Principles for selection and application

Friction

The friction in a spherical plain bearing or rod end depends primarily on the sliding contact surface combination, the load and the sliding velocity. Because there are so many influencing factors that are not mutually independent, it is not possible to quote exact values for the coefficient of friction. Under laboratory conditions, however, it is possible to record the coefficient of friction for different sliding contact surface combinations. The friction during the running-in phase is higher than the value recorded during the subsequent test period.

Guideline values for the coefficient of friction μ are listed in **table 1**. They have been determined in laboratory trials.

The coefficient of friction for maintenance-free steel/PTFE fabric and steel/PTFE sintered bronze sliding contact surface combinations decrease with increasing specific load. At a constant specific load, friction is reduced to the given minimum value as soon as the transfer of PTFE from the sliding layer to the opposing steel surface is complete. The frictional moment for a spherical plain bearing or rod end can be calculated using

$$M = 0,5\ \mu\ P\ d_m$$

where
M = frictional moment [Nm]
μ = coefficient of friction (→ **table 1**)
P = equivalent dynamic bearing load [kN]
d_m = inner ring mean diameter [mm]
d_m = d_k for radial spherical plain bearings and rod ends
d_m = 0,9 d_k for angular contact spherical plain bearings
d_m = 0,7 d_k for thrust spherical plain bearings
d_k = inner ring sphere diameter [mm]

Table 1

Coefficient of friction for different sliding contact surface combinations (guideline values)

Sliding contact surface combination	**Coefficient of friction μ** min	max
Steel/steel	0,08	0,20
Steel/bronze	0,10	0,25
Steel/PTFE sintered bronze	0,05	0,25
Steel/PTFE fabric	0,02	0,15
Steel/PTFE FRP	0,05	0,20

After the bearing has been in operation for an extended period of time, negative influences (contamination, inadequate lubrication) may cause the bearing to approach or exceed the maximum values for the coefficient of friction listed in the table. Bearings are susceptible to this phenomenon even under light loads and especially under harsh operating conditions. In applications where friction is particularly important, SKF recommends determining the power ratings by using the maximum values for the coefficient of friction that are listed in **table 1**. For bearings operating under conditions of mixed or dry friction, there may be slight differences between adhesive and sliding friction. Experience has shown that it is not possible to eliminate stick-slip entirely and that it most frequently occurs when support elements lack adequate stiffness. In most applications, however, the effects are negligible.

Design of bearing arrangements

Radial location of bearings

The inner and outer rings of spherical plain bearings must be radially secured (located) to the shaft and in the housing so that sliding movements occur in the bearing and do not result in ring creep. Ring creep occurs when a ring turns on its seat in the circumferential direction under load. To locate a bearing in the radial direction usually requires an interference fit. However, an interference fit cannot always be applied, e.g. if easy mounting and dismounting are required, or if the bearing must be able to be displaced axially without restraint.

The appropriate fit is always determined by the operating conditions.

1. Type and magnitude of the load

The degree of interference must suit the type and magnitude of the load, i.e. the heavier the load and the stronger the shock loads, the tighter the interference required (→ **fig. 1**).

- Under heavy loads, spherical plain bearings deform elastically, which may affect the interference fit and lead to ring creep.
- The strength of the associated components must be adequate to accommodate the loads and fully support the bearing.
- If the associated components deform, there is a risk that through-hardened bearing rings crack.
- Steel/steel radial spherical plain bearings require a tighter fit than comparable maintenance-free bearings, which have a lower coefficient of friction.

2. Bearing internal clearance

An interference fit on the shaft and in the housing causes the inner ring to expand elastically, and the outer ring to be compressed elastically. This reduces the initial internal clearance in the bearing, prior to operation. The operating clearance (→ **fig. 2**) furthermore takes the load and operating temperature into consideration.

The initial radial internal clearance of bearings differs, depending on the type and size of the bearing. The clearance has been selected so that if the recommended tolerances for the shaft and housing seats are applied, an appropriate operating clearance (or preload) remains in the bearing under normal operating conditions.

If a tight interference fit is used for both bearing rings, or if the operating temperatures are unusual, it may be necessary to use a larger initial internal clearance than “Normal” for steel/steel bearings.

3. Temperature conditions

In operation, the bearing rings normally have a higher temperature than their seats. This means that

- the inner ring fit gets loosen (→ **fig. 3**)
- the outer ring fit becomes tighter and may restrict any required axial displacement in the housing.

If there is a considerable temperature difference between the inner ring and outer ring, there is a change in the operating clearance. This condition must be considered when selecting the fit or the bearing could seize, making it difficult or impossible for the shaft to turn.

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Fig. 1

For heavier loads a tighter interference fit is needed

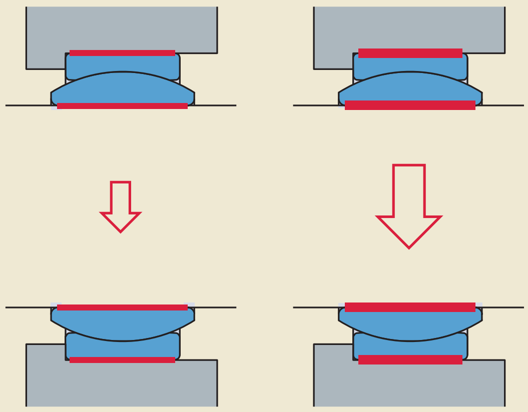


Fig. 2

Reduction of the clearance in the bearing

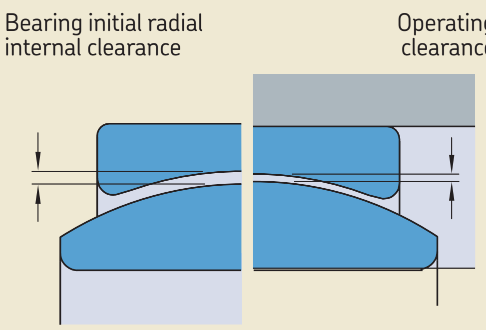
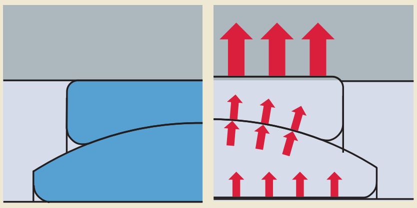


Fig. 3

Change to the fit with temperature

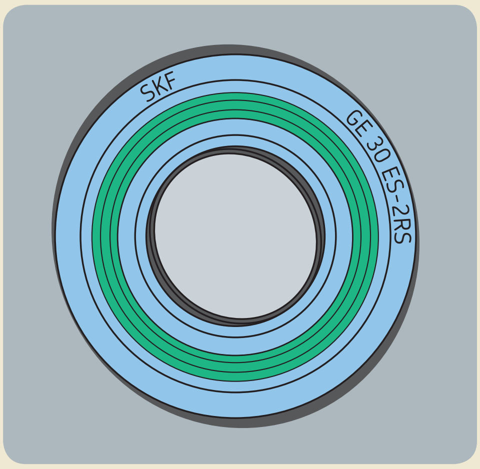


4. Design of associated components
The bearing seats on the shaft and in the housing must not lead to uneven distortion (out-of-round) of the bearing rings (→ **fig. 4**). Therefore:

- Split housings are not suitable for interference fits.
- Thin-walled housings, light alloy housings and hollow shafts require a tighter fit than thick-walled steel or cast iron housings and solid shafts – and must have sufficient strength.
- Heavy loads and interference fits require thick-walled one-piece steel or cast iron housings and solid steel shafts.

Fig. 4

Out-of-round bearing seat



5. Axial displacement of non-locating bearings
A non-locating bearing provides radial support only and must always be able to be displaced axially (→ **fig. 5**). This is normally achieved by selecting a loose fit for one of the bearing rings, generally the inner ring of a spherical plain bearing. Reasons include the following:

- The shaft seat can be easily and economically hardened and ground to facilitate axial displacement. The hardness of the shaft should be at least 50 HRC.
- The outer rings of most spherical plain bearings are axially fractured at one or two positions, or are radially split. This can make axial displacement difficult, if not impossible.
- The housing bore should be protected against wear.

Surface finish of seats
The recommended surface roughness for bearing seats is in accordance with ISO 4288:1997.

- for shaft seats $R_z \leq 10$ µm
- for housing bore seats $R_z \leq 16$ µm

Recommended fits
Only a limited number of ISO tolerance classes are appropriate for spherical plain bearings. **Fig. 6** shows schematically the relative positions of these in relation to the bore and outside diameter of the bearings. The recommended tolerance classes for

- the shaft seat are provided in **table 1**
- the housing bore are provided in **table 2**

These recommendations are based on the considerations described above and have been confirmed in a wide variety of bearing applications. The ISO tolerance limits are listed in

- **table 3** on **page 74** for shafts
- **table 4** on **page 74** for housing bores

To facilitate the calculation of the minimum and maximum values of the theoretical interference or clearance, the standardized bearing bore diameter deviations (Δ_{dmp}) and the bearing outside diameter deviations (Δ_{Dmp}) are listed in **tables 3** and **4**.

