Selection of bearing type

Bearing terminology

To better understand frequently used plain bearing and rod end specific terms, definitions are provided in **fig. 1** and **fig. 2**.

Spherical plain bearing
1 Outer ring
2 Sliding contact surfaces
3 Seal
4 Inner ring
5 Lubrication hole
6 Lubrication groove

Rod end
1   Spherical plain bearing
2   Rod end
2a Rod end housing
2b Rod end shank, with an external (male) thread. Shanks are also available with an internal (female) thread or with a welding shank.
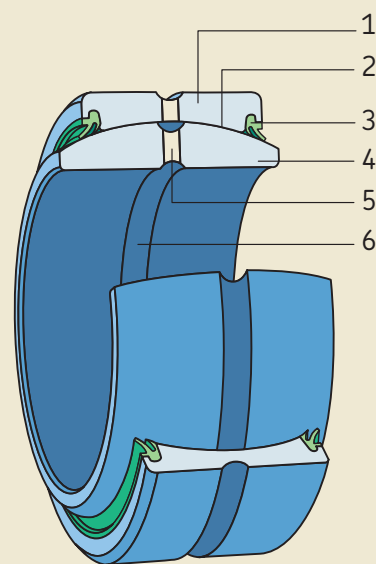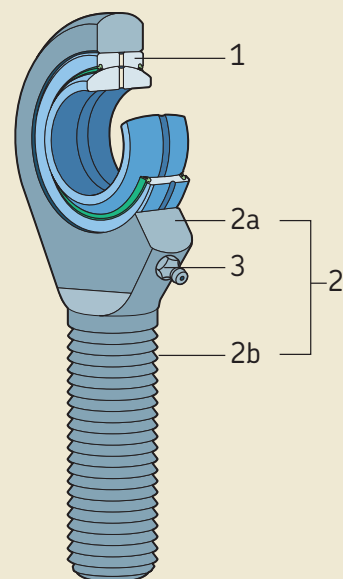3   Grease fitting

Fig. 1

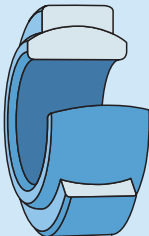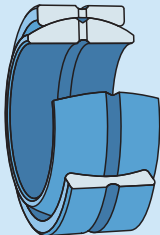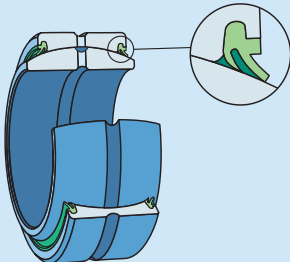
Fig. 2

Selection of bearing types

Bearing types

All the products listed below belong to the SKF standard assortment:

- radial spherical plain bearings requiring maintenance
- maintenance-free radial spherical plain bearings
- angular contact spherical plain bearings
- thrust spherical plain bearings
- steel/steel and steel/bronze rod ends requiring maintenance
- maintenance-free rod ends

If the standard assortment does not meet the requirements of an application, SKF can produce special bearings or rod ends, provided quantities are sufficient to enable manufacturing economy.

Radial spherical plain bearings requiring maintenance
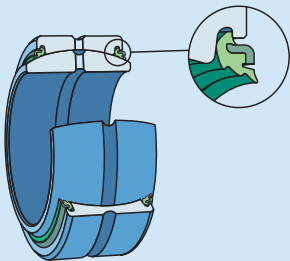
See chapter 2 starting on **page 99**

Bearing design Radial spherical plain bearings requiring maintenance	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/steel Suitable for heavy static or alternating loads, shock loads		
	GE .. E d = 4 – 12 mm	Open (without seals), can only be relubricated from the side
	GE .. ES d = 15 – 200 mm **GEZ .. ES** d = 0.5 – 6 in	Open (without seals), can be relubricated via lubrication holes and an annular groove in both rings
	GE .. ES-2RS d = 15 – 300 mm **GEZ .. ES-2RS** d = 0.75 – 6 in	With a double-lip seal on both sides, can be relubricated via lubrication holes and an annular groove in both rings

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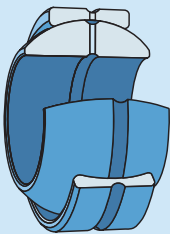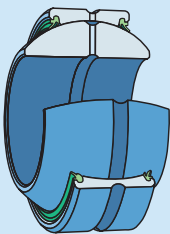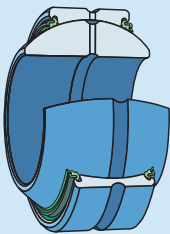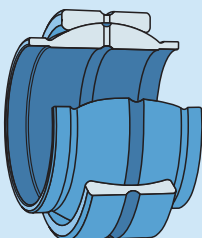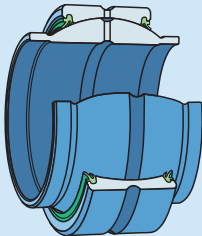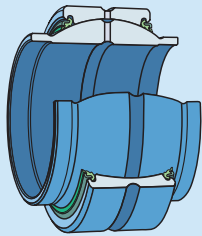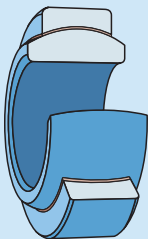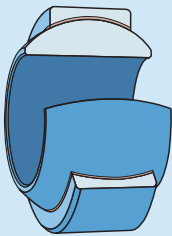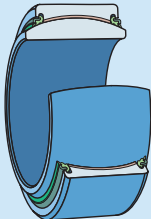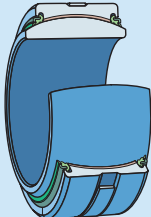| Bearing design Radial spherical plain bearings requiring maintenance	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/steel Suitable for heavy static or alternating loads, shock loads		
	GE .. ES-2LS d = 20 – 300 mm **GEZ .. ES-2LS** d = 1 – 6 in	With a triple-lip heavy-duty seal on both sides, can be relubricated via lubrication holes and an annular groove in both rings
	GEH .. ES upon request **GEZH ..ES** d = 1.25 – 5.5 in	Open (not sealed); wider inner ring and larger outside diameter compared to GE .. ES and GEZ .. ES series, to enable higher load ratings and larger tilt angle; can be relubricated via lubrication holes and an annular groove in both rings
	GEH .. ES-2RS d = 20 – 120 mm **GEZH ..ES-2RS** d = 1.25 – 5.5 in	With a double-lip seal on both sides; wider inner ring and larger outside diameter compared to GE .. ES-2RS and GEZ .. ES-2RS series, to enable higher load ratings and larger tilt angle; can be relubricated via lubrication holes and an annular groove in both rings
	GEH .. ES-2LS d = 20 – 120 mm **GEZH .. ES-2LS** d = 1.25 – 5.5 in	With a triple-lip heavy-duty seal on both sides; wider inner ring and larger outside diameter compared to GE .. ES-2RS and GEZ .. ES-2RS series, to enable higher load ratings and larger tilt angle; can be relubricated via lubrication holes and an annular groove in both rings
	GEM .. ES upon request **GEZM .. ES** d = 0.5 – 6 in	Open (without seals); with an extended inner ring on both sides; can be relubricated via lubrication holes and an annular groove in both rings. For bearing arrangements where a spacer sleeve is normally incorporated on both sides of the inner ring.
	GEG .. ES d = 16 – 200 mm	GEG series : The inner ring width equals the bore diameter
	GEG 12 ESA d = 12 mm	Can only be relubricated via the outer ring
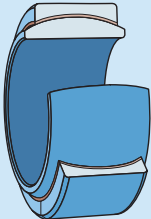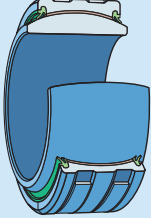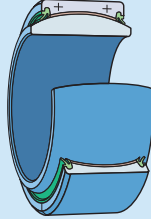
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Selection of bearing types

Bearing design Radial spherical plain bearings requiring maintenance	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/steel Suitable for heavy static or alternating loads, shock loads		
	GEM .. ES-2RS d = 20 – 80 mm **GEZM .. ES-2RS** d = 0.75 – 6 in	With a double-lip seal and an extended inner ring on both sides, can be relubricated via lubrication holes and an annular groove in both rings
	GEM .. ES-2LS d = 20 – 80 mm **GEZM .. ES-2LS** d = 1 – 6 in	With a triple-lip heavy-duty seal and an extended inner ring on both sides, can be relubricated via lubrication holes and an annular groove in both rings
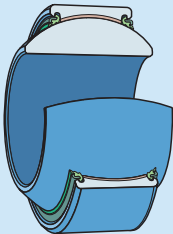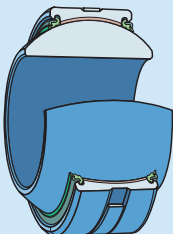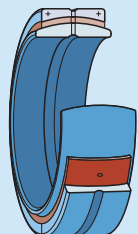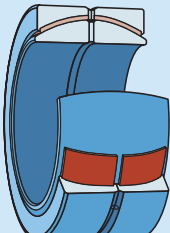
Maintenance-free radial spherical plain bearings

See chapter 3 starting on **page 125**

Bearing design Maintenance-free radial spherical plain bearings	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/PTFE sintered bronze Suitable for heavy, constant direction loads, where low friction is required; limited suitability for alternating loads, shock loads.		
	GE .. C d = 4 – 30 mm **GE .. CJ2** d = 35 – 60 mm	Open (without seals), self-lubricating sliding surfaces have to be externally protected from contaminants
	GEH .. C d = 10 – 25 mm	Open (without seals), self-lubricating sliding surfaces have to be externally protected from contaminants; wider inner ring and larger outside diameter compared to GE .. C series, to enable higher load ratings and larger tilt angle

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Bearing design Maintenance-free radial spherical plain bearings	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/PTFE fabric Suitable for very heavy, constant direction loads, where low friction is required; limited suitability for alternating loads, shock loads		
	GE .. TXE-2LS d = 20 – 90 mm **GEZ .. TXE-2LS** d = 1 – 3.75 in **GE .. TXG3E-2LS** d = 20 – 60 mm	High performance bearing with a triple-lip heavy-duty seal on both sides, outer ring fractured at one point, self-lubricating sliding surfaces GE .. TXG3E-2LS series in stainless steel execution for use in corrosive environments
	GE .. TXA-2LS d = 100 – 300 mm **GEZ .. TXA-2LS** d = 4 – 6 in **GE .. TXG3A-2LS** d = 70 – 200 mm	High performance bearing with a triple-lip heavy-duty seal on both sides, axially split outer ring that is held together by one band, self-lubricating sliding surfaces GE .. TXG3A-2LS series with rings made of stainless steel for use in corrosive environments
	GE .. TXGR d = 12 – 17 mm	Open (without seals), stainless steel execution for use in corrosive environments, self-lubricating sliding surfaces have to be externally protected from contaminants
	GEC .. TXA-2RS d = 320 – 400 mm	High performance bearing with a double-lip seal on both sides, self-lubricating sliding surfaces, axially split outer ring that is held together by two bands
	GEC .. TXA-2RS d = 420 – 800 mm	High performance bearing with a double-lip seal on both sides, self-lubricating sliding surfaces, axially split outer ring that is bolted together

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Selection of bearing types

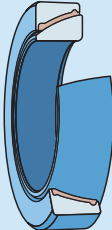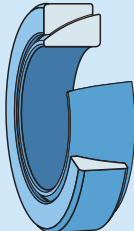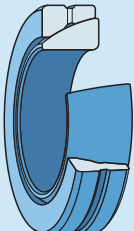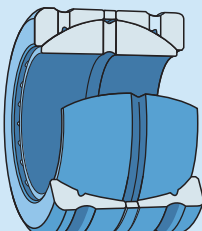| Bearing design Maintenance-free radial spherical plain bearings	Designation/ bore diameter range	Characteristics

Sliding contact surface combination: Steel/PTFE fabric
Suitable for very heavy, constant direction loads, where low friction is required;
limited suitability for alternating loads, shock loads

	GEH ..TXE-2LS d = 20 – 80 mm	High performance bearing with a triple-lip heavy-duty seal on both sides; self-lubricating sliding surfaces, wider inner ring and larger outside diameter compared to GE .. TXE-2LS series, to enable higher load ratings and larger tilt angle
	GEH ..TXG3E-2LS d = 20 – 50 mm	GEH .. TXG3E-2LS series with rings made of stainless steel for use in corrosive environments
	GEH ..TXA-2LS d = 90 – 120 mm	High performance bearing with a triple-lip heavy-duty seal on both sides, self-lubricating sliding surfaces, wider inner ring and larger outside diameter compared to GE .. TXE-2LS series, to enable higher load ratings and larger tilt angle; axially split outer ring that is held together by one band
	GEH ..TXG3A-2LS d = 60 – 120 mm	GEH .. TXG3A-2LS series with rings made of stainless steel for use in corrosive environments

Sliding contact surface combination: Steel/PTFE FRP
Suitable for heavy, constant direction loads, where low friction is required;
limited suitability for alternating loads, shock loads; relatively insensitive
to contaminants

	GEC .. FBAS d = 320 – 1 000 mm	Open (without seals); axially split outer ring that is bolted together; self-lubricating capability; factory greased; lubrication holes and an annular groove in both rings; does not require relubrication, however, relubrication can extend bearing service life
	GEP .. FS d = 100 – 1 000 mm	Open (without seals); radially split outer ring that is separable to facilitate mounting; self-lubricating capability; factory greased; lubrication holes and an annular groove in both rings; does not require relubrication, however, relubrication can extend bearing service life Compared to GEC .. FBAS series, these bearings are wider and have a larger outside diameter for a given shaft size, resulting in a higher basic load rating. However, they have a smaller tilt angle.

