MOTORSERVICE

KS Permaglide®
Plain Bearings

Catalogue 2015

KOLBENSCHMIDT

Motorservice

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KS Gleitlager

Within the Kolbenschmidt Pierburg Group,
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As long-standing partners to the automotive industry, the companies in the KSPG Group develop innovative components and system solutions with acknowledged competence for air supply and emission control, for oil and water pumps, for pistons, engine blocks and engine bearings. The products comply with the high demands and quality standards of the automotive industry. Low emission, reduced fuel consumption, reliability, quality and safety – these are the forces that drive innovation at KSPG.

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KS Permaglide® P1 plain bearings

- Maintenance-free
- Suitable for dry running

Characteristics & properties	Units	P10 P11	P14	P147*
lead-free	–	no	yes	yes
pv_{max}	MPa · m/s	1.8	1.6	1.4
$p_{max.stat.}$	MPa	250	250	250
$p_{max.dyn.}$	MPa	56	56	56
$v_{max.}$	m/s	2	1	0.8
T	°C	−200 to +280	−200 to +280	−200 to +280

Versions of the KS Permaglide® P1

PAP bushes
*P10, P11, P14, P147**

PAF collar bushes
*P10, P11, P14, P147**

PAW thrust washers
*P10, P11, P14, P147**

PAS strips
*P10, P11, P14, P147**

KS Permaglide® P1 materials

Standard material P10
- Contains lead
- Very low stick-slip tendency
- Low wear
- Good chemical resistance
- Low friction coefficient
- No tendency to fuse with metal
- Largely resistant to swelling
- Does not absorb water

Special material P11
- Contains lead
- Improved corrosion resistance
- Very good thermal conductivity and therefore greater reliability
- Anti-magnetic
- All other properties as P10

Standard material P14
- Lead-free
- Very low stick-slip tendency
- Low wear
- Low friction coefficient
- No tendency to fuse with metal
- Largely resistant to swelling

Special material P147*
- Lead-free
- Very good corrosion resistance
- All other properties as P14

* Auf Anfrage

KS Permaglide® P2 plain bearings

- Low-maintenance
- For grease or liquid-lubricated applications

Characteristics & properties	Unit	P20 P22*, P23*	P200 P202*, P203*
lead-free	–	no	yes
pv_{max}	MPa · m/s	3	3.3
$p_{max.stat.}$	MPa	250	250
$p_{max.dyn.}$	MPa	70	70
$v_{max.}$	m/s	3	3.3
T	°C	−40 to +110	−40 to +110

Versions of the KS Permaglide® P2

PAP bushes
P20, P22, P23*,*
P200, P202, P203**

PAW thrust washers
P20, P22, P23*,*
P200, P202, P203**

PAS strips
P20, P22, P23*,*
P200, P202, P203**

KS Permaglide® P2 materials

Standard material P20
- Contains lead
- With oil distributing pockets, ready to install
- Lifetime lubrication possible
- Low wear
- Low sensitivity to edge loading
- Good damping characteristics
- Insensitive to impact
- Good chemical resistance

Special material P22*
- Contains lead
- Smooth sliding surface, with machining allowance
- All other properties as P20

Special material P23*
- Contains lead
- Smooth sliding surface, ready to install
- All other properties as P20

Standard material P200
- Lead-free
- With oil distributing pockets, ready to install
- Lifetime lubrication
- Low wear
- Very good dry-running properties
- Insensitive to edge loading and impact
- Good damping characteristics
- Good chemical resistance

Special material P202*
- Lead-free
- Smooth sliding surface, with machining allowance
- All other properties as P20

Special material P203*
- Lead-free
- Smooth sliding surface, ready to install
- All other properties as P20

* On request

2 | Descriptions and units

Unless otherwise expressly noted in the text, the descriptions, units and meaning of the values used in this catalogue are as follows.