Fig. 5

Axial displacement

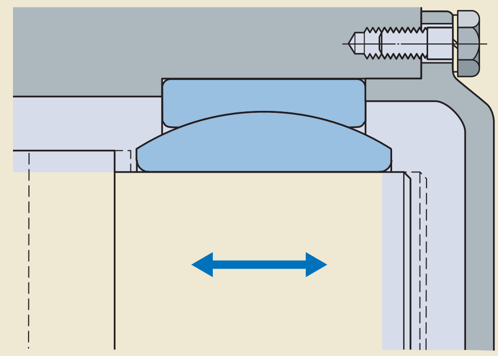


Fig. 6

ISO shaft and housing tolerance classes

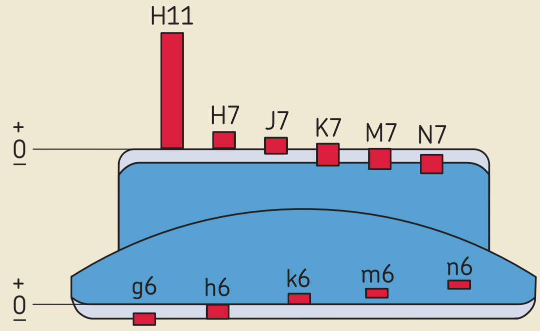


Table 1

Shaft fits

Operating conditions	Tolerance classes Sliding contact surface combination steel/steel and steel/bronze	 steel/PTFE sintered bronze, steel/PTFE fabric and steel/PTFE FRP
Radial spherical plain bearings		
Loads of all kinds, interference fit	m6 (n6)[1)]	k6
Loads of all kinds, clearance or transition fit	h6 (hardened shaft)	h6 or g6 (hardened shaft)
Angular contact spherical plain bearings		
Loads of all kinds, interference fit	m6 (n6)	m6
Thrust spherical plain bearings		
Loads of all kinds, interference fit	m6 (n6)	m6

The tolerance classes in brackets should be selected for very heavily loaded bearings. If selected, be sure that the residual operating clearance is sufficient for proper performance of the bearing or whether a bearing with larger clearance must be used.

[1)] These recommendations do not apply to bearings in the GEG series, which have a bore diameter tolerance class to H7 and are normally mounted on shaft seats machined to tolerance class m7. If, for mounting reasons, the shaft is machined to tolerance class f7, it should be hardened as movements of the shaft relative to the bearing bore take place and wear may result.

Table 2

Housing fits

Operating conditions	Tolerance classes Sliding contact surface combination steel/steel	 steel/PTFE sintered bronze, steel/PTFE fabric and steel/PTFE FRP
Radial spherical plain bearings		
Light loads, axial displacement required	H7	H7
Heavy loads	M7 (N7)	K7
Light alloy housings	N7	M7
Angular contact spherical plain bearings		
Loads of all kinds, interference fit	M7 (N7)	M7
Loads of all kinds, can generally be displaced axially	J7	J7
Thrust spherical plain bearings		
Purely axial loads	H11	H11
Combined loads	J7	J7

The tolerance classes in brackets should be selected for very heavily loaded bearings. If selected, be sure that the residual operating clearance of the radial bearing is sufficient for proper performance or whether a bearing with larger clearance must be used.

Table 3

ISO tolerance classes for shafts

Shaft Nominal diameter d over	incl.	**Bearing** Bore diameter tolerance Δ_{dmp} low	high	**Shaft diameter deviations** Tolerance classes g6 high	low	h6 high	low	k6 high	low	m6 high	low	n6 high	low
mm		µm		µm									
3	**6**	–8	0	–4	–12	0	–8	+9	+1	+12	+4	+16	+8
6	**10**	–8	0	–5	–14	0	–9	+10	+1	+15	+6	+19	+10
10	**18**	–8	0	–6	–17	0	–11	+12	+1	+18	+7	+23	+12
18	**30**	–10	0	–7	–20	0	–13	+15	+2	+21	+8	+28	+15
30	**50**	–12	0	–9	–25	0	–16	+18	+2	+25	+9	+33	+17
50	**80**	–15	0	–10	–29	0	–19	+21	+2	+30	+11	+39	+20
80	**120**	–20	0	–12	–34	0	–22	+25	+3	+35	+13	+45	+23
120	**180**	–25	0	–14	–39	0	–25	+28	+3	+40	+15	+52	+27
180	**250**	–30	0	–15	–44	0	–29	+33	+4	+46	+17	+60	+31
250	**315**	–35	0	–17	–49	0	–32	+36	+4	+52	+20	+66	+34
315	**400**	–40	0	–18	–54	0	–36	+40	+4	+57	+21	+73	+37
400	**500**	–45	0	–20	–60	0	–40	+45	+5	+63	+23	+80	+40
500	**630**	–50	0	–22	–66	0	–44	+44	0	+70	+26	+88	+44
630	**800**	–75	0	–24	–74	0	–50	+50	0	+80	+30	+100	+50
800	**1 000**	–100	0	–26	–82	0	–56	+56	0	+90	+34	+112	+56
1 000	**1 250**	–125	0	–28	–94	0	–66	+66	0	+106	+40	+132	+66

Table 4

ISO tolerance classes for housings

Housing Nominal bore diameter d over	incl.	**Bearing** Outside diameter tolerance Δ_{Dmp} high	low	**Housing bore diameter deviations** Tolerance classes H11 low	high	H7 low	high	J7 low	high	K7 low	high	M7 low	high	N7 low	high
mm		µm		µm											
10	**18**	0	–8	0	+110	0	+18	–8	+10	–12	+6	–18	0	–23	–5
18	**30**	0	–9	0	+130	0	+21	–9	+12	–15	+6	–21	0	–28	–7
30	**50**	0	–11	0	+160	0	+25	–11	+14	–18	+7	–25	0	–33	–8
50	**80**	0	–13	0	+190	0	+30	–12	+18	–21	+9	–30	0	–39	–9
80	**120**	0	–15	0	+220	0	+35	–13	+22	–25	+10	–35	0	–45	–10
120	**150**	0	–18	0	+250	0	+40	–14	+26	–28	+12	–40	0	–52	–12
150	**180**	0	–25	0	+250	0	+40	–14	+26	–28	+12	–40	0	–52	–12
180	**250**	0	–30	0	+290	0	+46	–16	+30	–33	+13	–46	0	–60	–14
250	**315**	0	–35	0	+320	0	+52	–16	+36	–36	+16	–52	0	–66	–14
315	**400**	0	–40	0	+360	0	+57	–18	+39	–40	+17	–57	0	–73	–16
400	**500**	0	–45	0	+400	0	+63	–20	+43	–45	+18	–63	0	–80	–17
500	**630**	0	–50	0	+440	0	+70	–	–	–70	0	–96	–26	–114	–44
630	**800**	0	–75	0	+500	0	+80	–	–	–80	0	–110	–30	–130	–50
800	**1 000**	0	–100	0	+560	0	+90	–	–	–90	0	–124	–34	–146	–56
1 000	**1 250**	0	–125	0	+660	0	+105	–	–	–105	0	–145	–40	–171	–66
1 250	**1 600**	0	–160	0	+780	0	+125	–	–	–125	0	–173	–48	–203	–78
1 600	**2 000**	0	–200	0	+920	0	+150	–	–	–150	0	–208	–58	–242	–92

Axial location of bearings

Locating bearings

An interference fit alone is not sufficient to axially locate a bearing ring. It is usually necessary to use a suitable locking device to secure the ring in place.

Both rings of a locating bearing should be located axially on both sides. The bearing rings generally have an interference fit and are usually supported on one side by a shaft or housing shoulder. Inner rings are axially secured on the opposite end by

- a plate bolted to the shaft end (→ **fig. 7**)
- a spacer sleeve between the ring and a neighbouring machine component (→ **fig. 8**)
- a retaining ring (circlip)

Outer rings are generally retained by the cover of the housing bore (→ **figs. 7** and **8**).

Non-locating bearings

For non-locating bearings, the outer ring (which normally has a tight fit) is axially located while the inner ring is free to move axially on the shaft (→ **fig. 5** on **page 72**).