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Angular contact spherical plain bearings

See chapter 4 starting on **page 151**

Bearing design Angular contact spherical plain bearings	Designation/ bore diameter range	Characteristics

Sliding contact surface combination: Steel/PTFE FRP
Suitable for single direction axial loads or combined axial and radial loads,
low coefficient of friction, relatively insensitive to contaminants

	GAC .. F d = 25 – 120 mm	Open (without seals); self-lubricating capability; factory greased; does not require relubrication, however, relubrication can extend bearing service life

Sliding contact surface combination: Steel/PTFE fabric
Suitable for single direction axial loads or combined axial and radial loads,
very high load carrying capacity and low coefficient of friction

	GACD .. TX upon request	Open (without seals), high performance bearing with self-lubricating sliding surface

Sliding contact surface combination: Steel/steel
Suitable for heavy single direction axial loads or heavy combined
axial and radial loads, heavy alternating loads

	GACD .. SA upon request **GAZ .. SA** upon request	Open (without seals), multi-groove system, can be relubricated via lubrication holes and an annular groove in the outer ring

Sliding contact surface combination: Steel/steel
Double direction angular contact bearing with a standard inner ring, bearing
can be used instead of two angular contact bearings in a face-to-face
arrangement, suitable for heavy combined radial and axial loads, heavy alternating loads

	GEZP(R) .. S upon request	Open (without seals), multi-groove system, can be relubricated via lubrication holes and an annular groove in the inner ring and the two outer rings

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Selection of bearing types

Thrust spherical plain bearings
See chapter 5 starting on **page 159**
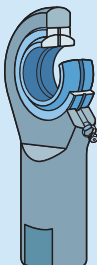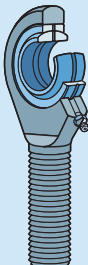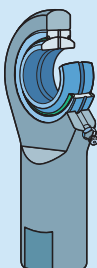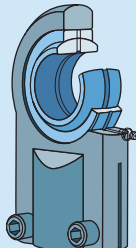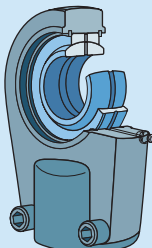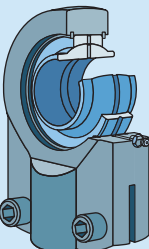
Bearing design Thrust spherical plain bearings	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/PTFE FRP Suitable for single direction axial loads or combined axial and radial loads, low coefficient of friction, relatively insensitive to contaminants		
	GX .. F d = 17 – 120 mm	Open (without seals); self-lubricating capability; factory greased; does not require relubrication, however, relubrication can extend bearing service life
Sliding contact surface combination: Steel/PTFE fabric Suitable for heavy single direction axial loads or combined axial and radial loads, very high load carrying capacity and low coefficient of friction		
	GXD .. TX upon request	Open (without seals), high performance bearing with self-lubricating sliding surface
Sliding contact surface combination: Steel/steel Suitable for heavy single direction axial loads or combined axial and radial loads, heavy alternating loads		
	GXD .. SA upon request	Open (without seals), multi-groove system, can be relubricated via lubrication holes and an annular groove in the housing washer

Rod ends with a threaded shank, requiring maintenance
See chapter 6 starting on **page 167**

Bearing design Rod ends with a threaded shank, requiring maintenance	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/steel Suitable for heavy static or alternating loads, shock loads		
SI series SA series	**SI(L) .. E** d = 6 – 12 mm **SA(L) .. E** d = 6 – 12 mm	With an open bearing (without seals), no relubrication facilities, available with a right-hand or left-hand thread (designation prefix L)

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Bearing design Rod ends with a threaded shank, requiring maintenance	Designation/ bore diameter range	Characteristics

Sliding contact surface combination: Steel/steel
Suitable for heavy static or alternating loads, shock loads

	SI(L) .. ES d = 15 – 30 mm **SA(L) .. ES** d = 15 – 30 mm	With an open bearing (without seals), can be lubricated via the relubrication facility in the rod end housing and via the pin (shaft), available with a right-hand or left-hand thread

SI series   SA series

	SI(L) .. ES-2RS d = 35 – 80 mm **SA(L) .. ES-2RS** d = 35 – 80 mm	With a double-lip seal on both sides of the bearing, can be lubricated via the relubrication facility in the rod end housing and via the pin (shaft), available with a right-hand or left-hand thread
	SI(L)A .. ES-2RS d = 40 – 80 mm **SA(L)A .. ES-2RS** d = 40 – 80 mm	SIA and SAA series with different fitting dimensions (thread, height of the housing)

SI(A) series   SA(A) series

Sliding contact surface combination: Steel/steel
Suitable for hydraulic cylinders, the slotted shank enables the rod end to be secured by tightening bolts

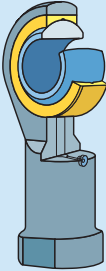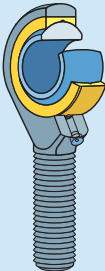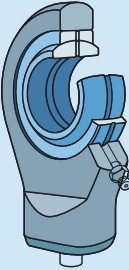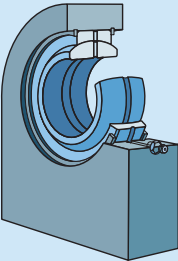|	**SI(L)J .. ES** d = 16 – 100 mm	With an open bearing (without seals), available with a right-hand or left-hand thread Sizes 16 and larger can be lubricated via the relubrication facility in the rod end housing and via the pin (shaft)
	SI(L)J 12 E d = 12 mm	No relubrication facilities
	SI(L)R .. ES d = 25 – 120 mm	With an open bearing (without seals), compact design, shorter female thread, can be lubricated via the relubrication facility in the rod end housing and via the pin (shaft), available with a right-hand or left-hand thread
	SI(L)QG .. ES d = 16 – 200 mm	With an open bearing (without seals), with an inner ring extended on both sides, can be lubricated via the relubrication facility in the rod end housing and via the pin (shaft), available with a right-hand or left-hand thread
	SI(L)QG 12 ESA d = 12 mm	Can only be relubricated via the relubrication facilities in the rod end housing

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Selection of bearing types

Bearing design Rod ends with a threaded shank, requiring maintenance	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/bronze Lower load carrying capacity compared to steel/steel rod ends, but more suitable for applications where lubricant starvation might occur		
 SIKAC .. M SAKAC .. M	**SI(L)KAC .. M** d = 5 – 30 mm **SA(L)KAC .. M** d = 5 – 30 mm	With an open bearing (without seals), available with a right-hand or left-hand thread Sizes 6 and larger can be lubricated via the relubrication facility in the rod end shank or housing

Rod ends with a welding shank, requiring maintenance

See chapter 6 starting on **page 167**
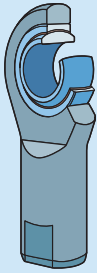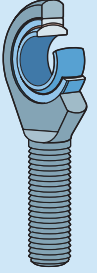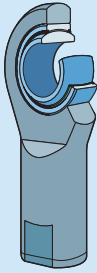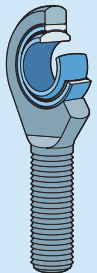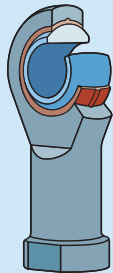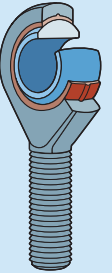
Bearing design Rod ends with a welding shank, requiring maintenance	Designation/ bore diameter range	Characteristics
Sliding contact surface combination: Steel/steel Suitable for heavy static or alternating loads, shock loads		
	SC ..ES d = 20 – 80 mm	With an open bearing (without seals), can be lubricated via a the relubrication facility in the rod end housing and via the pin (shaft) Primarily used for welding to piston rods and the bases of hydraulic cylinders Centred by a dowel pin
	SCF ..ES d = 20 – 120 mm	With an open bearing (without seals); can be lubricated via the the relubrication facility in the rod end housing and via the pin (shaft); high capacity design rod end compared to SC .. ES series, to enable heavier static loads Rectangular welding shank without a dowel pin

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Maintenance-free rod ends with a threaded shank

See chapter 7 starting on **page 189**

Bearing design Maintenance-free rod ends with a threaded shank	Designation/ bore diameter range	Characteristics

Sliding contact surface combination: Steel/PTFE sintered bronze
Suitable for heavy, constant direction loads, where low coefficient
of friction is required; limited suitability for alternating loads,
shock loads

SI .. C SA .. C	**SI(L) .. C** d = 6 – 30 mm **SA(L) .. C** d = 6 – 30 mm	With an open bearing (without seals), available with a right-hand or left-hand thread

Sliding contact surface combination: Steel/PTFE fabric
Suitable for very heavy, constant direction loads, where low coefficient
of friction is required; limited suitability for alternating loads,
shock loads

SI(A) .. TXE-2LS SA(A) .. TXE-2LS	**SI(L) .. TXE-2LS** d = 35 – 80 mm **SA(L) .. TXE-2LS** d = 35 – 80 mm **SI(L)A .. TXE-2LS** d = 40 – 60 mm **SA(L)A .. TXE-2LS** d = 40 – 60 mm	With a high performance bearing with a tri- ple-lip heavy-duty seal on both sides of the bearing, available with a right-hand or left- hand thread SIA and SAA series with different fitting dimensions (thread, height of the housing)

Sliding contact surface combination: Steel/PTFE FRP
Suitable for heavy, constant direction loads, where low coefficient
of friction is required; limited suitability for alternating loads,
shock loads

SIKB .. F SAKB .. F	**SI(L)KB .. F** d = 5 – 22 mm **SA(L)KB .. F** d = 5 – 22 mm	With an open bearing (without seals), but relatively insensitive to contaminants, avail- able with a right-hand or left-hand thread

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Selection of bearing size

Load ratings

There is no standardized method for determining the load ratings of spherical plain bearings and rod ends, nor is there any standardized definition. As different manufacturers define load ratings differently, it is not possible to compare the load ratings of bearings produced by one manufacturer with those of another.

Basic dynamic load rating

The basic dynamic load rating C is used, together with other influencing factors, to determine the basic rating life of spherical plain bearings and rod ends. As a rule, it represents the maximum load that a spherical plain bearing or rod end can accommodate at room temperature when there is movement between the sliding contact surfaces (→ **fig. 1**). The maximum load in any application should always be considered in relation to the required rating life. The basic dynamic load ratings quoted in the product tables are based on the specific load factor K (→ **table 4** on **page 45**) and the effective projected sliding surface.

Basic static load rating

The basic static load rating C_0 represents the maximum permissible load that a spherical plain bearing or rod end can accommodate when there is no relative movement between the sliding contact surfaces (→ **fig. 2**).

For spherical plain bearings, the basic static load rating represents the maximum load that the bearing can accommodate at room temperature without inadmissible deforming, fracturing or damaging the sliding contact surfaces.

The basic static load ratings quoted for SKF spherical plain bearings are based on a specific
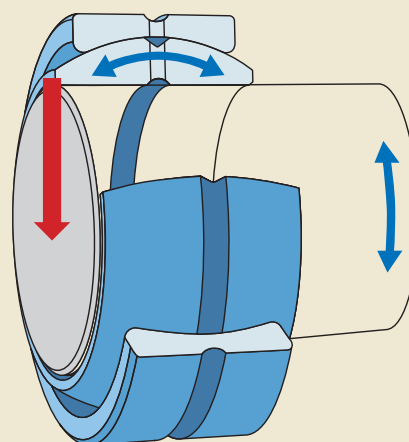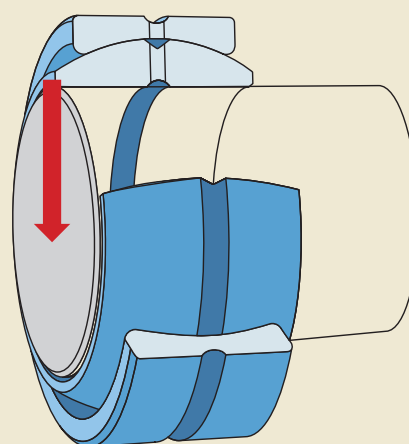

Fig. 1
Dynamic bearing load

Fig. 2
Static bearing load

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static load factor K_0 (→ **table 4** on **page 45**) and the effective projected sliding surface. It is assumed that the bearing is adequately supported. To fully exploit the static load rating of a spherical plain bearing, it is generally necessary to use shafts and housings made of high-strength materials. The basic static load rating must also be considered when bearings are dynamically loaded and subjected to additional heavy shock loads. The total load in these cases must not exceed the basic static load rating.