Symbol	Unit	Description
B	mm	Bush width, total strip width
B_1	mm	Usable strip width
C_i	mm	Inside bevel of bush (bevelled edge)
C_o	mm	Outside bevel of bush
D_{FL}	mm	Collar diameter
D_i	mm	Bush inside diameter Inside diameter of thrust washer
D_{iE}	mm	Bush inside diameter in pressed-in state
D_O	mm	Outside diameter of bush Outside diameter of thrust washer
d_{ch}	mm	Diameter of test holder (adjusting mandrel)
d_G	mm	Diameter of housing bore
d_H	mm	Inside diameter of auxiliary ring
d_K	mm	Diameter of calibrating mandrel
d_L	mm	Oil hole diameter
d_W	mm	Shaft diameter
d_1	mm	Diameter of mounting hole in thrust washer
d_{6a}	mm	Diameter of housing recess for thrust washer
F	N	Bearing load, press-in force
F_{ch}	N	Test force
F_E	N	Press-in force per mm of bush width
F_{Ges}	N	Total press-in force
f_G	mm	Chamfer width on housing
f_A	–	Load type correction factor
f_L	–	Linear movement correction factor
f_p	–	Load correction factor
f_R	–	Roughness depth correction factor
f_T	–	Temperature correction factor
f_v	–	Sliding speed correction factor
f_W	–	Material correction factor

Symbol	Unit	Description (continued)
H	mm	Stroke on linear movement
J	mm	Pitch circle diameter of thrust washer
L	mm	Strip length
L_N	h	Nominal service life
m	g	Weight
n	min^{-1}	Speed
n_{OSZ}	min^{-1}	Oscillating frequency of oscillating movement
p	MPa	Specific bearing load
pv	MPa · m/s	pv value, product of specific bearing load and sliding speed
R, r	mm	Radius
R_z	µm	Roughness depth
s_1	mm	Thickness of steel or bronze back
s_3	mm	Wall thickness of bush
s_{FL}	mm	Collar thickness
T	°C	Temperature
t_a	mm	Depth of housing recess
v	m/s	Sliding speed
x	mm	Measuring line distance
z	mm	Distance btwn. test holder halves
α_{Bz}	K^{-1}	Thermal expansion coefficient of bronze
α_{St}	K^{-1}	Thermal expansion coefficient of steel
Δs	mm	Theoretical bearing clearance
Δz	mm	Measured value in test holder
λ_{Bz}	$W(mK)^{-1}$	Coeff. of thermal conductivity, bronze
λ_{St}	$W(mK)^{-1}$	Coeff. of thermal conductivity, steel
μ	–	Coefficient of friction
τ_S	N/mm^2	Shear strength
φ	°	Swivel angle

Plain bearings are used to absorb and convey forces between parts that move relative to one another. They determine the position of the moved components in relation to one another and ensure accuracy of the movement.

Plain bearings must satisfy a great many requirements. They must be capable of tolerating high mechanical loads, while suffering only minimal wear throughout their service life. Likewise, they must withstand high sliding speeds and be insensitive to disturbances from the bearing environment.

Figure 1 shows just how complex a tribological system can be, at the centre of which a plain bearing is working.

Influences in a tribological system

1 Intermediate material
2 Load
3 Interacting sliding part
4 Relative movement
5 Base body
6 Ambient conditions

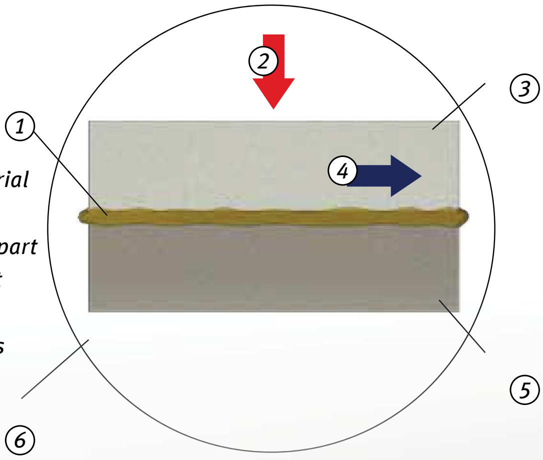


Fig. 1: Tribological system

Ambient conditions
- Temperature, medium, dirt

Load
- Amount and type of load (static, dynamic)
- Load time (constant, with intervals), circumferential load, concentrated load

Interacting sliding part
- Material, hardness, surface roughness, thermal conductivity

Relative movement
- Rotating, oscillating, linear
- Sliding speed, duration of movement

Intermediate material
- Solid lubricant, grease, liquid, viscosity
- Ageing resistance

Base body
- Material, hardness, surface roughness, wear resistance, limp-home capability
- Chemical resistance

In terms of the method of operation, we distinguish between three different functional systems:
- Dry-running, maintenance-free plain bearings
- Grease-lubricated, low-maintenance plain bearings
- Hydrodynamically operated plain bearings

Plain bearings that work on the principles of hydrodynamics can satisfy the various requirements comparatively well.
In this way, oil-lubricated plain bearings, in particular, can be designed for optimum, reliable operation with the aid of modern calculation methods.