Note that for bearings in the GEP series (→ **fig. 9**), which have a radially split outer ring, expansion forces are produced under purely radial load; the axial components of these forces act on the housing cover. The axial load acting on the cover may be as much as 30% of the radial load. This must be taken into account when

Fig. 7

Using an end plate and cover to locate a bearing axially

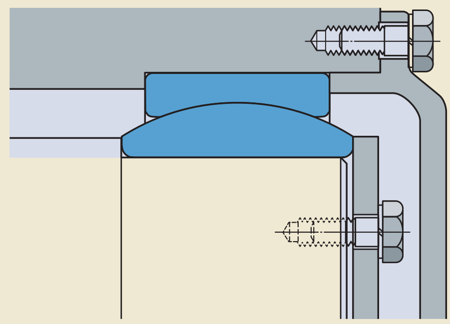


Fig. 8

Using a spacer sleeve and cover to locate a bearing axially

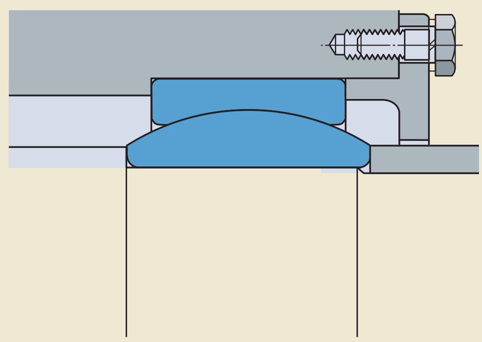
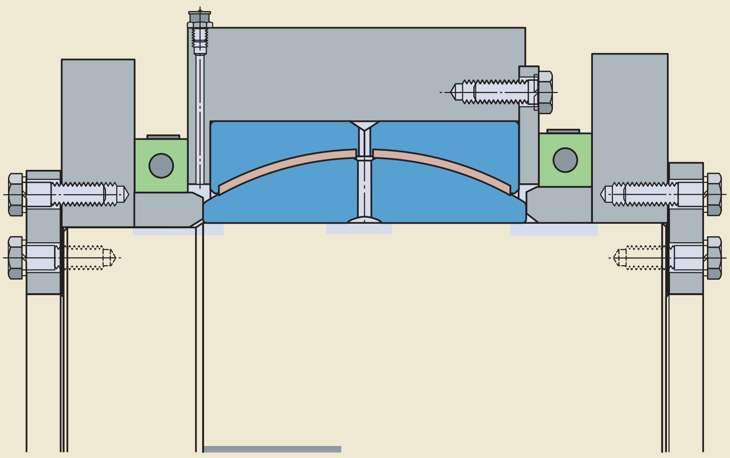


Fig. 9

Locating a radial spherical plain bearing having a radially split outer ring



dimensioning the housing cover and selecting the size and number of the attachment bolts.

If shaft and/or housing shoulders are undesirable because of manufacturing or assembly considerations, spacer sleeves or rings can be inserted between a bearing ring and an adjacent machine component (→ **figs. 10** and **11**).

Axially locating a non-separable bearing with locating rings (→ **figs. 10** and **11**) saves space, enables quick mounting and dismounting and simplifies the machining of the seats. If larger axial forces have to be accommodated, a support ring (→ **fig. 11**) should be placed between the bearing ring and the locating ring, so that the locating ring is not subjected to excessive bending moments.

To locate the bearing, retaining rings (also known as circlips) with a constant radial width in accordance with DIN 471:1981 or DIN 472:1981 can be used.

Fig. 10

Locating a bearing axially, using retaining rings in the housing and adjacent components on the shaft

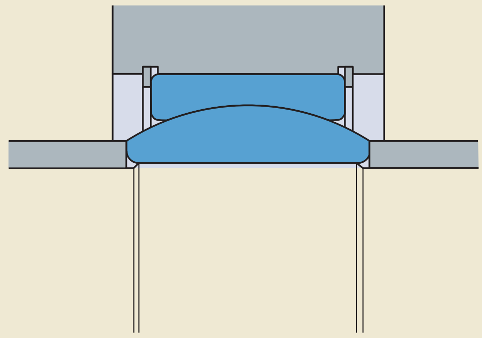


Fig. 11

Locating a bearing axially, using adjacent components in the housing and a support ring and a retaining ring on the shaft

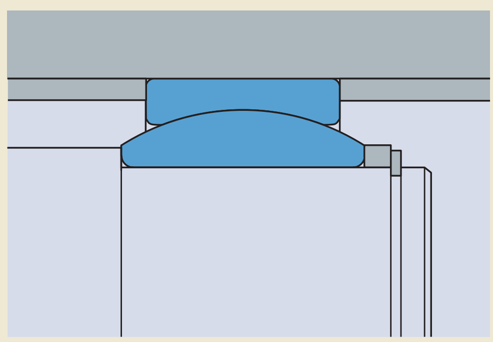


Fig. 12

Shaft and housing abutment dimensions

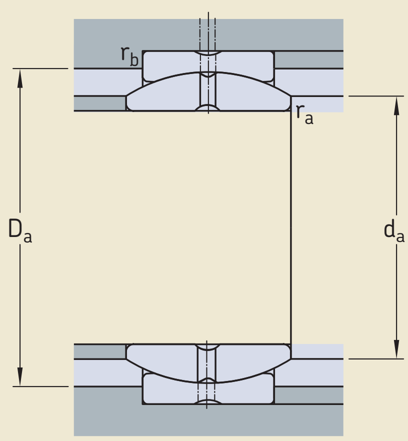


Fig. 13

Shaft and housing fillet dimensions, no undercut

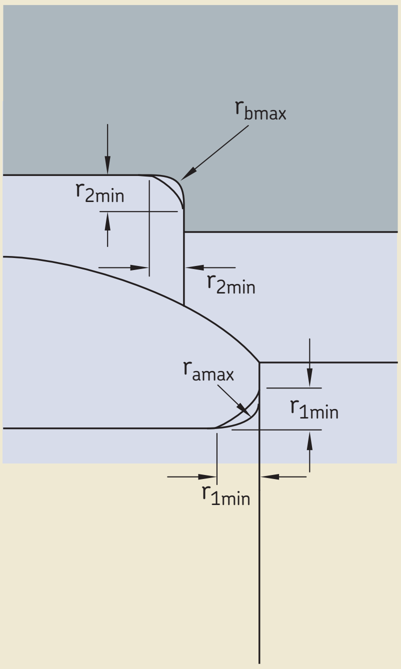
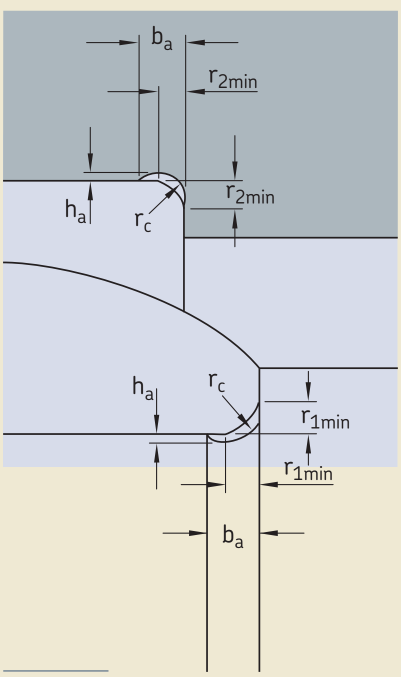


Fig. 14

Shaft and housing fillet dimensions, with an undercut



Abutment and fillet dimensions

The abutment and fillet dimensions should be such that:

- A sufficiently large support surface is available for the bearing ring.
- Moving parts of the bearing arrangement cannot contact stationary components.
- The fillet radius should be smaller than the chamfer of the bearing.

Appropriate abutment dimensions (→ **fig. 12**) are provided for each bearing in the product tables. The transition from the bearing seat to the shaft or housing shoulder can be either a simple fillet (→ **fig. 13**) or an undercut (→ **fig. 14**). Dimensions for r_{amax} and r_{bmax} are listed in the product tables.

Dimensions for undercuts are provided in **table 5**.

The larger the fillet radius (for the simple form) of the transition to the shaft shoulder, the more favourable is the stress distribution in the shaft fillet area.