For rod ends, it is the strength of the housing at room temperature, under a constant load acting in the direction of the shank axis, that is the determining factor. The basic static load rating represents a safety factor of at least 1,2 relative to the yield strength of the material of the rod end housing, under the above conditions.

Basic rating life

For spherical plain bearings, a lubricant film that fully separates the sliding contact surfaces cannot be formed. Therefore, the sliding contact surfaces make direct contact with each other, resulting in a certain and unavoidable degree of wear. This increases the internal clearance in the bearing.

Regarding the life of spherical plain bearings or rod ends, a distinction is made between the basic rating life and the service life. The basic rating life is a theoretical guideline value, used to estimate the service life. Service life depends on the actual operating conditions and is the actual life achieved by the bearing in service.

The basic rating life is based on a large number of laboratory tests. The bearings were tested for an operating period until a specific increase in bearing clearance or friction occurred (→ **table 1** on **page 40**). The basic rating life considers several influencing factors and can be expressed in operating hours or the number of oscillating movements (→ **fig. 3**). In some cases, however, it is not possible to quantify factors such as contamination, corrosion, and complex kinematic loads. Therefore, the basic rating life can be attained or exceeded by

Fig. 3

Angle of oscillation
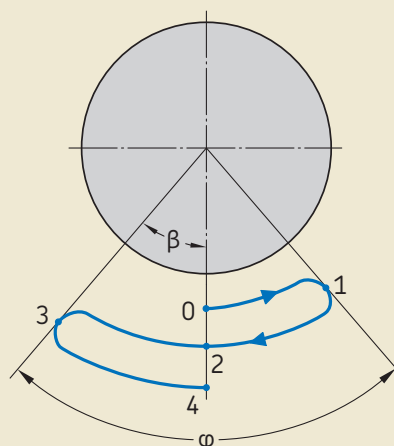
φ = angle of oscillation = 2 β
A complete oscillation is from point 0 to point 4 and = 4 β

the majority of many apparently identical spherical plain bearings under the same operating conditions. For the calculation methods of the different sliding contact surface combinations as well as calculation examples, refer to the section *Basic rating life calculation* starting on **page 51**.

The service life cannot be calculated as it is too complex to determine and evaluate all the influencing factors. Therefore, depending on the application conditions, the service life may differ from the basic rating life.

NOTE: By using the *SKF Interactive Engineering Catalogue* and its incorporated calculation programs, it is possible to perform the necessary calculations to select a spherical plain bearing with the click of a mouse. The product data necessary for the calculations is automatically put in by selecting a spherical plain bearing or rod end from the product tables. It is then only necessary to fill in the fields for the operating data.

The *SKF Interactive Engineering Catalogue* is available online at www.skf.com.

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Selection of bearing size

Failure criteria for basic rating life tests			Table 1
Sliding contact surface combination	**Increase in bearing clearance**	**Coefficient of friction μ**	
–	mm	–	
Steel/steel	$> 0,004\ d_k$ [1]	0,20	
Steel/bronze	$> 0,004\ d_k$ [1]	0,25	
Steel/PTFE[2] sintered bronze			
constant direction load	0,2	0,25	
alternating direction load	0,4	0,25	
Steel/PTFE fabric			
constant direction load	0,3	0,15	
alternating direction load	0,6	0,15	
Steel/PTFE FRP[3]	design and size dependent	0,20	

[1] d_k = sphere diameter of the inner ring.
[2] Polytetrafluoroethylene.
[3] Fibre reinforced polymer.

Fig. 4

Radial load

Fig. 5

Axial load

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1
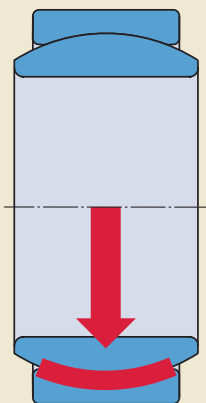
Fig. 6

Combined load

Load

When considering load, a distinction is made between:

- load direction
  – radial load (→ **fig. 4**)
  – axial load (→ **fig. 5**)
  – combined (axial and radial) load (→ **fig. 6**)
- type of load
  – dynamic load, i.e. there is relative sliding movement in the loaded bearing
  – static load, i.e. there is no relative movement in the loaded bearing
- load conditions
  – constant load (→ **fig. 7**), i.e. the direction in which the load is applied does not change and the same part of the bearing (loaded zone) is always subjected to the load
  – alternating load (→ **fig. 8**), i.e. change of load direction so that zones at opposite positions in the bearing are alternately loaded and unloaded

Equivalent dynamic bearing load

The load can be inserted directly into the equation for the specific bearing load p (→ **page 46**) if the magnitude of the load is constant and if the load acting on:

- radial and angular contact spherical plain bearings is purely radial
- thrust spherical plain bearings is purely axial
- rod ends is purely radial and in the direction of the shank axis

In all other cases it is necessary to calculate the equivalent dynamic bearing load P. If the magnitude of the load is not constant, use the equation provided in the section *Variable load and sliding velocity* (→ **page 61**).

Fig. 7

Constant direction load

Fig. 8

Alternating direction load

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Selection of bearing size

Radial spherical plain bearings

Radial spherical plain bearings can accommodate a certain magnitude of axial load F_a in addition to a simultaneously acting radial load F_r (→ **fig. 6** on **page 41**). When the resultant load is constant in magnitude, the equivalent dynamic bearing load can be calculated using

$$P = y\,F_r$$

where
P = equivalent dynamic bearing load [kN]
F_r = radial component of the load [kN]
y = load factor that depends on the ratio of the axial to the radial load F_a/F_r
  – for bearings requiring maintenance
    (→ **diagram 1**)
  – for maintenance-free bearings
    (→ **diagram 2**)

Diagram 1

Factor y for radial spherical plain bearings requiring maintenance
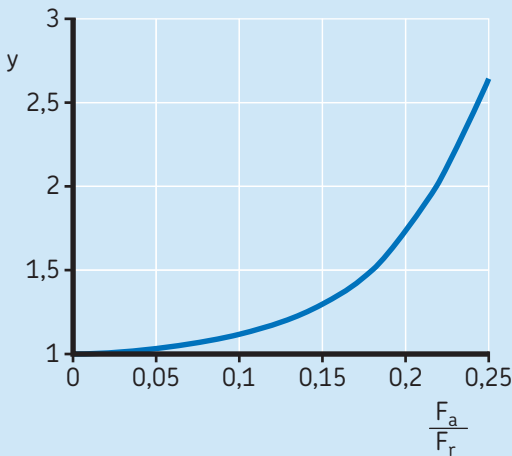
Diagram 2

Factor y for maintenance-free radial spherical plain bearings

Diagram 3

Factor y for angular contact spherical plain bearings
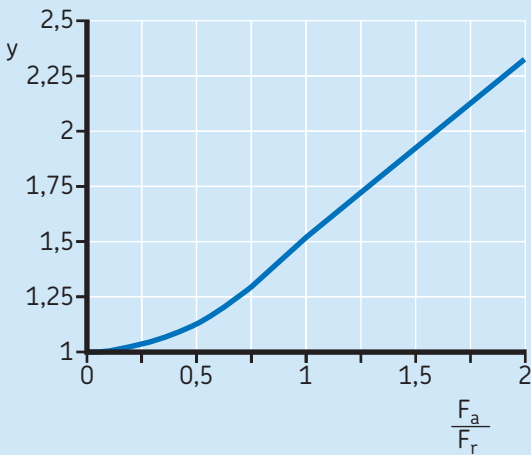
If $F_a/F_r > 2$, use a thrust spherical plain bearing instead, or contact the SKF application engineering service.

Diagram 4

Factor y for thrust spherical plain bearings
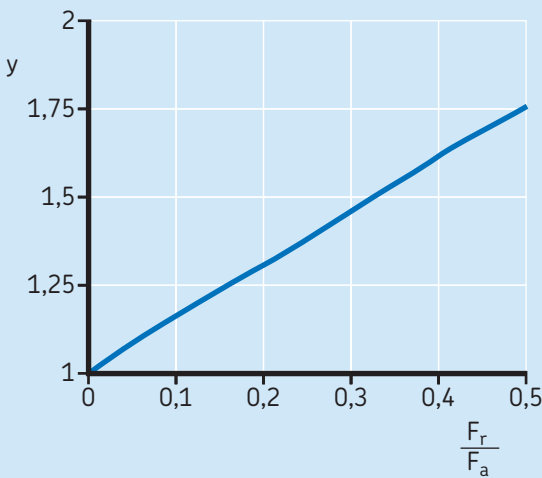
If $F_r/F_a > 0,5$, use an angular contact spherical plain bearing instead, or contact the SKF application engineering service.

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Angular contact spherical plain bearings

When the resultant load (→ **fig. 9**) is constant in magnitude, then use

$$P = y\, F_r$$

where
P = equivalent dynamic bearing load [kN]
F_r = radial component of the load [kN]
y = load factor that depends on the ratio of the axial to the radial load F_a/F_r (→ **diagram 3**)

Thrust spherical plain bearings

Thrust spherical plain bearings can accommodate a radial load F_r in addition to an axial load F_a (→ **fig. 10**). However, the radial load must not exceed 50% of the simultaneously acting axial load. When the resultant load is constant in magnitude, then use

$$P = y\, F_a$$

where
P = equivalent dynamic bearing load [kN]
F_a = axial component of the load [kN]
y = load factor depending on the ratio of the radial to the axial load F_r/F_a
(→ **diagram 4**)

Equivalent static bearing load

If spherical plain bearings and rod ends are subjected to static loads, or very slight alignment movements, then the permissible load is not limited by wear, but by the strength of the sliding contact layer or the strength of the rod end housing.

If the actual load is a combined load, then an equivalent static bearing load must be calculated. For radial and angular contact spherical plain bearings, it can be calculated using

$$P_0 = y\, F_r$$

For thrust spherical plain bearings, it can be calculated using

$$P_0 = y\, F_a$$

Fig. 9

Angular contact spherical plain bearing under combined load
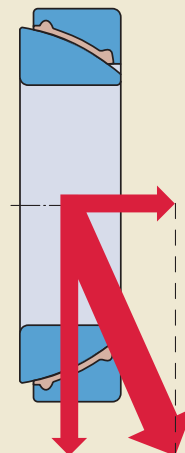
Fig. 10

Thrust spherical plain bearing under combined load
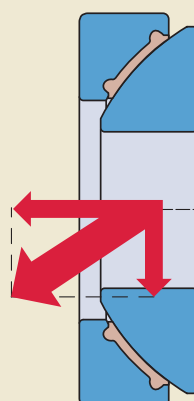
where
P_0 = equivalent static bearing load [kN]
F_r = radial component of the load [kN]
F_a = axial component of the load [kN]
y = load factor that depends on the ratio of the axial to the radial load F_a/F_r
– for radial bearings requiring maintenance (→ **diagram 1**)
– for maintenance-free radial bearings (→ **diagram 2**)
– for angular contact spherical plain bearings (→ **diagram 3**)
and load factor that depends on the ratio of the radial to the axial load F_r/F_a
– for thrust spherical plain bearings (→ **diagram 4**)

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Selection of bearing size

Permissible loads for rod ends

Rod ends are primarily intended for the support of radial loads acting in the direction of the shank axis. If loads act at angles to the shank axis (→ **fig. 11**), the maximum permissible load is reduced, as additional bending stresses occur in the shank. Under these conditions, consider the design and size dependent material used for the rod end housing (→ **table 6** on **page 170**).

The load portion acting perpendicular to the direction of the shank axis should never exceed the value of 0,1 C_0. If heavier loads are involved, a larger rod end should be selected.

The maximum permissible load for a rod end in the direction of the shank axis can be calculated using

$$P_{perm} = C_0\, b_2\, b_6$$

where
P_{perm} = maximum permissible load [kN]
C_0 = static load rating [kN]
b_2 = temperature factor
  – for rod ends requiring maintenance
   (→ **table 5** on **page 52**)
  – for maintenance-free rod ends with the sliding contact surface combination
   – steel/PTFE sintered bronze
    (→ **diagram 16** on **page 55**)
   – steel/PTFE fabric
    (→ **diagram 17** on **page 56**)
   – steel PTFE FRP
    (→ **diagram 19** on **page 59**)
b_6 = factor for the type of load (→ **table 2**)

Fig. 11

Rod end under combined load
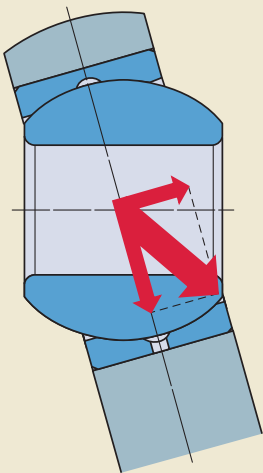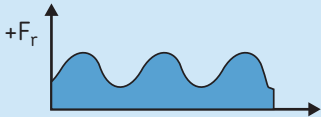
Table 2

Factor b_6 for rod end load type

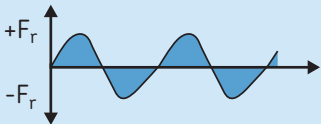| Type of load	Factor b_6
Constant	1
Pulsating magnitude (single direction)	0,5 (0,35)
Alternating direction	0,5 (0,35)

The values in brackets apply to rod ends with a relubrication facility.