Low-maintenance plain bearings are generally lubricated with grease. The quantity of grease applied during installation is normally sufficient for the entire service life.
If a grease-lubricated plain bearing is used in difficult conditions, subsequent lubrication is recommended. Correctly timed relubricating intervals can considerably lengthen service life.

Due to the many influencing factors however, calculating the expected service life of grease-lubricated plain bearings is fraught with uncertainty and can only be used as a guide. In many cases, lubrication using oil or grease is not possible or not permitted. In cases like this, maintenance-free, dry-running plain bearings are employed. Here, too, calculating the service life is not sufficiently precise.

The common practice of calculating service life using simple methods and taking into account influencing factors (such as specific load, sliding speed, temperature, etc.) can provide only approximate values. It is therefore recommended to verify the design and layout of both maintenance-free, dry-running and low-maintenance plain bearings, through field-oriented tests.

The sections that follow discuss the special functional models of maintenance-free and low-maintenance plain bearings.

3.1 Introduction to material P1

3.1.1 General

The P1 material group includes the materials P10, P11, P14 and P147. P10 and P11 contain lead in the bronze sliding layer and the lubricant mass. P14 and P147 are lead-free.

3.1.2 Material composition

Materials in the P1 group consist of a steel or bronze back, a sintered sliding layer of special bronze with a layer thickness of 0.2 mm to 0.35 mm and a solid lubricant mass. The bronze sliding layer is sintered in such a way as to achieve a porosity volume of approx. 30 %. A solid lubricant mixture – usually PTFE with bulking agents – is rolled in to fill the gaps in the porous sliding layer. The solid lubricant mixture completely fills the cavities and forms a running-in layer up to 0.03 mm thick above the bronze sliding layer (Fig. 2).

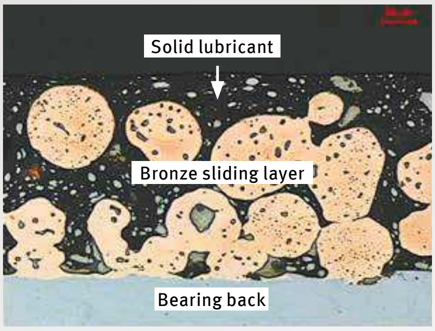
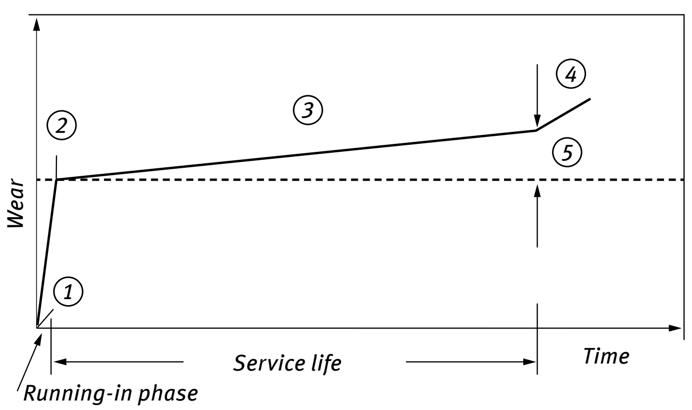


Fig. 2: P1 layer system

3.1.3 Functional description

Maintenance-free, dry-running P1 plain bearings go through four phases during their overall service life (Fig. 3).



1 Initial state
2 End of running-in process
3 During service life
4 End of service life
5 Maximum permitted wear

Fig. 3: Wear curve of P1 plain bearing (schematic) /1/

Initial state
The cavities in the bronze sliding layer are completely filled with solid lubricant, and the running-in layer above the bronze sliding layer is still in perfect condition (Fig. 4).

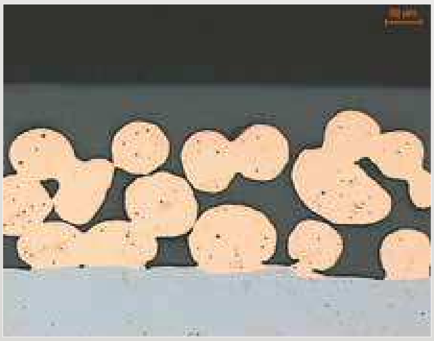


Fig. 4: Condition of sliding surface in the initial state

Running-in process

As the sliding movement commences, parts of the running-in layer are transferred to the moving interacting sliding part (Fig. 6). During this process, a sealed film of solid lubricant forms on the interacting sliding part, which considerably reduces the friction. This running-in process causes up to 0.005 and 0.030 mm of material to be removed from the sliding layer of the bearing. The condition of the sliding surface at the end of the running-in period can be seen in Fig. 5.