Table 5

Undercut dimensions

Chamfer dimensions r_{1min}, r_{2min}	Fillet dimensions b_a	h_a	r_c
mm	mm		
1	2	0,2	1,3
1,1	2,4	0,3	1,5
1,5	3,2	0,4	2
2	4	0,5	2,5
2,5	4	0,5	2,5
3	4,7	0,5	3
4	5,9	0,5	4
5	7,4	0,6	4
6	8,6	0,6	6
7,5	10	0,6	7

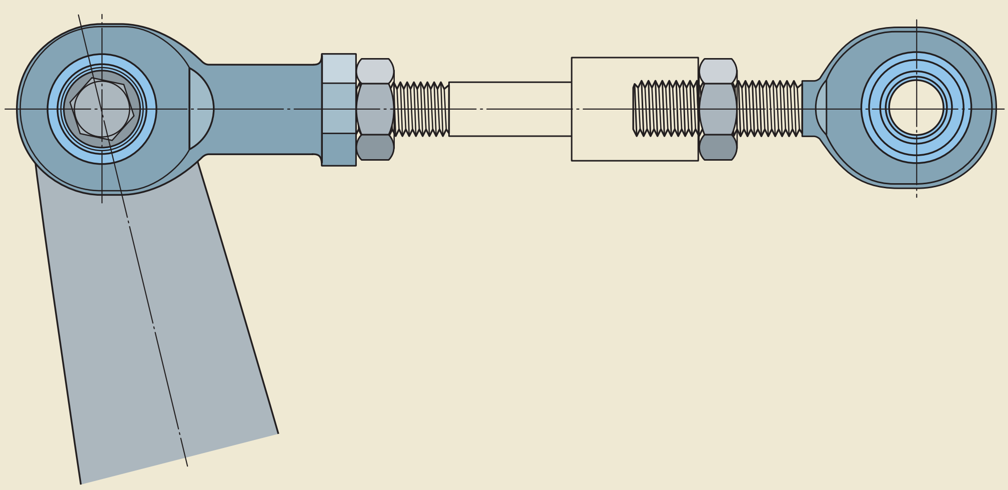
Location of rod ends

The inner rings of rod ends can be axially located by a shaft shoulder, a nut or a retaining ring.

Rod ends mounted on threaded rods or in extension tubes should be secured by an extra nut on the rod or the external thread of the rod end shank. The nut should be securely tightened against the support surface on the rod end housing or on the tube (→ **fig. 15**).

Fig. 15

Attachment of rod ends



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Sealing

Most bearing arrangements must be sealed to prevent contaminants, such as dirt and moisture, from entering the bearing. The efficiency of the seal has a decisive influence on the service life of the bearing. In contrast to most other bearing types, which only move in one plane, the alignment capabilities of spherical plain bearings place additional demands on the seal.

To select appropriate seals, several factors have to be considered, including:

- the permissible angle of tilt
- the available space
- environmental conditions
- the effectiveness of the seal
- the type of lubricant and the frequency of relubrication
- the justifiable cost

Depending on the application, one or more of the above factors outweigh the others. It is therefore not possible to establish general rules for seal design.

Most SKF radial spherical plain bearing series are available with integral seals. Standard sealed bearings can increase the service life of the bearings and save space, while reducing inventory and assembly costs. Design characteristics and suitability of the RS seals and the LS heavy-duty seals are provided in **table 6**.

Table 7 on **pages 80** to **81**, provides an overview of external sealing possibilities, their design characteristics and their suitability to meet different application requirements. SKF supplies most of the external seals introduced in **table 7**.

NOTE: SKF additional information about the seals referred to in **table 7** on **pages 80** to **81**, refer to the *SKF Interactive Engineering Catalogue*, available online at www.skf.com.

SKF also supplies sealing strips made of felt (FS strips) or aluminium-boron silicate (FSB strips) for high temperature applications.

Table 6

SKF integral seals for spherical plain bearings

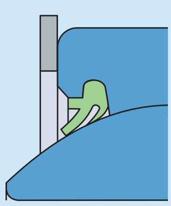
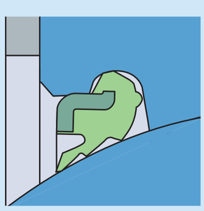
Seal	Illustration	Design characteristics	Suitability
RS design		Double-lip contact seal made of • polyester elastomer for metric bearings with a bore diameter d < 320 mm (–30 to +130 °C) • acrylonitrile-butadiene rubber for metric bearings with a bore diameter d ≥ 320 mm (–35 to +100 °C) • polyurethane for inch bearings (–20 to +80 °C)	• for compact bearing arrangements, mainly indoors • for cramped spaces • for high sealing demands when combined with an outboard seal • for long service life with minimal maintenance • for arrangements with bearings that rotate
LS design		Triple-lip heavy-duty contact seal made of acrylonitrile-butadiene rubber with sheet steel insert (–55 to +110 °C, for short periods up to +125 °C)	• for compact bearing arrangements • for high sealing demands • for long service life with minimal maintenance • for arrangements with bearings that rotate • for difficult operating conditions in the presence of sand or mud

Table 7

External seals for spherical plain bearings

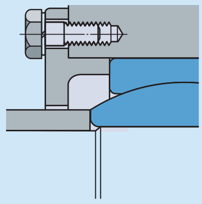
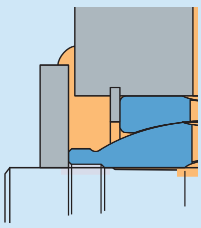
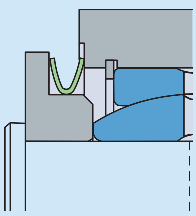
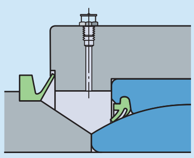
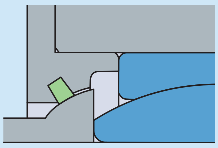
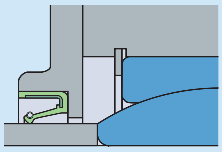
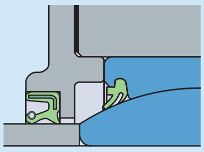
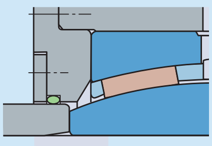
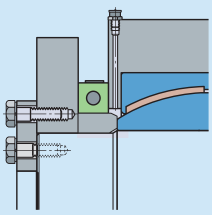
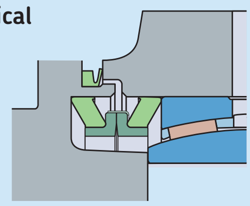
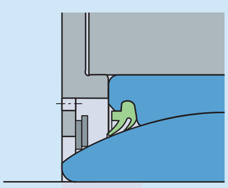
Seal	Illustration	Design characteristics	Suitability
Gap-type		Simple and economic, no wear, simple mounting	• for maintenance-free bearings • for small angles of tilt • for high temperatures • for moderately dusty environments • for arrangements with bearings that rotate
Gap-type with grease		Simple and efficient with periodic relubrication	• for bearings and rod ends requiring maintenance • for small angles of tilt • for rough conditions in the presence of sand, clay, slush etc.
V-shaped		Simple, lightly preloaded seal made of polyurethane (–40 to +100 °C) Good wear strength and resistance to grease, oil and other environmental influences	• for contaminant exclusion • for angles of tilt up to 2° • for bearing arrangements with shaft diameters up to 300 mm • for arrangements with bearings that rotate
V-ring		Elastic seal that sits on the shaft and turns with it, axial sealing lip made of acrylonitrile-butadiene rubber (–40 to +100 °C) or fluoro rubber (–40 to +200 °C) Good wear and chemical resistance	• for contaminant exclusion • for maintenance-free and grease-lubricated bearings • for all shaft diameters • for angles of tilt between 2 and 4°, depending on size • for arrangements with bearings that rotate
Felt		Simple to install, good resistance to grease (–40 to +100 °C)	• for dust and minor dampness exclusion • for grease retention • for large angles of tilt • for all bearing sizes • for arrangements with bearings that rotate
Radial shaft		Steel reinforced (either externally or internally) elastomer with a acrylonitrile-butadiene rubber lip (–40 to +100 °C) or fluoro rubber lip (–40 to +200 °C) Good wear resistance, good resistance to grease, oil and other environmental influences	• for contaminant exclusion • for grease retention • for oil retention • for small angles of tilt • for all bearing sizes • for arrangements with bearings that rotate

Table 7

External seals for spherical plain bearings

Seal	Illustration	Design characteristics	Suitability
Radial shaft with an auxiliary dust lip		Steel reinforced (either externally or internally) elastomer with an acrylonitrile-butadiene rubber lip (–40 to +100 °C) or fluoro rubber lip (–40 to +200 °C) Good wear resistance, good resistance to grease, oil and other environmental influences	• for highly contaminated environments • for oil retention • for small angles of tilt • for bearings with a bore diameter d up to approx. 300 mm • for arrangements with bearings that rotate
O-ring		Acrylonitrile-butadiene rubber (–40 to +100 °C) or fluoro rubber (–40 to +200 °C)	• for reliable moisture exclusion • for oil and grease retention • for very small angles of tilt • for slow oscillating movements
Profiled rubber with clamp and lock		Elastomer strip (–40 to +100 °C) Good wear resistance, good resistance to grease, oil and other environmental influences	• for hermetically sealed bearing arrangements • for slow oscillating movements. Initial oiling or greasing of faces reduces friction • for small angles of tilt
Mechanical seals		Stainless steel rings and cup springs of acrylonitrile-butadiene rubber (–40 to +100 °C) Good wear resistance, good resistance to grease, oil and other environmental influences	• for contaminant exclusion • for oil and grease retention • for small angles of tilt • for arrangements with bearings that rotate
Spring steel washers		Set of washers for high temperatures. Excellent wear resistance, good chemical resistance	• for contaminant exclusion • grease exit vents needed in housing cover if grease used • for small angles of tilt • for arrangements with bearings that rotate

WARNING!
Some of the external seals listed in this table can be made of fluoro rubber. Note that fluoro rubber gives off dangerous fumes at temperatures above 300 °C and can be hazardous if touched. As handling seals made of fluoro rubber constitutes a potential safety risk, the safety precautions must always be followed. For detailed information about the safety precautions, refer to the *SKF Interactive Engineering Catalogue*, available online at www.skf.com, the *SKF General Catalogue* or the publication *Industrial shaft seals*.