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Requisite bearing size

To determine the requisite size of a spherical plain bearing or rod end, it is necessary to know the requisite rating life for the application. This depends on the type of machine, the operating conditions and the demands regarding operational reliability. The following steps can be used to determine requisite bearing size:

1 Use the guideline values of the load ratio C/P provided in **table 3** to obtain a requisite basic dynamic load rating C. Compare this value with the basic dynamic load rating of the bearings listed in the product tables.

2 Use **diagrams 5** to **10** on **pages 46** to **50** to check whether the sliding contact surface combination of the selected bearing or rod end can be used under the actual load p and sliding velocity v conditions. The specific bearing load p and the sliding velocity v needed to perform this check can be calculated as explained in the following sections:

a) If the pv diagram indicates that the basic rating life equation can be used, proceed to step 3.

b) If the pv diagram shows that the pv range is exceeded, select a bearing with a higher load carrying capacity.

3 Calculate the basic rating life (**→ page 51**) and proceed as follows:

a) If the calculated rating life is shorter than the requisite rating life, a larger bearing or rod end should be selected and the calculation repeated.

b) If the calculated rating life is larger than the requisite rating life, the bearing or rod end can be selected for the application.

The bearing or rod end size is often determined by the dimensions of the associated components. In these cases, check the pv diagram to determine if the product is suitable.

1

Table 3

Guideline values for C/P

Sliding contact surface combination	Load ratio C/P
Steel/steel	2
Steel/bronze	2
Steel/PTFE sintered bronze	1,6
Steel/PTFE fabric	2
Steel/PTFE FRP	
GAC .. F	1,25
GX .. F	1,25
GEP .. FS	1,6
GEC .. FBAS	1,6
Rod ends	1,25

Table 4

Specific load factors

Sliding contact surface combination	Specific load factors	
	dyn. K	stat. K_0
–	N/mm^2	
Steel/steel		
Metric bearings	100	500
Inch bearings	100	300
Steel/bronze	50	80
Steel/ PTFE sintered bronze	100	250
Steel/PTFE fabric		
Metric bearings	300	500
Inch bearings	150	300
Steel/PTFE FRP		
GAC .. F	50	80
GX .. F	50	80
GEP .. FS	80	120
GEC .. FBAS	80	120
Rod ends	50	80

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Selection of bearing size

Specific bearing load

The magnitude of the specific bearing load can be calculated using

$$p = K \frac{P}{C}$$

where
p = specific bearing load [N/mm^2]
K = specific load factor depending on the bearing design and sliding contact surface combination (→ **table 4** on **page 45**) [N/mm^2]
P = equivalent dynamic bearing load [kN]
C = basic dynamic load rating [kN]

Mean sliding velocity

The mean sliding velocity for constant movement can be calculated using

$$v = 5{,}82 \times 10^{-7}\, d_m\, \beta\, f$$

where
v = mean sliding velocity [m/s]
       When the operation is intermittent (not continuous), the mean sliding velocity should be calculated for a cycle of operation
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]
β   = half the angle of oscillation (→ **fig. 3** on **page 39**), degrees [°], for rotation β = 90°
f   = frequency of oscillation [min^{-1}], or rotational speed [min^{-1}]

Diagram 5

pv diagram for steel/steel sliding contact surface combination
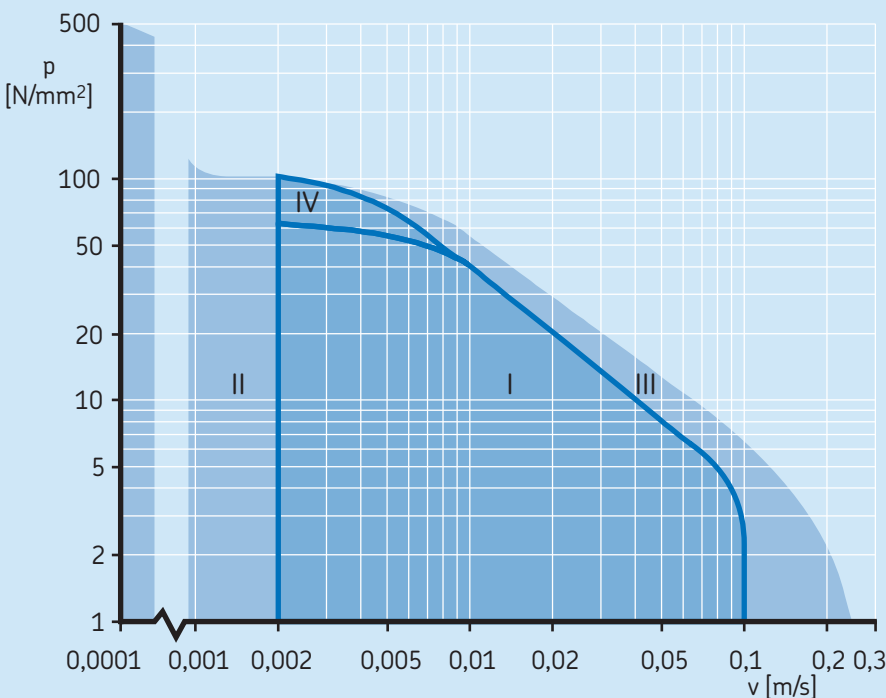
Refer to *Note 1* (→ **page 47**) for explanation of operating ranges.

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For intermittent movement, the angle of oscillation is usually given in units of time. In this case the mean sliding velocity can be calculated using

$$v = 8{,}73 \times 10^{-6} \, d_m \frac{4\beta}{t}$$

where
β = half the angle of oscillation [°]
($\rightarrow$ **fig. 3** on **page 39**)
t = time taken to pass through complete oscillation [s]

NOTE 1: pv operating ranges
I   Range where rating life equation is valid
II   Quasi-static range; before using the rating life equation, contact the SKF application engineering service
III Possible range of use, e.g. with very good lubrication; before using the rating life equation, contact the SKF application engineering service for additional information
IV   Extended range where rating life equation is valid provided the load is exclusively alternating

Diagram 6

pv diagram for steel/bronze sliding contact surface combination
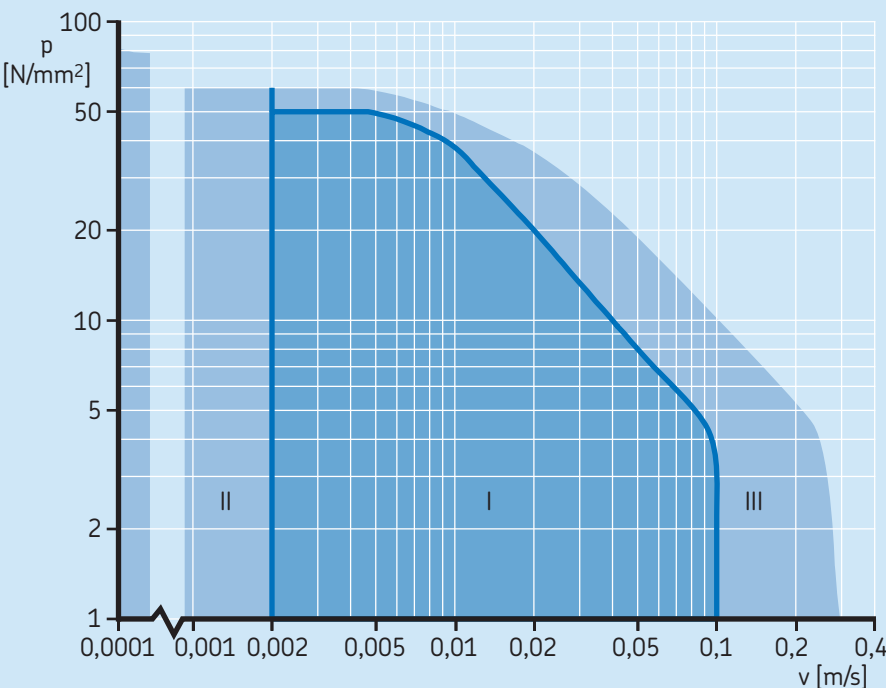
Refer to *Note 1* for explanation of operating ranges.

Selection of bearing size

NOTE 2: pv operating ranges
I Range where rating life equation is valid
II Quasi-static range; rating life equation has limited validity, refer to the section *Basic rating life*, starting on **page 39**
III Possible range of use, e.g. with very good heat dissipation; before using the rating life equation, contact the SKF application engineering service for additional information

Diagram 7

pv diagram for steel/PTFE sintered bronze sliding contact surface combination
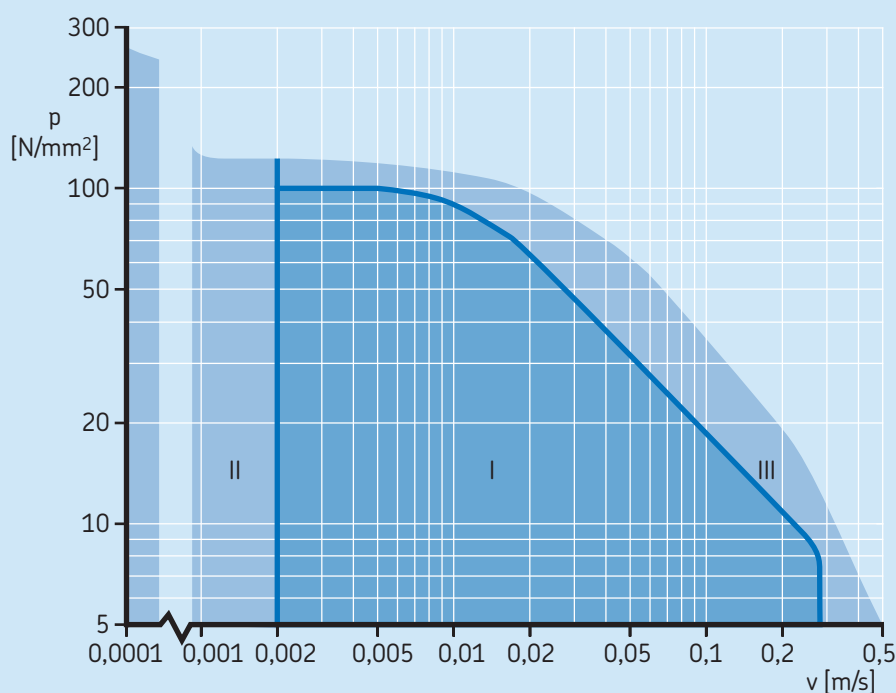
Refer to *Note 2* for explanation of operating ranges.

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Diagram 8

1

pv diagrams for steel/PTFE fabric sliding contact surface combination

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Metric bearings

Inch bearings

Refer to *Note 2* (**→ page 48**) for explanation of operating ranges.

Selection of bearing size

Diagram 9

pv diagram for steel/PTFE FRP sliding contact surface combination, FS and FBAS designs

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Refer to *Note 2* (→ **page 48**) for explanation of operating ranges.

