, textile machines and feeding mechanisms.
















A one-piece housing accommodates two bearings. Depending on the operating conditions, users can choose from six bearing variations. The completely assembled units are equipped with deep groove ball bearings, cylindrical roller bearings or matched angular contact ball bearings.

For more detailed information, see Publ. No. WL 90 121 "FAG Bearing Units for Fans, Series VRE3".

Plummer block unit VRE3



Checklist for rolling bearing determination

Dimensions [mm]	Bore d = _____		Outside diameter D = _____		Width B = _____		
	Other dimensions _____						
Rolling bearing type	<input type="checkbox"/> single row		<input type="checkbox"/> double row		<input type="checkbox"/> multi row (number of rows) _____		
	<input type="checkbox"/> with cage		<input type="checkbox"/> without cage				
	Radial bearing				Thrust bearing		
	Ball bearing						
		Deep groove ball bearing single row	Deep groove ball bearing double row	Angular contact ball bearing single row	Angular contact ball bearing double row	Four point bearing	Self-aligning ball bearing
<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		
Roller bearing							
	Cylindrical roller bearing single row	Cylindrical roller bearing double row	Needle roller bearing	Tapered roller bearing	Barrel roller bearing	Spherical roller bearing	
<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		
<input type="checkbox"/> Other types							
Cage material	Pressed cage		Machined/moulded cage				
	<input type="checkbox"/> Steel		<input type="checkbox"/> Steel		<input type="checkbox"/> Polyamide		
	<input type="checkbox"/> Brass		<input type="checkbox"/> Brass		<input type="checkbox"/> Textile laminated phenolic resin		
	<input type="checkbox"/>		<input type="checkbox"/> Light metal		<input type="checkbox"/>		
Cage guidance		<input type="checkbox"/> by rolling elements			<input type="checkbox"/> by outer ring		
		<input type="checkbox"/> by inner ring					
Special features	<input type="checkbox"/> Seal		<input type="checkbox"/> on one side		<input type="checkbox"/> on both sides		
	<input type="checkbox"/> Dust shield						
	<input type="checkbox"/> Cylindrical bore		<input type="checkbox"/> Tapered bore				
	<input type="checkbox"/> Circular groove for snap ring						
	<input type="checkbox"/> Lubricating groove and lubricating holes		<input type="checkbox"/> in the outer ring		<input type="checkbox"/> in the inner ring		
<input type="checkbox"/> Other features (e.g. spherical outer ring)							
Markings	Manufacturer _____		Country of origin _____		Number _____		
Operating conditions	Bearing location _____						
	Speed min ⁻¹ _____						
	Temperature °C _____						
	Lubrication						
<input type="checkbox"/> Grease		<input type="checkbox"/> Oil sump		<input type="checkbox"/> Oil circulation			
<input type="checkbox"/> Oil throwaway							
<input type="checkbox"/> Other lubrication modes _____							
<input type="checkbox"/> Lubricant designation _____							

Index

Additives	9, 14, 17	Index of dynamic stressing f_L	11
Adjusted bearing arrangement/Adjusting	31	Index of static stressing f_s	9
Adjusted rating life calculation	12	Kinematic viscosity	20
Ageing	17	Kinematically permissible speed	22
Alignment	27	Life	10
Angular contact bearings	4	Life exponent p	11
Arcanol (FAG rolling bearing greases)	17, 18	Limiting speed	22
Attainable life L_{na} , L_{hna}	12	Lithium soap base greases	19
Axial clearance	24	Load angle	8
Ball bearings	4	Load rating	8
Base oil	13, 17	Locating bearing/floating bearing arrangement	29
Basic a_{23II} factor	13	Locating bearing	29
Bearing clearance	24	Lubricating conditions	19
Bearing life	10	Lubricating greases	19
Bearing rings	6	Lubricating oils	19
Boundary lubrication	19	Lubrication interval	19
Cages	6	Machined cages	6
Changing operating conditions	12	Matched rolling bearings	49
Circumferential load	28	Mineral oils	19
Cleanliness factor s	13, 16	Mixed lubrication	19
Combined load	8	Modified life	12
Consistency	17	Moulded cages	7
Contact angle	4	Mounting and dismounting	28
Contact lines	4	Nominal rating life	11
Contamination factor V	14	Nominal viscosity	20
Counter guidance	32	Non-rubbing seals	21
Curvature ratio	8	O arrangement	29, 31, 49
Dimensioning	9	Oil cleanliness classes	15
Dry lubricants	17	Oil lubrication	17
Dynamic load rating C	8	Operating clearance	25
Dynamic viscosity	20	Operating viscosity ν	13, 19
Dynamically stressed rolling bearings	10	Penetration -> <i>Consistency</i>	
EP additives	17	Point load	28
Equivalent dynamic load P	10	Polyamide cages	7
Equivalent static load P_0	9	Precision bearings/Precision design	26
Factor a_1	12	Pressed cages	6
Factor a_{23} (life adjustment factor)	12	Pressure cone apex	4
Fatigue life	10	Radial bearings	4
Filtration ratio	16	Radial clearance/Radial clearance group	24
Fits	28	Rated viscosity ν_1	13, 19
Floating bearing arrangement	31	Reference speed	22
Floating bearing	29	Relubrication interval	19
Full fluid film lubrication	19	Roller bearings	4
Grease lubrication	17	Rolling bearing catalogue on CD-ROM	2
Grease life	19	Rolling Bearing Learning System W.L.S.	2
High temperature suitability	23	Rolling elements	4, 5
		Rubbing seals	21

Index

Sealing/Seals	21
Self-aligning bearings	27
Separable bearings	6
Service life	9
Speed factor f_n	11
Speed index $n \cdot d_m$	19
Speed suitability	22
Spread	31
Static load rating C_0	8
Statically stressed rolling bearings	9
Stress index f_{s^*}	14
Synthetic lubricants/Synthetic oils	19
Tandem arrangement	32, 49
Thermally permissible operating speed	22
Thickener	20
Thrust bearings	4
Tolerance classes	26
Type of guidance (cage)	7
Universal design -> <i>Matched rolling bearings</i>	
Value K	13
Varying loads and speeds	10
Viscosity	20
Viscosity classification	20
Viscosity ratio ν	12, 20
Viscosity-temperature behaviour (V-T behaviour)	20
Wear	9
Worked penetration -> <i>Consistency</i>	
X arrangement	29, 31, 49

FAG OEM und Handel AG

A company of the FAG Kugelfischer Group

Postfach 12 60 · D-97419 Schweinfurt

Telephone (09721) 91 37 07 · Telefax (09721) 91 31 33

<http://www.fag.de>

FAG Rolling Bearings **Fundamentals · Types · Designs**

Every care has been taken to ensure the correctness of the information contained in this publication but no liability can be accepted for any errors or omissions. We reserve the right to make changes in the interest of technical progress.

© by FAG 1999. This publication or parts thereof may not be reproduced without our permission.

TI No. WL 43-1190 EA/94/10/99 · Printed in Germany by Weppert GmbH & Co. KG, Schweinfurt