Designing a bearing arrangement for easy mounting and dismounting

To facilitate mounting, the shaft ends and housing bores should have a 10 to 20 degree lead-in chamfer (→ **fig. 16**). This is particularly important for applications using larger bearings, as the rings may skew, causing damage to the mating surfaces.

To facilitate the use of withdrawal tools when removing bearings, it can be advantageous to:

- provide recesses in the shaft shoulder (→ **fig. 17**)
- provide recesses or threaded holes in the housing bore (→ **fig. 18**)

To dismount larger maintenance-free bearings with a bore diameter d ≥ 80 mm that have a tight shaft fit, SKF recommends using the oil injection method. With the oil injection method, oil under high pressure is injected between the bearing inner ring and its shaft seat to form an oil film. This oil film separates the mating surfaces, greatly reducing the force required to dismount the bearing and virtually eliminating any risk of damage to the bearing or shaft.

To use the oil injection method, there must be an oil supply duct in the shaft as well as an oil distribution groove in the seat (→ **fig. 19**). As a general rule, the distance between the groove and the bearing side face from which mounting and dismounting are to be performed should be approximately one third of the seat width (→ **fig. 19**). Recommended dimensions for the ducts and grooves as well as for the threads for the oil supply connection are provided in **tables 8** and **9**.

Fig. 16

Chamfering shaft ends and housing bore entrances

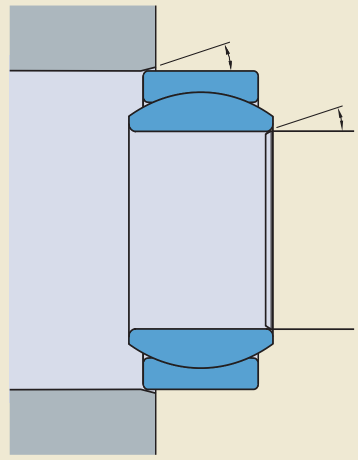


Fig. 17

Shaft shoulder with a recess

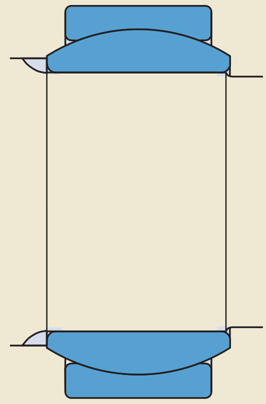
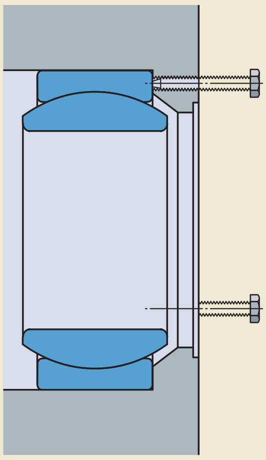


Fig. 18

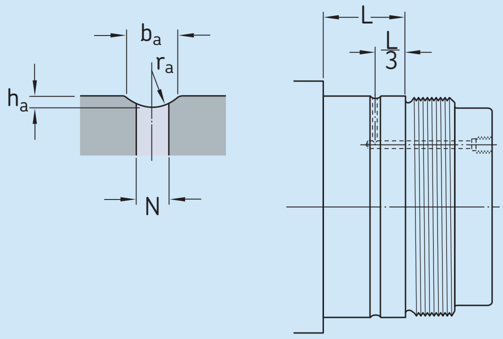
Housing shoulder with threaded holes



SKF

Table 8

Recommended dimensions for oil supply ducts and distribution grooves

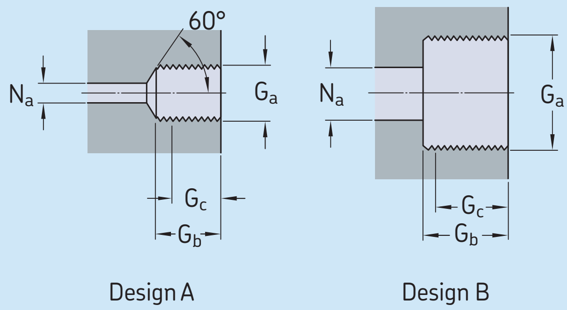


Bearing seat diameter over	incl.	Dimensions b_a	h_a	r_a	N
mm		mm			
–	100	3	0,5	2,5	2,5
100	150	4	0,8	3	3
150	200	4	0,8	3	3
200	250	5	1	4	4
250	300	5	1	4	4
300	400	6	1,25	4,5	5
400	500	7	1,5	5	5
500	650	8	1,5	6	6
650	800	10	2	7	7
800	1 000	12	2,5	8	8

L = width of bearing seat.

Table 9

Design and recommended dimensions for threaded holes for connecting oil supply

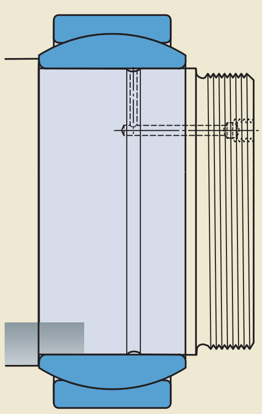


Thread G_a	Design	Dimensions G_b	G_c[1]	N_a max
–		mm		
M6	A	10	8	3
G 1/8	A	12	10	3
G 1/4	A	15	12	5
G 3/8	B	15	12	8
G 1/2	B	18	14	8
G 3/4	B	20	16	8

[1] Effective threaded length.

Fig. 19

Shaft with oil ducts and a distribution groove to facilitate dismounting



Lubrication

The SKF traffic light concept

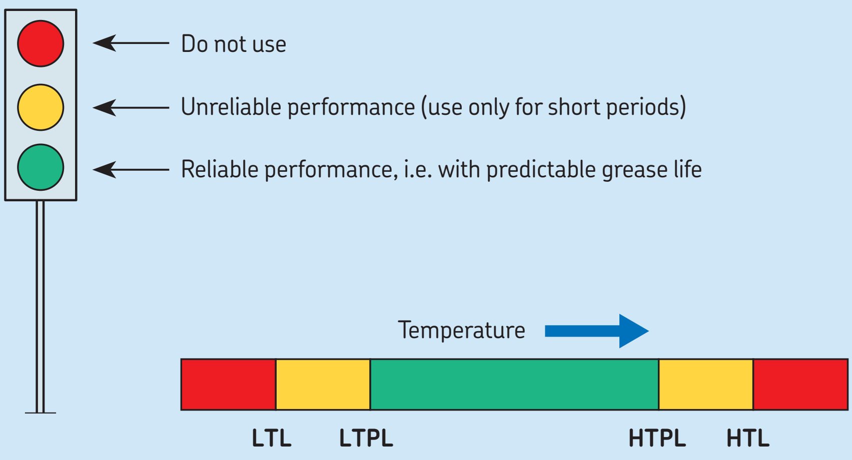
Most grease suppliers indicate the specific values for the low and high temperature limits in their product information. The SKF traffic light concept is distinctly different from that. SKF recognizes that the really important temperatures for reliable operation lie within a smaller range. This range depends largely on the type of base oil and thickener used as well as the additives. The relevant temperatures are given by the SKF traffic light concept. They are schematically illustrated in **diagrams 1** and **2** in the form of a double traffic light.

It is evident that grease in the red zones should not be applied at all, as damage may occur. Within the green zone the grease functions reliably, and the grease life can be determined accurately.

At temperatures in the amber zone above the high temperature performance limit (HTPL), grease ages and oxidize with increasing rapidity and the by-products of the oxidation have a detrimental effect on lubrication. An amber zone also exists for low temperatures. Short periods in this zone, e.g. during a cold start, are not harmful since the heat caused by friction brings the bearing temperature into the green zone.

Diagram 1

The SKF traffic light concept – general



LTL – Low temperature limit
This limit indicates the lowest temperature at which the grease allows the bearing to be started up without difficulty.

LTPL – Low temperature performance limit
Below this limit, the supply of grease to the contact surfaces becomes insufficient.

HTPL – High temperature performance limit
Above this limit, the grease ages and oxidize in an uncontrolled way, so that grease life cannot be determined accurately.

HTL – High temperature limit
When exceeding this limit, the grease loses its structure permanently.