Diagram 10

pv diagram for steel/PTFE FRP sliding contact surface combination, F design

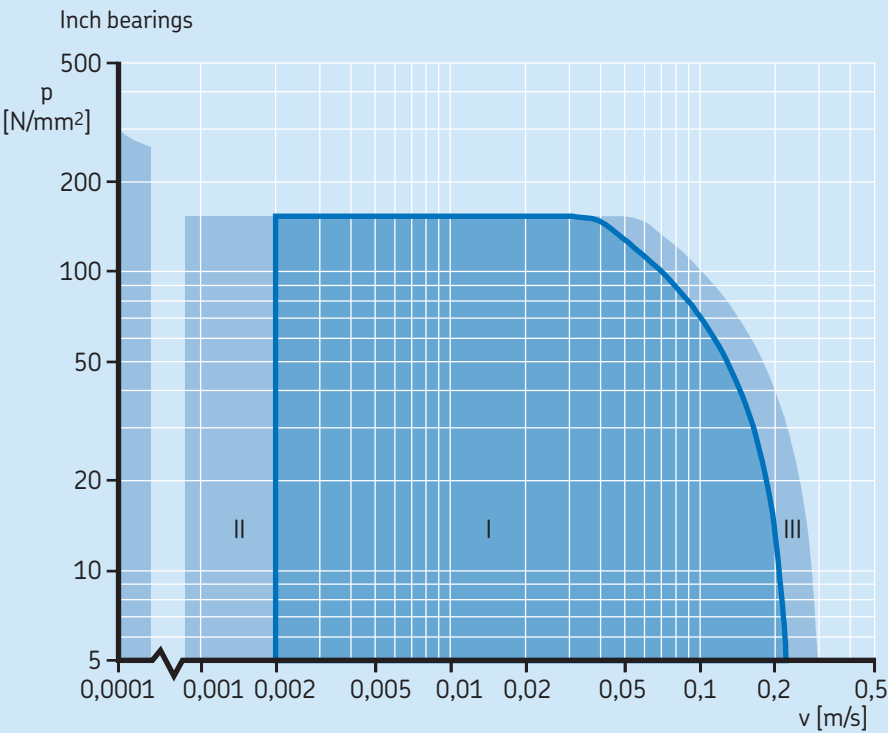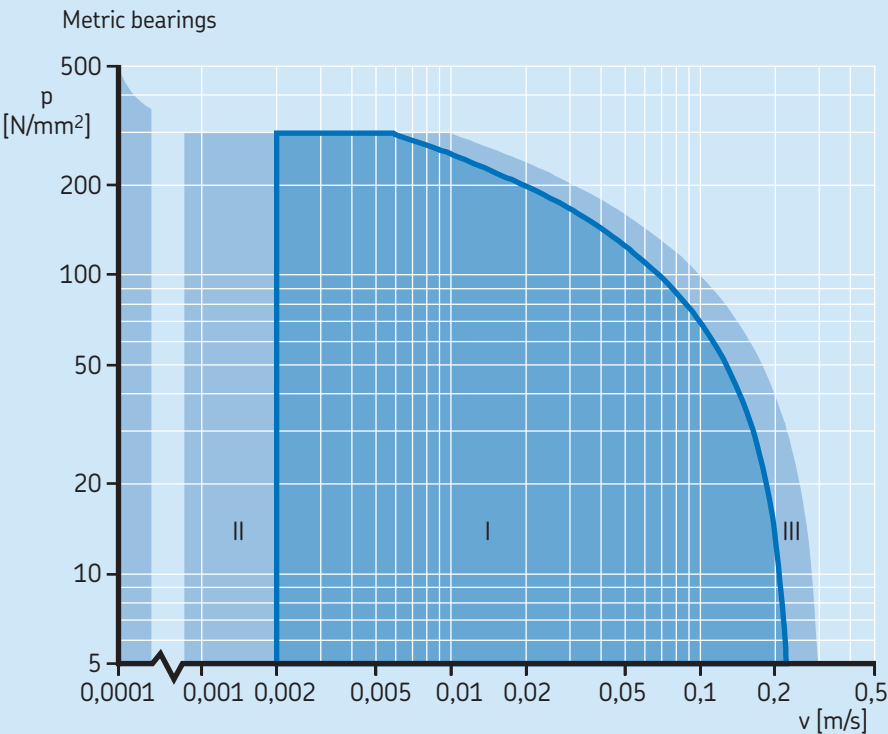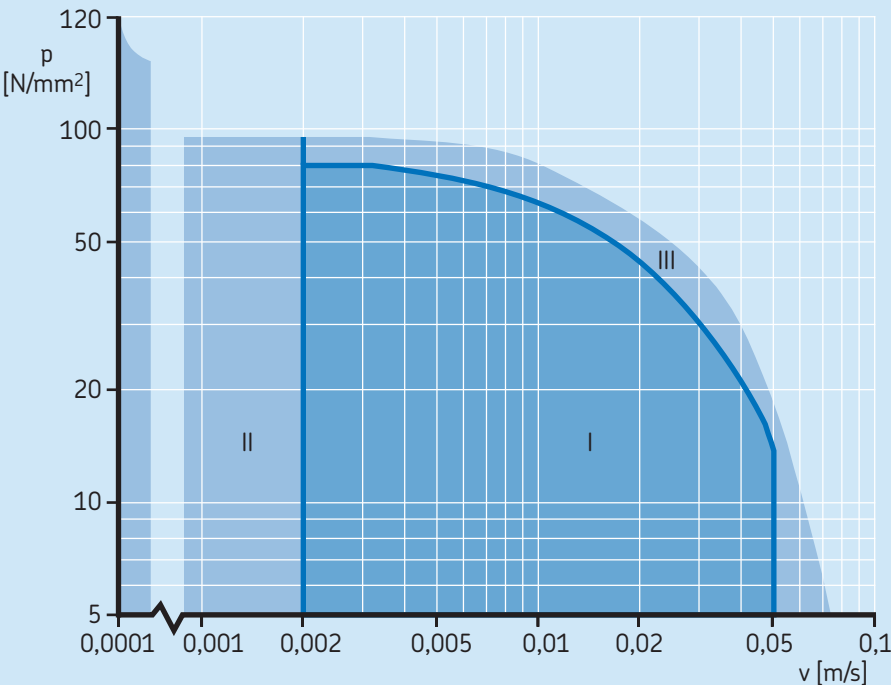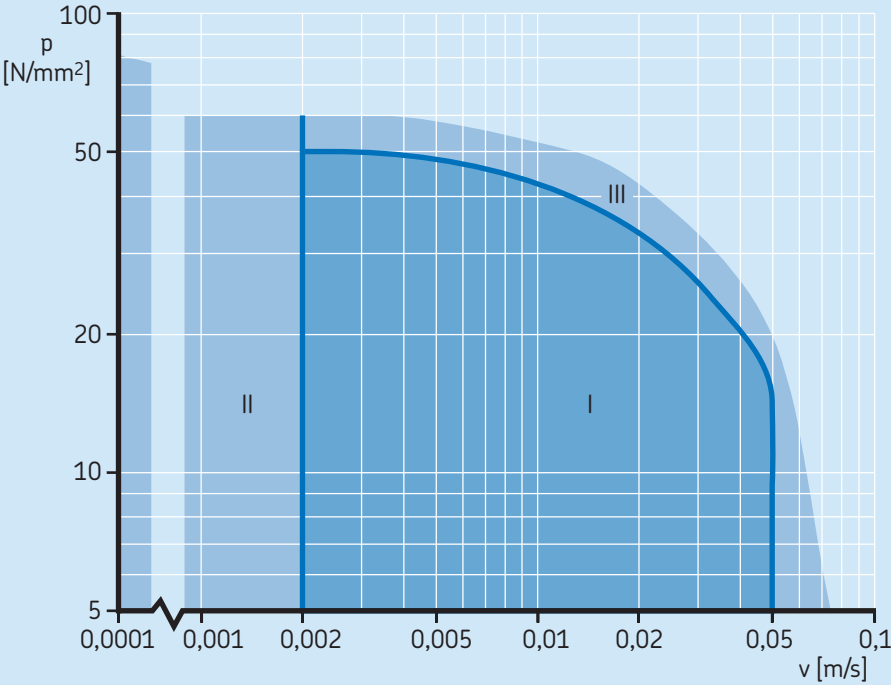Refer to *Note 2* (→ **page 48**) for explanation of operating ranges.

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Basic rating life calculation

Steel/steel and steel/bronze sliding contact surface combinations, requiring maintenance

The basic rating life for initial lubrication only, can be calculated using

$$G_h = b_1\, b_2\, b_3\, b_4\, b_5\, \frac{330}{p^{2,5}\, v}$$

When the bearing is regularly relubricated after the initial lubrication

$$G_{hN} = G_h\, f_\beta\, f_H$$

or

$$G_N = 60\, f\, G_{hN}$$

The frequency of relubrication can be calculated using

$$H = \frac{G_h}{N}$$

where
G_h = basic rating life with initial lubrication only, operating hours [h]
G_{hN} = basic rating life with regular relubrication, operating hours [h]
G_N = basic rating life with regular relubrication, number of oscillations

H = frequency of relubrication (→ **diagram 15** on **page 53**)
b_1 = load condition factor,
$\quad b_1$ = 1 for constant direction load
$\quad b_1$ = 2 for alternating direction load
b_2 = temperature factor (→ **table 5** on **page 52**)
b_3 = sliding factor (→ **diagram 11**)
b_4 = velocity factor (→ **diagram 12** on **page 52**)
b_5 = factor for angle of oscillation (→ **diagram 13** on **page 52**), refer to *Note* (→ **page 53**)
p = specific bearing load [N/mm^2] (for values of $p < 10$ N/mm^2 use $p = 10$ N/mm^2)
v = mean sliding velocity [m/s]
f_β = factor depending on the angle of oscillation (→ **diagram 14** on **page 53**), refer to *Note* (→ **page 53**)
f_H = factor depending on the frequency of relubrication (→ **diagram 15** on **page 53**)
f = frequency of oscillation [min^{-1}]
N = relubrication interval [h]

If the basic rating life requirement is not met, the relubrication interval N should be shortened, or a larger bearing or rod end should be selected.

Diagram 11

Sliding factor b_3 for steel/steel and steel/bronze sliding contact surface combinations

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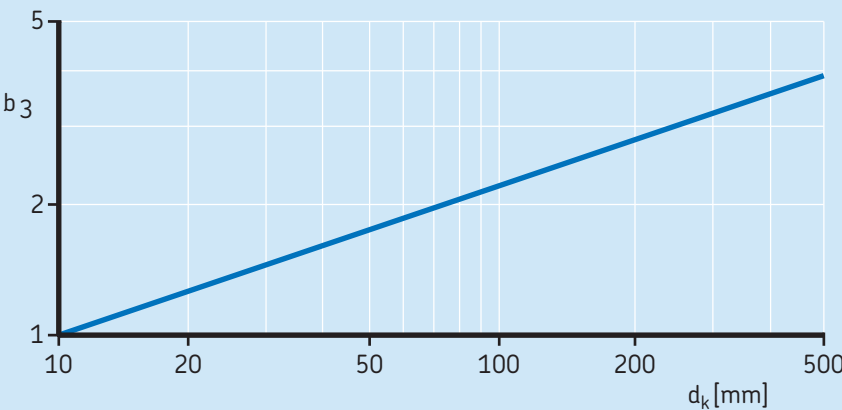
Selection of bearing size

Diagram 12

Velocity factor b_4 for steel/steel and steel/bronze sliding contact surface combinations
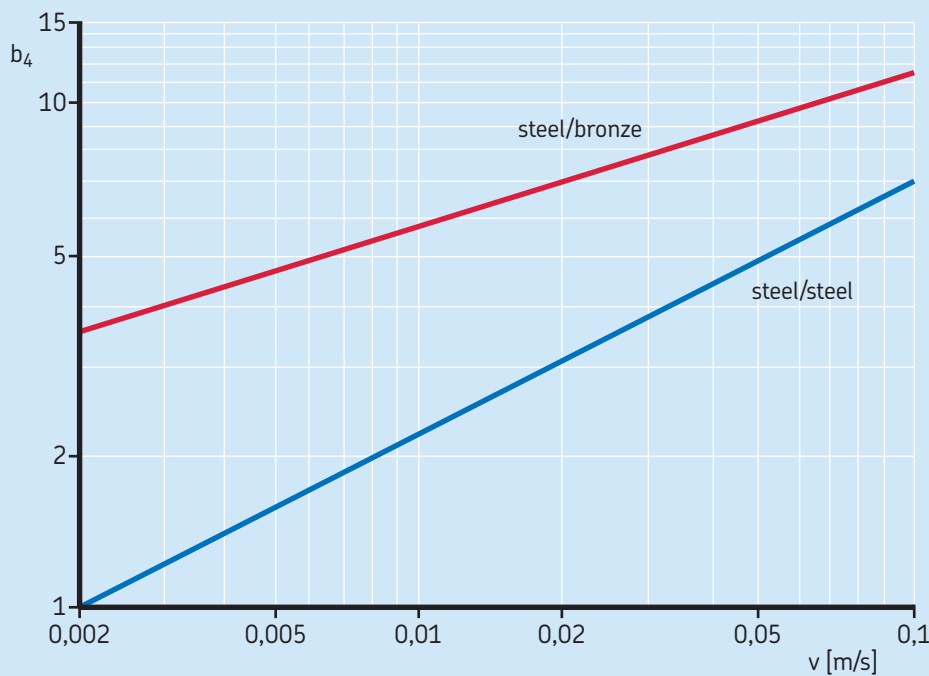
Table 5

Temperature factor b_2 for steel/steel and steel/bronze sliding contact surface combinations

Operating temperature over	incl.	Temperature factor b_2
°C	–	–
–	120	1,0
120	160	0,9
160	180	0,8
180	–	Contact the SKF application engineering service

The temperature limits for integral seals (→ **table 6** on **page 79**) and SKF greases (→ **table 1** on **page 87**) must also be considered.

Diagram 13

Angle of oscillation factor b_5 for steel/steel and steel/bronze sliding contact surface combinations
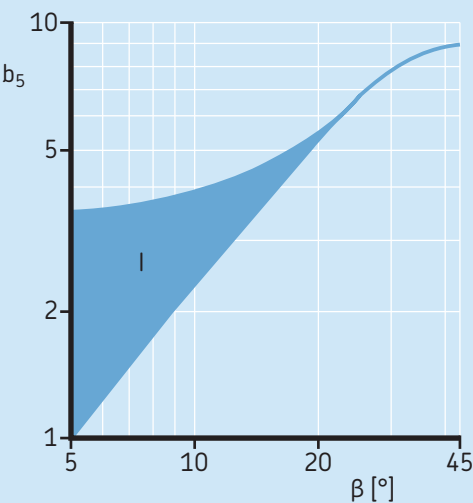
If $\beta < 5°$, the value of b_5 for $\beta = 5°$ should be used.

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Diagram 14

Multiplication factor f_β for steel/steel and steel/bronze sliding contact surface combinations
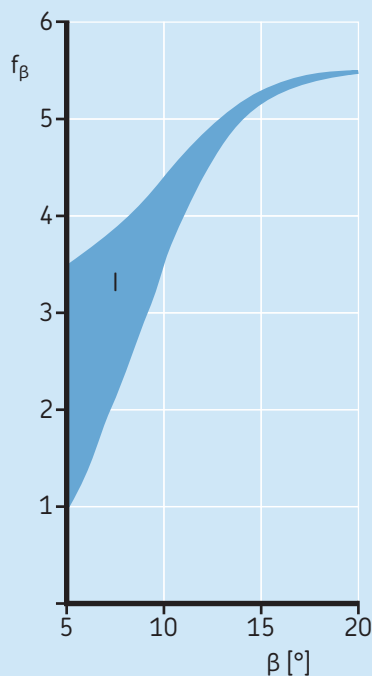
If β < 5°, the value of f_β for β = 5° should be used.

NOTE: SKF manufactures all metric steel/steel radial spherical plain bearings with an outside diameter D ≥ 150 mm as standard with the multi-groove feature in the outer ring (→ **page 17**). The extra large grease reservoir in the bearing, made possible by the multi-groove system, extends relubrication intervals and bearing service life, especially in applications where there are constant direction loads (→ **page 40**).

These advantages are considered in the calculation of the basic rating life by the coloured regions in **diagrams 13** and **14** for the factors for the angle of oscillation b_5 and f_β. The values of these two factors in the upper limit of the coloured area may be used for bearings with the multi-groove system.

Diagram 15

Relubrication factor f_H for steel/steel and steel/bronze sliding contact surface combinations
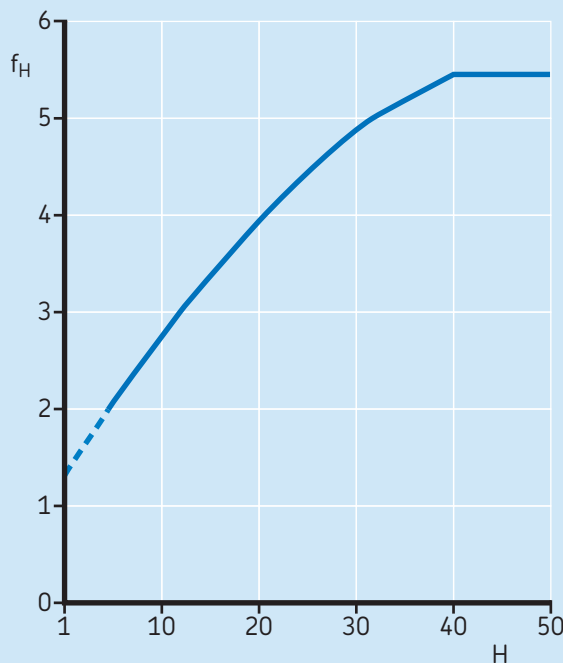
If H < 5, the values indicated by the broken line can be used.

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Selection of bearing size

Maintenance-free steel/PTFE sintered bronze sliding contact surface combination

The basic rating life can be calculated using

$$G_h = b_1\, b_2\, \frac{1\,400}{p^{1,3}\, v}$$

or

$$G = 60\, f\, G_h$$

where
G_h = basic rating life, operating hours
G = basic rating life, number of oscillations
b_1 = load condition factor ($\rightarrow$ **table 6**)
b_2 = temperature factor ($\rightarrow$ **diagram 16**)
p = specific bearing load [N/mm^2]
v = mean sliding velocity [m/s]
f = frequency of oscillation [min^{-1}]

NOTE: Basic rating life calculations consider the influence of the load and sliding velocity. Under very light loads and/or low sliding velocities, the result shows relatively long life. The longer the service life the more important is the influence of contaminants such as dirt, moisture and corrosion. Depending on the operating conditions, accurate life calculations may not be possible.

		Table 6
Load condition factor b$_1$ for the steel/PTFE sintered bronze sliding contact surface combination		
Type of load	**Factor b$_1$**	**Permissible specific bearing load**[1]
–	–	N/mm^2
Constant load[2] Single direction	1	up to 100
Variable load Alternating direction or pulsating magnitude at a frequency up to 0,5 Hz over 0,5 up to 5 Hz	0,4 0,2	up to 60 up to 40

[1] Inertia forces should also be taken into consideration.
[2] For constant load, oscillating frequencies above 300 min^{-1} and very short sliding distances, b$_1$ = 1 cannot be used because of possible material fatigue. For additional information, contact the SKF application engineering service.

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Diagram 16

1

Temperature factor b_2 for the steel/PTFE sintered bronze sliding contact surface combination

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Selection of bearing size

Maintenance-free steel/PTFE fabric sliding contact surface combination

The basic rating life can be calculated using

$$G_h = b_1\, b_2\, b_4\, \frac{K_p}{p^n\, v}$$

or

$$G = 60\, f\, G_h$$

where
G_h = basic rating life, operating hours
G = basic rating life, number of oscillations
b_1 = load condition factor (→ **table 7**)
b_2 = temperature factor (→ **diagram 17**)
b_4 = velocity factor (→ **diagram 18** on **page 58**)
K_p = constant for the specific bearing load
(→ **table 8**)
p = specific bearing load [N/mm^2]
n = exponent for the specific bearing load
(→ **table 8**)
v = mean sliding velocity [m/s]
f = frequency of oscillation [min^{-1}]

NOTE: Basic rating life calculations consider the influence of the load and sliding velocity. Under very light loads and/or low sliding velocities, the result shows relatively long life. The longer the service life the more important is the influence of contaminants such as dirt, moisture and corrosion. Depending on the operating conditions, accurate life calculations may not be possible.
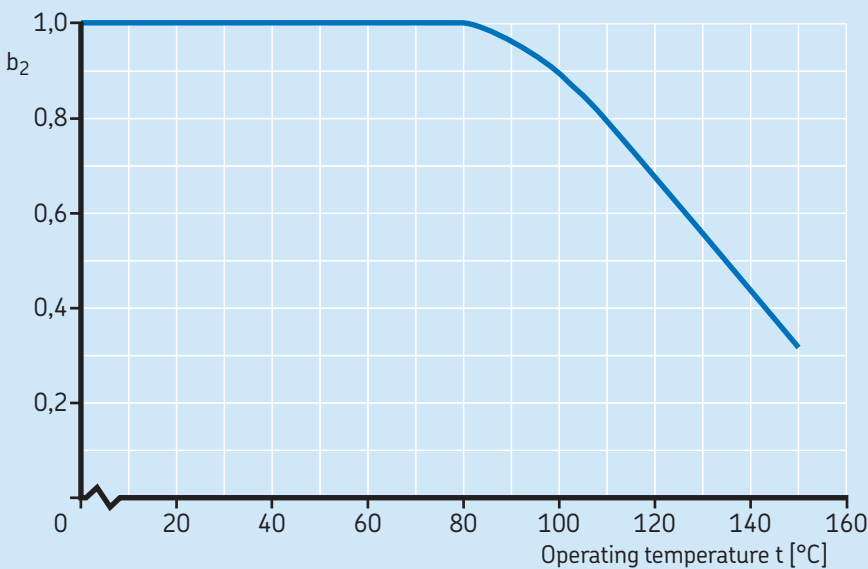
Diagram 17

Temperature factor b_2 for steel/PTFE fabric sliding contact surface combination

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Table 7

Load condition factor b_1 for steel/PTFE fabric sliding contact surface combination

Type of load	Factor b_1[1]	Specific bearing load
–	–	N/mm^2
Constant Single direction	1	up to 300
Variable load Alternating direction or pulsating magnitude at a frequency up to 0,5 Hz	0,55 0,4	up to 50 50 to 100
over 0,5 to 1 Hz	0,35 0,15	up to 50 50 to 100
over 1 to 5 Hz	0,1	up to 50

[1] The factor b_1 covers several parameters that affect the bearing life. Depending on the operating conditions, higher b_1 values can be applied. Contact the SKF application engineering service.

Table 8

Constant K_p and exponent n for steel/PTFE fabric sliding contact surface combination

Specific bearing load[1]		Constant K_p	Exponent n
over	incl.		
N/mm^2		–	–
–	25	770	0,2
25	90	4 000	0,7
90	300	40 000	1,2

[1] For inch bearings, specific bearing load may not exceed 150 N/mm^2 (→ **table 4** on **page 45**).

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Selection of bearing size

Diagram 18

Velocity factor b_4 for steel/PTFE fabric sliding contact surface combination

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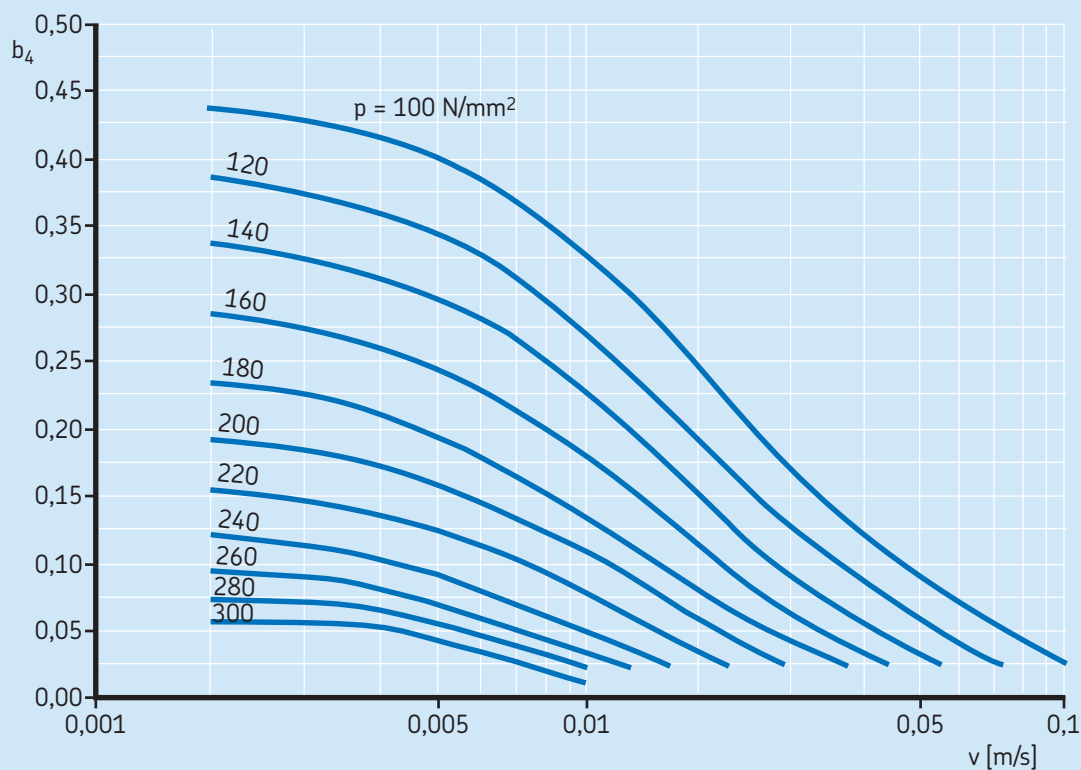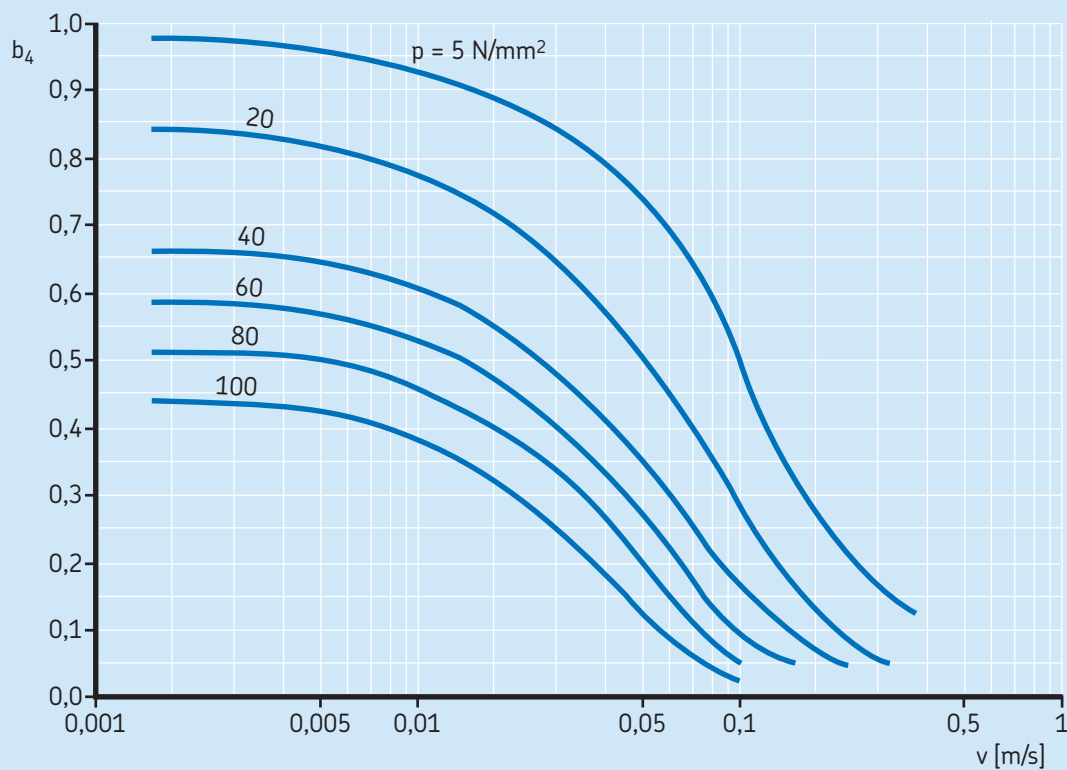
Maintenance-free steel/PTFE FRP sliding contact surface combination