Diagram 2

The SKF traffic light concept – temperature limits for SKF greases when used in spherical plain bearings requiring maintenance

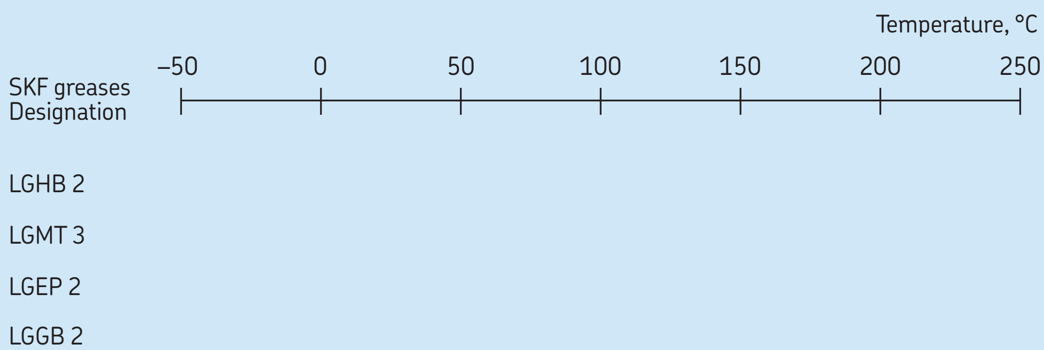


Fig. 1

Relubricating the bearing via the outer ring

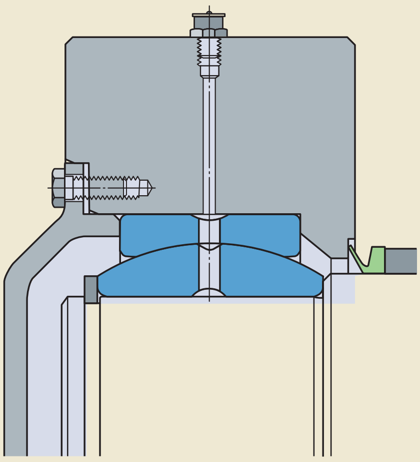


Fig. 2

Relubricating the bearing via the inner ring

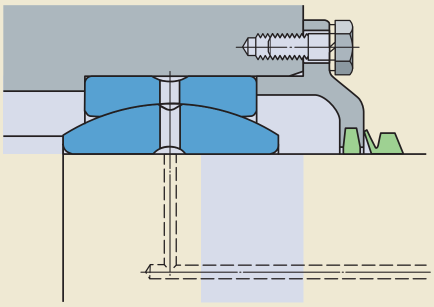
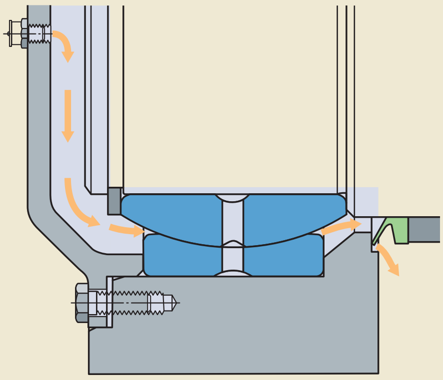


Fig. 3

Relubricating the bearing from the side



Spherical plain bearings requiring maintenance

Steel/steel radial spherical plain bearings must be relubricated to:

- reduce friction
- reduce wear
- extend bearing service life
- protect against corrosion and contaminants

The sliding contact surfaces are phosphated and treated with a “running-in” lubricant. This special surface treatment has a favourable influence during the running-in phase. The bearings must be greased prior to use and relubricated on a regular basis.

To reliably relubricate the bearings, grease ducts should be provided in the housing (→ **fig. 1**) or shaft (→ **fig. 2**) so that fresh grease can be supplied directly to the bearing. All SKF steel/steel radial spherical plain bearings (with the exception of the smallest E and ESA design bearings) have an annular groove and lubrication holes in both the inner and outer rings to facilitate lubricant distribution to the sliding surfaces of the bearing.

If the arrangement is appropriately designed, the bearing can also be supplied with grease from the side. To facilitate the passing of grease through the bearing, the grease should be prevented from exiting the bearing arrangement from the side it is supplied, e.g. by an end cover, and to provide an opening for the grease to exit on the opposite side, e.g. a V-ring seal that can open if there is pressure from the inside (→ **fig. 3**).

Generally, where possible, the free space surrounding the bearing should be filled with grease.

SKF recommends using SKF LGHB 2 grease to lubricate steel/steel spherical plain bearings. Its properties include:

- excellent performance under heavy loads
- very good rust inhibitor
- very good resistance to ageing
- good water resistance
- a wide operating temperature range.

If operating temperatures exceed the temperature range limits, special grease should be used (→ **table 1**).

For additional information, contact the SKF application engineering service.

Table 1

SKF grease recommendations

Property	**SKF greases** (designation) **LGHB 2**	**LGMT 3**	**LGEP 2**	**LGGB 2**1)
	for sliding contact surface combinations steel/steel	steel/bronze	steel/PTFE FRP	steel/PTFE FRP
Thickener	Calcium sulphonate complex soap	Lithium soap	Lithium soap	Lithium/calcium soap
Base oil	Mineral oil	Mineral oil	Mineral oil	Ester oil
Colour	Brown	Yellowish brown	Light brown	White
Temperature range2), °C LTL to HTPL	–20 to +150	–30 to +120	–20 to +110	–40 to +120
Kinematic viscosity of base oil, mm^2/s at +40 °C	400 to 450	120 to 130	200	110
at +100 °C	26,5	12	16	13
Consistency (to NLGI Scale)	2	3	2	2

1) Grease biologically degradable, for use in applications where strict ecological demands must be met and where lubrication cannot be dispensed with.
2) Refer to the SKF traffic light concept, starting on **page 84**.

Maintenance-free spherical plain bearings

Steel/PTFE sintered bronze and steel/ PTFE fabric sliding contact surface combinations

During operation, PTFE is transferred from the dry sliding contact surface of the outer ring to the hard chromium plated steel surface of the inner ring. Any external lubricant on the sliding contact surfaces would disturb this self-lubrication and shorten bearing service life.

As a result, these bearings must not be lubricated and do not have any relubrication facility.

Steel/PTFE FRP sliding contact surface combination

Bearings with this sliding contact surface combination are also self-lubricating and can be operated grease-free.

However, initial lubrication followed by occasional relubrication of steel/PTFE FRP bearings can extend the service life of the bearing by a factor of two or more. The inner rings of radial bearings or shaft washers of angular contact and thrust bearings are coated with a lithium base grease before leaving the factory.

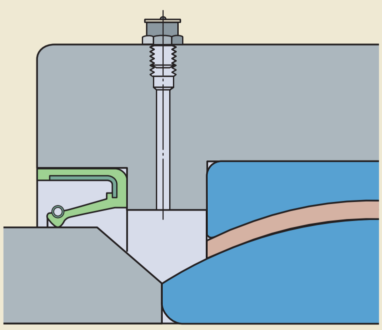
If operating conditions are such that protection against corrosion and enhanced sealing are required, the free space surrounding the bearing (→ **fig. 4**) can be filled with the same grease that was used to lubricate the bearing. The appropriate time to replenish or renew the grease in the bearing arrangement is determined by the operating conditions and the ageing of the grease.

Rust inhibiting, water-repellent lithium base greases with a consistency of 2 on the NGLI scale should be used. SKF recommends SKF LGEP 2 grease (→ **table 1** on **page 87**). Greases containing molybdenum disulphide or other solid lubricants should never be used.

CAUTION: Depending on their design, SKF spherical plain bearings are either completely or partially coated with an oily preservative or filled with grease. Avoid skin contact as these substances may cause skin irritation or an allergic reaction.

Fig. 4

Relubricating the bearing from the side



Rod ends requiring maintenance

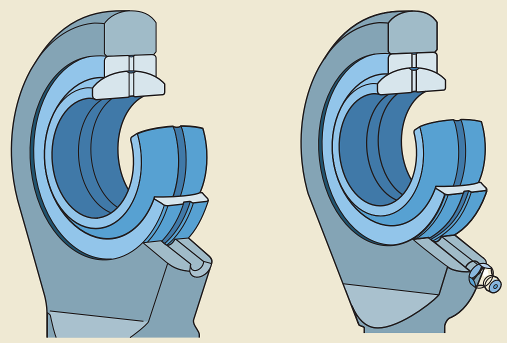
Steel/steel and steel/bronze rod ends require lubrication. To facilitate this:

- All SKF steel/steel rod ends, with the exception of small-sized E and ESA design rod ends, can be relubricated via a lubrication hole or grease fitting in the rod end housing as well as via the pin and the inner ring (→ **fig. 5**).
- All SKF steel/bronze rod ends can be relubricated via a lubrication hole or grease fitting in the rod end housing (→ **fig. 6**).