The basic rating life can be calculated using

$$G_h = b_1\, b_2\, b_3\; \frac{K_M}{p\, v}$$

or

$$G = 60\, f\, G_h$$

where
G_h = basic rating life, operating hours
G = basic rating life, number of oscillations
b_1 = load condition factor ($\rightarrow$ **table 9**)
b_2 = temperature factor ($\rightarrow$ **diagram 19**)
b_3 = sliding factor ($\rightarrow$ **table 10** on **page 60**)
K_M = material constant ($\rightarrow$ **table 10** on **page 60**)
p = specific bearing load [N/mm^2]
v = mean sliding velocity [m/s]
f = frequency of oscillation [min^{-1}]

NOTE:
1. The basic rating life calculated from the above equation can be doubled if the bearings are relubricated occasionally (refer to the sections *Lubrication*, starting on **page 84** and *Relubrication* on **page 90**)
2. Rating life calculations consider the influence of the load and sliding velocity. Under very light loads, and/or low sliding velocities, the result shows relatively long life. The longer the service life the more important is the influence of contaminants such as dirt, moisture and corrosion. Depending on the operating conditions, accurate life calculations may not be possible.
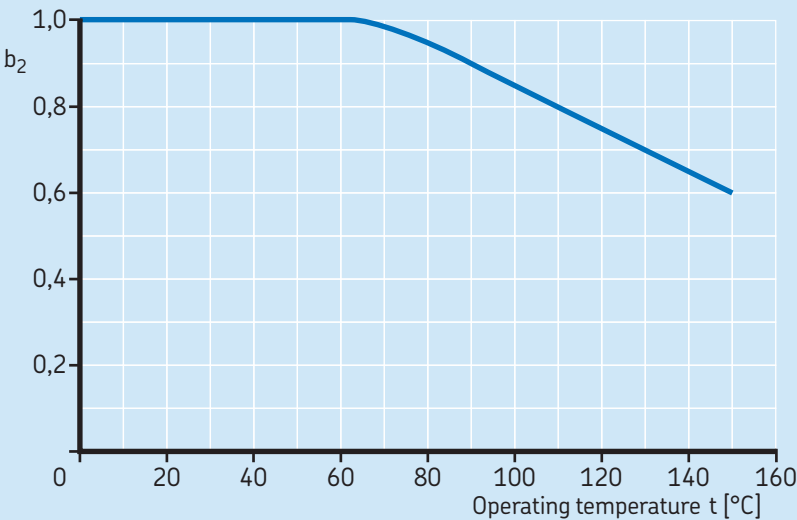

Table 9

Load condition factor b_1 for steel/PTFE FRP sliding contact surface combination

Type of load	Factor b_1	Permissible specific bearing load[1]
–	–	N/mm²
Constant load[2]		
Single direction		
GAC .. F	1	up to 50
GX .. F	1	up to 50
GEP .. FS	1	up to 80
GEC .. FBAS	1	up to 80
Variable load		
Alternating direction		
or pulsating magnitude		
at a frequency		
up to 0,5 Hz	0,25	up to 40
over 0,5 up to 5 Hz	0,1	up to 25

[1] Inertia forces should also be taken into consideration.
[2] For constant load, oscillating frequencies above 300 min^{-1} and very short sliding distances, $b_1 = 1$ cannot be used because of possible material fatigue. For additional information, contact the SKF application engineering service.

Diagram 19

Temperature factor b_2 for steel/PTFE FRP sliding contact surface combination

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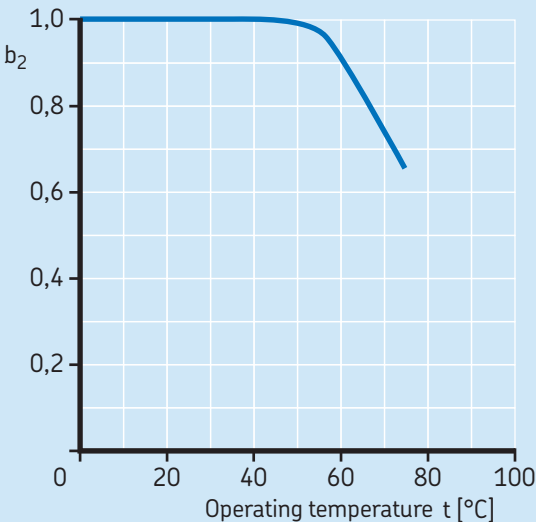
Selection of bearing size

				Table 10
Sliding factor b_3 and constant K_M for steel/PTFE FRP sliding contact surface combination				
Bearing type Series	**Nominal bore diameter d** over	incl.	**Sliding factor** b_3	**Constant** K_M
–	mm		–	–
Radial bearings				
GEP .. FS	–	180	1	1 055
	180	440	1,15	1 055
	440	–	1,35	1 055
GEC .. FBAS	–	440	1	1 055
	440	–	1,15	1 055
Angular contact bearings[1]				
GAC .. F	–	60	1	480
	60	–	1,5	480
Thrust bearings				
GX .. F	–	60	1	670
	60	–	1,5	670
Rod ends			1	530

[1] For preloaded bearings that cannot be re-adjusted, always use $b_3 = 1$.

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Variable load and sliding velocity

If the load and/or sliding velocity change during operation, calculate individual rating lives for the periods of constant load and sliding velocity. If the load and sliding velocity occur as shown in **diagram 20a**, the individual basic rating life can be calculated using the constant values of p and v. If the load and sliding velocity are not constant as shown in **diagram 20b**, first calculate the basic rating life for the individual time periods, using mean values for the load and sliding velocity for the individual time periods. Then calculate the total basic rating life using

$$G_h = \frac{1}{\dfrac{t_I}{T\,G_{hI}} + \dfrac{t_{II}}{T\,G_{hII}} + \dfrac{t_{III}}{T\,G_{hIII}} + \dots}$$

where
G_h = total basic rating life, operating hours
$t_I, t_{II} \dots$ = time during which p_1 and v_1, p_2 and v_2 etc. pertain [h]
T = total duration of one cycle $(= t_I + t_{II} + t_{III} + \dots)$ [h]
$G_{hI} \dots$ = individual values of basic rating life for conditions p_1 and v_1, p_2 and v_2 etc., operating hours

Diagram 20

Alternating load and variable sliding velocity

a

b
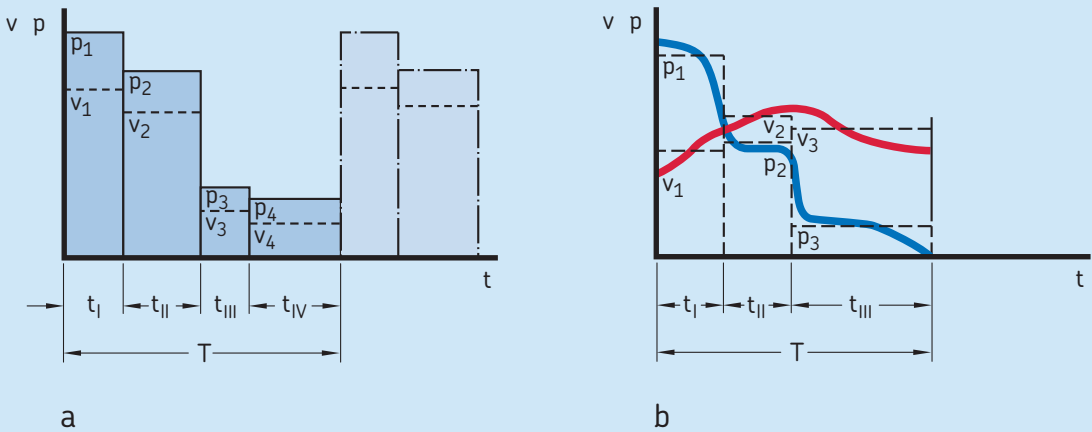
Selection of bearing size

Calculation examples

The following calculation examples illustrate the methods used to determine the requisite bearing size or the basic rating life for spherical plain bearings and rod ends.

1. Torque support of a concrete transporter

Given data
Purely radial load that alternates direction:
F_r = 12 kN
Half angle of oscillation: β = 15°
(→ **fig. 3** on **page 39**)
Frequency of oscillation: f = 10 min^{-1}
Maximum operating temperature: +80 °C

Requirements
The bearing must have a basic rating life of 7 000 h.

Calculations and selection
Because a bearing in this application must accommodate an alternating load, a steel/steel radial spherical plain bearing is the appropriate choice. Relubrication is planned after every 40 hours of operation.

If, for the first check, a guideline value of 2 is used for the load ratio C/P (→ **table 3** on **page 45**), the required basic dynamic load rating C for the bearing is

C = 2 P = 24 kN

Bearing GE 20 ES, with a C = 30 kN and a sphere diameter d_k = 29 mm, is chosen from the product table on **page 104**.

To check the suitability of the bearing using the pv diagram (→ **diagram 5** on **page 46**), calculate the specific bearing load using K = 100 from **table 4** on **page 45**.

$$p = K\ \frac{P}{C} = 100 \times \frac{12}{30} = 40\ N/mm^2$$

and the sliding velocity v using d_m = d_k = 29 mm, β = 15° and f = 10 min^{-1}

$$v = 5{,}82 \times 10^{-7}\ d_m\ β\ f$$

$$= 5{,}82 \times 10^{-7} \times 29 \times 15 \times 10 = 0{,}0025\ m/s$$

The values for p and v lie within the permissible operating range l of the pv diagram (→ **diagram 5** on **page 46**), for steel/steel radial spherical plain bearings. To calculate the basic rating life for initial lubrication, the values that apply are

b_1 = 2 (alternating direction load)
b_2 = 1 (operating temperature < 120 °C from **table 5** on **page 52**)
b_3 = 1,5 (from **diagram 11** on **page 51**, for d_k = 29 mm)
b_4 = 1,1 (from **diagram 12** on **page 52**, for v = 0,0025 m/s)
b_5 = 3,7 (from **diagram 13** on **page 52**, for β = 15°)
p   = 40 N/mm^2
v   = 0,0025 m/s

Therefore

$$G_h = b_1\ b_2\ b_3\ b_4\ b_5\ \frac{330}{p^{2,5}\ v}$$

$$= 2 \times 1 \times 1{,}5 \times 1{,}1 \times 3{,}7 \times \frac{330}{40^{2,5} \times 0{,}0025}$$

$$≈ 160\ \text{operating hours}$$

The basic rating life of the bearing that is relubricated regularly can now be calculated using

$f_β$ = 5,2 (from **diagram 14** on **page 53**)
f_H = 1,8 (from **diagram 15** on **page 53**, for a relubrication frequency H = G_h/N = 160/40 = 4 with the relubrication interval of 40 h)

$$G_{hN} = G_h\ f_β\ f_H = 160 \times 5{,}2 \times 1{,}8$$

$$≈ 1\ 500\ \text{operating hours}$$

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Because this life is shorter than the required rating life of 7 000 h, a larger bearing is chosen and calculations are repeated.

Bearing GE 25 ES, with C = 48 kN and d_k = 35,5 mm, is chosen. The values for the specific bearing load lie within the permissible operating range I of the pv diagram (→ **diagram 5** on **page 46**)

$$p = 100 \times \frac{12}{48} = 25 \text{ N/mm}^2$$

and the sliding velocity is

$$v = 5,82 \times 10^{-7} \times 35,5 \times 15 \times 10 = 0,0031 \text{ m/s}$$

As before

$$b_1 = 2, b_2 = 1, b_5 = 3,7$$

and now
b_3 = 1,6 (from **diagram 11** on **page 51**, for d_k = 35,5 mm)
b_4 = 1,2 (from **diagram 12** on **page 52** , for v = 0,0031 m/s)

Therefore, the basic rating life for initial lubrication is

$$G_h = 2 \times 1 \times 1,6 \times 1,2 \times 3,7 \times \frac{330}{25^{2,5} \times 0,0031}$$

≈ 480 operating hours

With f_β = 5,2 (from **diagram 14** on **page 53**) and f_H = 3 (from **diagram 15** on **page 53** for H = 480/40 = 12) the basic rating life for regular relubrication (N = 40 h) becomes

$$G_{hN} = 480 \times 5,2 \times 3 \approx 7\ 490 \text{ operating hours}$$

This larger bearing satisfies the rating life requirement.

NOTE: The *SKF Interactive Engineering Catalogue* incorporates programs to perform these and many other calculations quickly and accurately. These programs can be run any number of times to find the best possible solution.

The *SKF Interactive Engineering Catalogue* is available online at www.skf.com.

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Selection of bearing size

2. Attachment of a shock absorber of an off-highway vehicle

Given data:
Radial load: F_r = 7 kN
Axial load: F_a = 0,7 kN
Half angle of oscillation: β = 8° (→ **fig. 3** on **page 39**)
Frequency of oscillation: f = 15 min⁻¹
Load frequency: 2–5 Hz
Maximum operating temperature: +75 °C

Requirements:
This bearing must have a basic rating life corresponding to a driven distance of 100 000 km at an average speed of 65 km/h without maintenance.

Calculations and selection
For design reasons, a GE 20 C spherical plain bearing with a steel/PTFE sintered bronze sliding contact surface combination is proposed. From the product **table** on **page 132**, the basic dynamic load rating C = 31,5 kN and the sphere diameter d_k = 29 mm are obtained.

First, the equivalent dynamic bearing load must be determined by

$$F_a/F_r = 0,7/7 = 0,1$$

From **diagram 2** on **page 42** factor y = 1,4. The equivalent dynamic bearing load is therefore

$$P = y\ F_r = 1,4 \times 7 = 9,8\ \text{kN}$$

To check the suitability of the bearing size using the pv **diagram 7** on **page 48**, calculate the values for the specific bearing load (using K = 100 from **table 4** on **page 45**) using

$$p = K\ \frac{P}{C} = 100 \times \frac{9,8}{31,5} = 31\ \text{N/mm}^2$$

and the sliding velocity (d_m = d_k = 29 mm).

$$v = 5,82 \times 10^{-7}\ dm\ β\ f$$

$$= 5,82 \times 10^{-7} \times 29 \times 8 \times 15 = 0,002\ \text{m/s}$$

The values for p and v lie within the permissible operating range I of the pv diagram where

b_1 = 0,2 (from **table 6** on **page 54**, for a load frequency over 0,5 Hz and 25 < p < 40 N/mm²)
b_2 = 1 (from **diagram 16** on **page 55**, for temperatures < 80 °C)

The basic rating life for a GE 20 C bearing with the steel/PTFE sintered bronze sliding contact surface combination is

$$G_h = b_1\ b_2\ \frac{1\ 400}{p^{1,3}v}$$

$$= 0,2 \times 1 \times \frac{1\ 400}{31^{1,3} \times 0,002}$$

$$\approx 1\ 600\ \text{operating hours}$$

This basic rating life corresponds to a distance (at an average speed of 65 km/h) of 1 600 × 65 = 104 000 km. Therefore, the bearing satisfies the rating life requirement.

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3. A 320-bar hydraulic cylinder on a fully automatic press for building industry waste

Given data
Radial load (constant direction)

Operation case	Load F_r	Time period t
I	300 kN	10%
II	180 kN	40%
III	120 kN	50%

The number of press cycles n = 30 per hour, and the movement between the end positions (90°) is made in 10 seconds. The operating temperature is less than +50 °C.

Requirements
A maintenance-free radial spherical plain bearing with a steel/PTFE fabric sliding contact surface combination is required for a rating life of 5 years with 70 h of operation per week.

Calculations and selection
Using a guideline value for the load ratio C/P = 2 (→ **table 3** on **page 45**), and with P = F_{rI} the required basic dynamic load rating

C = 2 P = 2 × 300 = 600 kN

From the product **table** on **page 136**, a GE 60 TXE-2LS bearing with a basic dynamic load rating C = 695 kN and a sphere diameter $d_k = d_m = 80$ mm is chosen.

First, it is necessary to check that the operation cases I to III fall within the permissible range of the pv **diagram 8** on **page 49**.

The sliding velocity is the same for all three cases. The angle of oscillation is specified as 2β, the time t as the time taken to pass through 2β in seconds. Complete cycle duration is 4β (→ **fig 3** on **page 39**).

$$v = 8{,}73 \times 10^{-6}\, d_m \frac{2\beta}{t}$$

$$= 8{,}73 \times 10^{-6} \times 80 \times \frac{90}{10} = 0{,}0063 \text{ m/s}$$

The specific bearing load, p = K(P/C), using K = 300 from **table 4** on **page 45** , is

for case I

$$p_I = K\frac{P}{C} = 300 \times \frac{300}{695} = 129{,}5 \text{ N/mm}^2$$

for case II

$$p_{II} = K\frac{P}{C} = 300 \times \frac{180}{695} = 77{,}7 \text{ N/mm}^2$$

for case III

$$p_{III} = K\frac{P}{C} = 300 \times \frac{120}{695} = 51{,}8 \text{ N/mm}^2$$

The values for p_I, p_{II}, p_{III} and v are within the permissible range I of the pv **diagram 8** on **page 49**.

To make the lifetime estimate for variable loads and/or sliding velocities, the calculation of each load case has to be made separately, with the equation for TX bearings first

$$G_h = b_1\, b_2\, b_4\, \frac{K_p}{p^n v}$$

The parameters b_1, b_2, b_4, K_p and n are defined on **page 56** and are as follows

b_1 = 1 (from **table 7** on **page 57**, constant load)
b_2 = 1 (from **diagram 17** on **page 56**, operating temperature < +50 °C)
b_4 = (from **diagram 18** on **page 58**)
    $b_{4\,I}$ = 0,31
    $b_{4\,II}$ = 0,48
    $b_{4\,III}$ = 0,57
K_p = (from **table 8** on **page 57**)
    $K_{p\,I}$ = 40 000
    $K_{p\,II}$ = 4 000
    $K_{p\,III}$ = 4 000
n = (from **table 8** on **page 57**)
    n_1 = 1,2
    n_2 = 0,7
    n_3 = 0,7

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Selection of bearing size

for case I

$$G_{hI} = 1 \times 1 \times 0{,}31 \times \frac{40\,000}{129{,}5^{1{,}2} \times 0{,}0063}$$

= 5 745 operating hours

for case II

$$G_{hII} = 1 \times 1 \times 0{,}48 \times \frac{4\,000}{77{,}7^{0{,}7} \times 0{,}0063}$$

= 14 477 operating hours

for case III

$$G_{hII} = 1 \times 1 \times 0{,}57 \times \frac{4\,000}{51{,}8^{0{,}7} \times 0{,}0063}$$

= 22 833 operating hours

Using the calculated basic rating lives of the three operation cases, the total basic rating life for continuous operation is (→ **page 61**)

$$G_h = \frac{1}{\dfrac{t_I}{T\,G_{hI}} + \dfrac{t_{II}}{T\,G_{hII}} + \dfrac{t_{III}}{T\,G_{hIII}}}$$

For t_I, t_{II} etc., the percentages given in the operating data are inserted (with $T = t_I + t_{II} + t_{III} = 100\%$.)

$$G_h = \frac{1}{\dfrac{10}{100 \times 5\,745} + \dfrac{40}{100 \times 14\,477} + \dfrac{50}{100 \times 22\,833}}$$

≈ 14 940 operating hours

The required life of five years should be met assuming the machine is operated 70 h/week, 30 cycles/hour and 50 weeks per year, to 525 000 cycles or 2 916 operating hours. (Note that time for a complete cycle is 20 s.)

$G_{N,\,Req} = 5 \times 70 \times 30 \times 50 = 525\,000$ cycles
$G_{h,\,Req} = (525\,000 \times 20)/3600 = 2\,916$ h.

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4. Linkages of a conveyor installation

Given data
Radial load of alternating direction: F_r = 5,5 kN
Half angle of oscillation: β = 15° (→ **fig. 3** on **page 39**)
Frequency of oscillation: f = 25 min^{-1}
Operating temperature: +70 °C

Requirements
A rod end is needed that provides a basic rating life of 9 000 hours under alternating load conditions.

Calculations and selection
Because the load is alternating, a steel/steel rod end is appropriate. Relubrication is planned every 40 hours of operation. Using the guideline value for the load ratio C/P = 2 from **table 3** on **page 45**, and as P = F_r, the requisite basic dynamic load rating is

C = 2 P = 2 × 5,5 = 11 kN

The SI 15 ES rod end with a basic dynamic load rating C = 17 kN is selected (→ **page 172**). The basic static load rating is C_0 = 37,5 kN and the sphere diameter d_k = 22 mm.
   To check the suitability of rod end size using the pv **diagram 5** on **page 46**, calculate the values for the specific bearing load (using K = 100 from **table 4** on **page 45**)

$$p = K \; \frac{P}{C} = 100 \times \frac{300}{695} = 32,4 \text{ N/mm}^2$$

and the mean sliding velocity ($d_m = d_k$ = 22 mm)

v = 5,82 × 10^{-7} d_k β f

   = 5,82 × 10^{-7} × 22 × 15 × 25 = 0,0048 m/s

The values for p and v lie within the permissible range I of the pv **diagram 5** on **page 46**.
   Checking the permissible load on the rod end housing

C_0 = 37,5 kN
b_2 = 1 (from **table 5** on **page 52**,
          for temperatures < 120 °C)
b_6 = 0,35 (from **table 2** on **page 44**,
          for rod ends with a lubrication hole)
P_{perm} = C_0 b_2 b_6

          = 37,5 × 1 × 0,35

          = 13,125 kN > P

The following values of the factors are used to determine the basic rating life for initial lubrication only

b_1 = 2 (alternating load)
b_2 = 1 (for operating temperatures < 120 °C, from **table 5** on **page 52**)
b_3 = 1,3 (from **diagram 11** on **page 51**, for d_k = 22 mm)
b_4 = 1,6 (from **diagram 12** on **page 52**, for v = 0,0048 m/s)
b_5 = 3,7 (from **diagram 13** on **page 52**, for β = 15°)
p   = 32 N/mm^2
v   = 0,0048 m/s

Therefore

$$G_h = b_1 \, b_2 \, b_3 \, b_4 \, b_5 \; \frac{330}{32,4^{2,5} \times 0,0048}$$

$$= 2 \times 1 \times 1,3 \times 1,6 \times 3,7 \times \frac{330}{32,4^{2,5} \times 0,0048}$$

   ≈ 177 operating hours

The basic rating life for regular relubrication (N = 40 h) with

$f_β$ = 5,2 (from **diagram 14** on **page 53**) and
f_H = 2 (from **diagram 15** on **page 53**, for H = G_h/N = 177/40 = 4,4)
G_{hN} = G_h f_b f_H = 177 × 5,2 × 2

      ≈   1 840 operating hours

Selection of bearing size

The required basic rating life of 9 000 h is not achieved; therefore a larger rod end has to be selected. A SI 20 ES rod end, with C = 30 kN, C_0 = 57 kN and d_k = 29 mm is selected and the calculation repeated.

The values for the specific bearing load

$$p = K \frac{P}{C} = 100 \times \frac{5,5}{30} = 18,3 \text{ N/mm}^2$$

and the mean sliding velocity ($d_m = d_k$ = 29 mm)

$$v = 5,82 \times 10^{-7} \times 29 \times 15 \times 25 = 0,0063 \text{ m/s}$$

both lie within the permissible range I. It is not necessary to check the permissible rod end housing load since the basic static load rating of the larger rod end is higher. Also, as before

b_1 = 2; b_2 = 1 and b_5 = 3,7

while
b_3 = 1,4 (from **diagram 11** on **page 51**, for d_k = 29 mm)
b_4 = 1,8 (from **diagram 12** on **page 52**, for v = 0,0063 m/s)

so that

$$G_h = 2 \times 1 \times 1,4 \times 1,8 \times 3,7 \times \frac{330}{18,3^{2,5} \times 0,0063}$$

≈ 681 operating hours

With f_β = 5,2 (from **diagram 14** on **page 53**) and f_H = 3,7 (from **diagram 15** on **page 53**, for H = 681/40 ≈ 17) the basic rating life for regular relubrication (N = 40 h) becomes

$$G_{hN} = 681 \times 5,2 \times 3,7$$

≈ 13 100 operating hours

Therefore, the larger rod end meets the rating life requirements.

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