The general recommendations for steel/steel radial spherical plain bearings also apply to steel/steel rod ends as well as steel/bronze rod ends.
For steel/bronze rod ends in the SIKAC .. M and SAKAC .. M series, SKF recommends SKF LGMT 3 grease (→ **table 1** on **page 87**). Lithium based greases with a normal consistency without solid lubricant additives can also be used.

Fig. 5

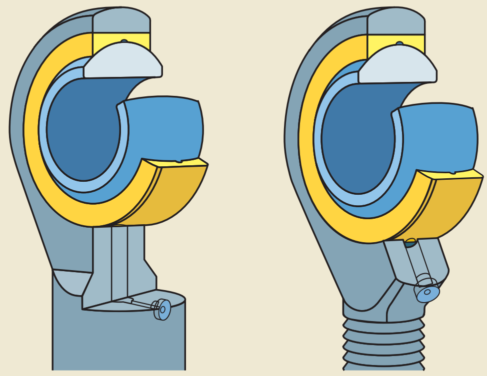
Relubrication facilities for steel/steel rod ends



Lubrication hole   Grease fitting

Fig. 6

Relubrication facilities for steel/bronze rod ends (sizes 6 and larger)



SIKAC .. M series   SAKAC .. M series

Maintenance-free rod ends

Maintenance-free, self-lubricating rod ends are designed to be used as dry sliding bearings and must not be lubricated. Consequently, these rod ends do not have a relubrication facility in their housings.

Steel/PTFE FRP rod ends are an exception. They can be used without additional lubricant, but their service life can be extended appreciably if they are lubricated prior to use.

CAUTION: Depending on their design, SKF rod ends are either completely or partially coated with an oily preservative or filled with grease. Avoid skin contact as these substances may cause skin irritation or an allergic reaction.

Relubrication

To maximize the service life of spherical plain bearings and rod ends requiring maintenance, they must be relubricated on a regular basis. This also applies to maintenance-free bearings with a steel/PTFE FRP sliding contact surface. Used grease containing wear debris and contaminants should be removed from the contact zone and replaced with fresh grease.

Determining the proper relubrication interval is extremely important because the attainable service life depends on several factors including:

- the magnitude of the load
- the type of load
- the angle of oscillation
- the frequency of oscillation
- the operating temperature
- the sealing arrangement
- other environmental conditions

Long bearing service life can be attained when the following basic relubrication rules are observed:

- the same type of grease is always used (→ **table 1** on **page 87**)
- the lubricant is applied at operating temperature
- the lubricant is applied before a long interruption, e.g. before construction or agricultural equipment is stored

Relubrication of non-locating bearings

Non-locating bearings, where axial displacement takes place along the shaft or pin, should always be relubricated via the shaft and bearing inner ring (→ **fig 2** on **page 86**). By supplying lubricant in this way, grease also enters between the mating surfaces of the inner ring and shaft seat. This reduces friction and induced axial loads when axial displacement occurs.

Storage

SKF spherical plain bearings and rod ends are treated with a preservative before they are packaged. They can, therefore, be stored in their original packages for several years. However, the relative humidity in the storeroom should not exceed 60%.

NOTE: SKF also supplies a comprehensive assortment of greases for various application requirements. For additional information, refer to the catalogue *SKF Maintenance and Lubrication Products* or online at www.mapro.skf.com.

SKF has the appropriate greases for spherical plain bearings and rod ends, including the biologically degradable SKF LGGB 2 grease

Mounting

Skill and cleanliness when mounting are necessary if spherical plain bearings and rod ends are to achieve maximum service life and not fail prematurely.

Bearings and rod ends should only be removed from their packages immediately prior to mounting so that they do not become contaminated. Bearing components that could have become dirty as a result of improper handling or damaged packaging should be wiped clean with a lint-free cloth.

The sliding contact surfaces of spherical plain bearings are matched to provide favourable friction and wear characteristics. Therefore, any alteration of the sliding surfaces can reduce bearing service life. Alterations in this context also include washing or exposing the sliding surfaces to solvents, cleaners, oils or similar media.

All associated components should be clean and free of any burrs. Also make sure to check each associated component for dimensional accuracy before the installation process is started.

Spherical plain bearings

When mounting spherical plain bearings with a fractured or split outer ring, it is essential that the joint is positioned at 90° to the direction of load (→ **fig. 1**), otherwise service life is reduced.

Steel or plastic bands that hold together spherical plain bearing outer rings must not be removed prior to mounting. They are positioned in an annular groove and do not protrude from the outside diameter surface.

Spherical plain bearing outer rings that are axially split and bolted together must be mounted as such, without loosening the bolts.

Mechanical mounting

The following tools are suitable for mounting spherical plain bearings:

- a mounting dolly (→ **fig. 2**) or length of tubing; the ring with an interference fit should generally be mounted first
- a dolly having two abutment surfaces (→ **fig. 3**) for simultaneously mounting the bearing on the shaft and in the housing
- for larger numbers of bearings, suitable tools can be used in combination with a press (→ **fig. 4**)

When mounting spherical plain bearings, consider the following:

- Never use a hammer or pin punch to drive a bearing in place, as either could damage the rings (→ **fig. 5**).
- The mounting force should never be directed through the sliding contact surfaces (→ **fig. 6**). This could damage the sliding contact surfaces and/or expand fractured or split bearing outer rings, which can cause an increase in the mounting force required.

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Fig. 1

Plane of fracture or split and main direction of load

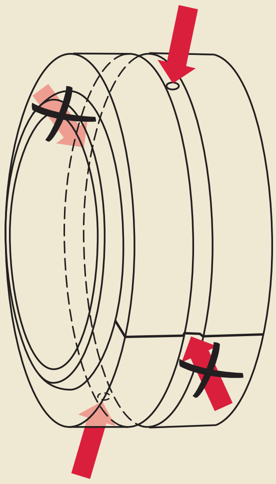


Fig. 2

Mounting with the aid of a dolly

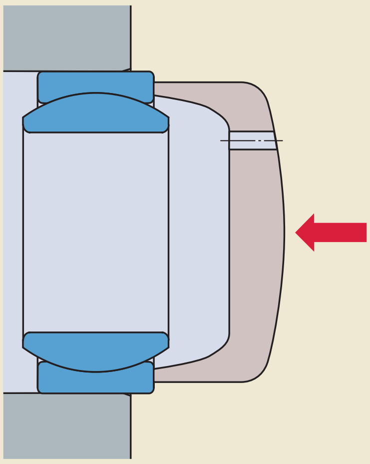


Fig. 3

Simultaneous mounting in the housing and on the shaft

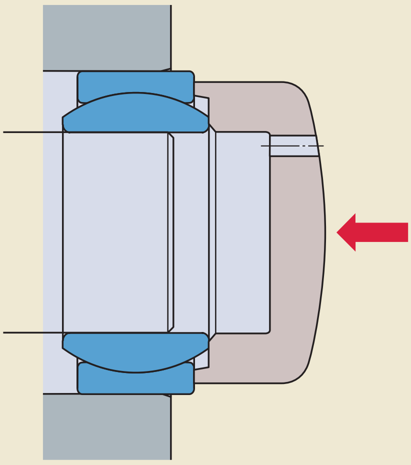


Fig. 4

Mounting using a press

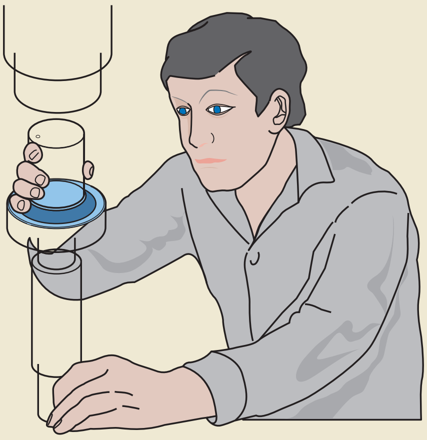


Fig. 5

Never hit the bearing rings directly

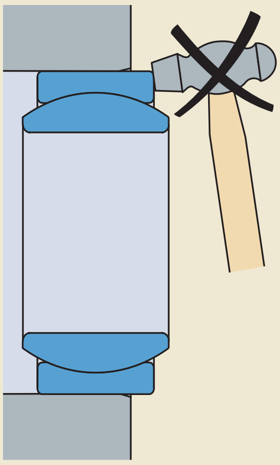
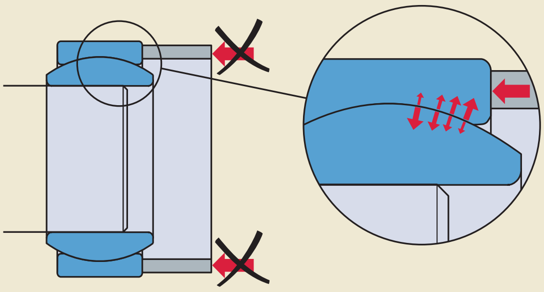


Fig. 6

Never apply the mounting force via the sliding contact surfaces



Hot mounting

As a rule, larger bearings cannot be mounted cold because the force required to press a bearing into position increases considerably with its size. Therefore, SKF recommends the following:

- heat the bearing before it is mounted on the shaft (→ **fig. 7**)
- heat non-split housings before inserting the bearing

To mount a bearing on a shaft, a temperature differential of 60 to 80 °C between ambient temperature and the heated inner ring, is usually sufficient. For housings, the appropriate differential depends on the degree of interference and the seat diameter. However, a moderate increase in temperature is usually sufficient. When heating the bearing, do not exceed the temperature limit of any associated components, such as the seals.

For an even and risk-free heat source, an induction heater should be used. The use of an SKF induction heater has a number of advantages. It heats the bearing rapidly and a built-in thermostat prevents overheating. The non-metallic components, such as the seals or PTFE fabric, remain cold as does the heater itself. SKF induction heaters automatically demagnetize the bearing after it has been heated.

Mounting bearings by cooling the shaft or the bearing is not recommended, as the very low temperatures required inevitably cause condensation, thus creating the risk of corrosion.

To ease the mounting of large bearings, particularly if they have been heated, it is possible to use slings and a hoist. Metal or textile slings placed around the outer ring can be used. A spring between the hoist hook and the sling also facilitates bearing handling (→ **fig. 8**).

Fig. 7

Mounting a heated bearing

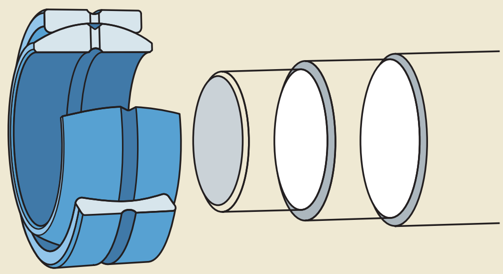
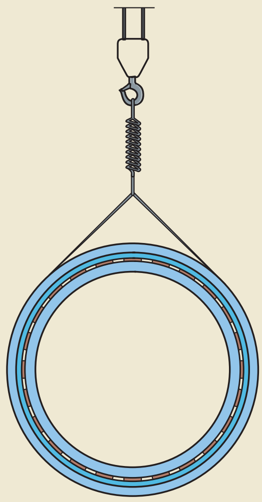


Fig. 8

Mounting a heated large bearing



WARNING!
Maintenance-free spherical plain bearings and rod ends must never be subjected to temperatures in excess of +280 °C due to the PTFE content. PTFE is completely inert below this temperature but at higher temperatures (from approx. 320 °C) it rapidly decomposes. The fluorine compounds released during this process are extremely toxic, even in small quantities, and can cause serious injury. It should also be remembered that the material is dangerous to handle once it has been overheated, even after it has cooled.

Heat-resistant gloves should be worn when handling hot components.

Rod ends

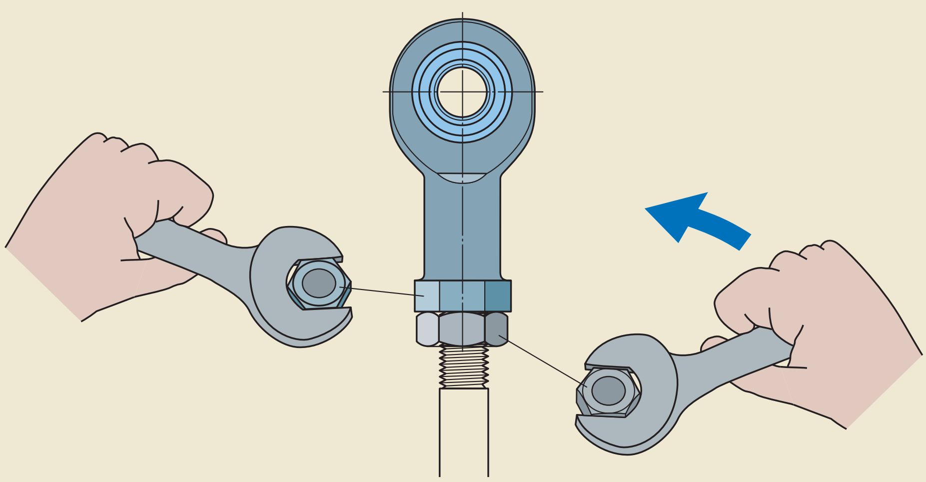
Rod ends are fitted on pins and shafts in the same way as spherical plain bearings. Slight heating reduces the force required for mounting and reduce the risk of damaging associated components.

When attaching rod ends to threaded rods or extension tubes (→ **fig. 9**) a counter lock nut should be used on the rod or on the external thread of the rod end. It should be securely tightened against the abutment surface on the rod end or tube.

NOTE: SKF supplies a comprehensive range of mechanical and hydraulic tools as well as heating equipment for bearing mounting and dismounting. For additional information, refer to the catalogue *SKF Maintenance and Lubrication Products* or online at www.mapro.skf.com.

Fig. 9

Securing a rod end with a right-hand thread



Dismounting

Spherical plain bearings

If bearings are to be re-used after dismounting, the same care and attention are required during dismounting as when mounting. The requisite withdrawal force should always be applied to the ring which is being dismounted.

SKF offers an assortment of different pullers to accommodate many applications. If the shaft is pre-machined to accommodate the arms of a jaw puller, then a two- or three-armed puller can be used (→ **fig. 1**).

In other cases where there is enough space behind the ring, a strong back puller such as the SKF TMBS series can be used (→ **fig. 2**).

For large bearings with an interference fit, dismounting is considerably facilitated if the SKF oil injection method is used (→ **fig. 3**). The oil ducts and distributor grooves should be provided when designing the bearing arrangement (→ **page 82**).

Small bearings can be dismounted using a mounting dolly or a length of tubing applied to the outer ring. For larger bearings with an interference fit, a mechanical or hydraulic press should be used when possible.

It is also possible to dismount a bearing from the housing bore by quickly heating the housing without heating the bearing outer ring to any extent.

Rod ends

To dismount rod ends, the lock nut securing the shank should be loosened and, if possible, the rod end should be unscrewed from its rod or tube. The rod end can then be removed from the pin or shaft in the same way as a bearing, e.g. using a puller or a press.

Fig. 1

Removing a bearing with a jaw puller

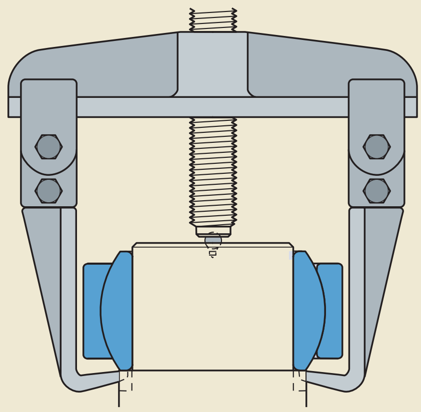


Fig. 2

A strong back puller facilitates dismounting of the inner ring

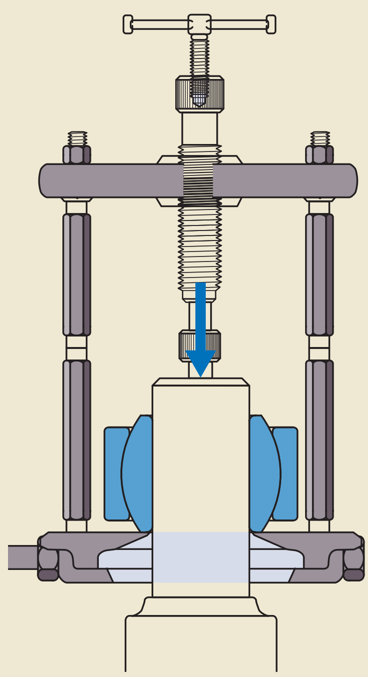
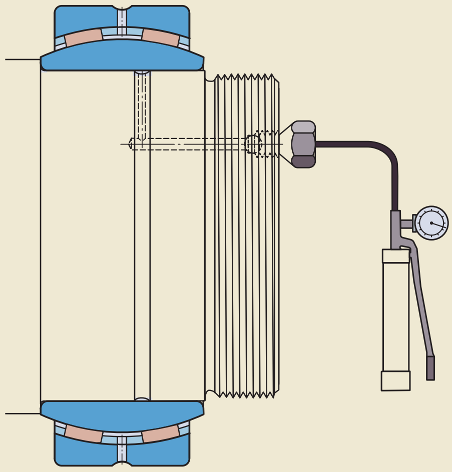


Fig. 3

Dismounting a bearing using the SKF oil injection method

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