Continuous operation

Once the running-in process is complete, the plain bearing commences its actual useful life. This is determined by the load collective and ambient conditions, but also by the ratio of the bronze sliding layer volume to the solid lubricant volume. During the period of operation, new solid lubricant is constantly entering the contact zone, replacing the used bits of solid lubricant. This process is triggered, above all, by the different expansion coefficients of the bronze sliding layer and the solid lubricant (ratio ~1:5.5). When the sliding layer heats up due to the friction work in the contact zone, the solid lubricant expands to a greater extent, lubricating the moving interacting sliding part. This lowers the friction coefficient and the bearing temperature.

When the lubricant is used up, a new cycle commences. Fig. 7 shows a typical curve of this development. Fig. 8 illustrates the condition of the sliding surface during service life.

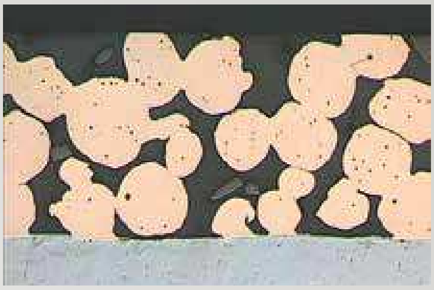


Fig. 5: Condition of sliding surface at end of running-in process

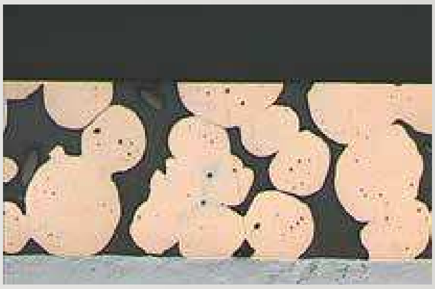


Fig. 8: Condition of sliding surface during service life

Fig. 6: Material transfer

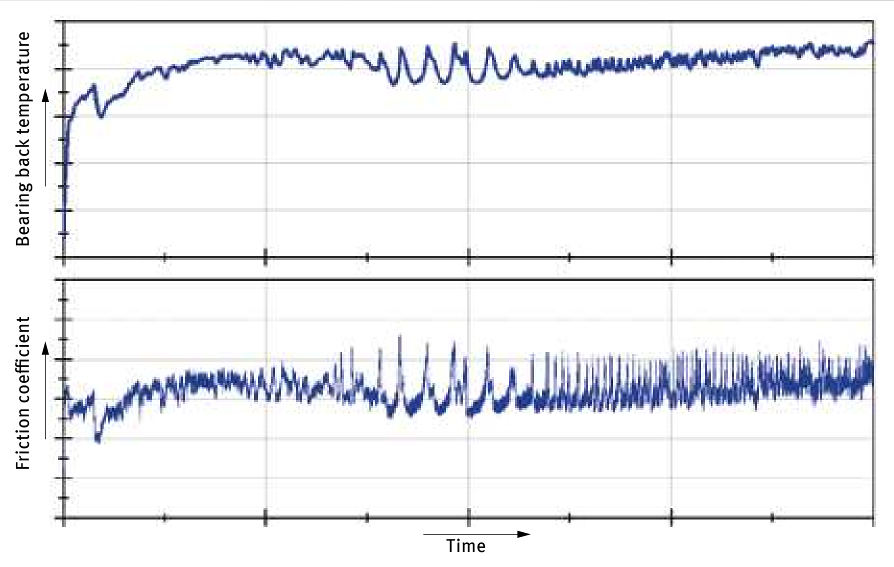


Fig. 7: Oscillation characteristic of friction coefficient and temperature

End of service life

The solid lubricant in the plain bearing system is only available to a limited extent (determined by the pore volume of the porous, sintered bronze sliding layer). If the lubricant volume is used up due to a longer period of use, the friction coefficient rises and wear intensity increases. In most cases, this also causes the permitted wear limit to be exceeded. In P1 plain bearings, this is normally › 0.05 mm. At high sliding speeds, in particular, this may also result in overheating of the bearing and subsequent shaft seizure. The condition of the sliding surface at the end of the service life can be seen in Fig. 9.

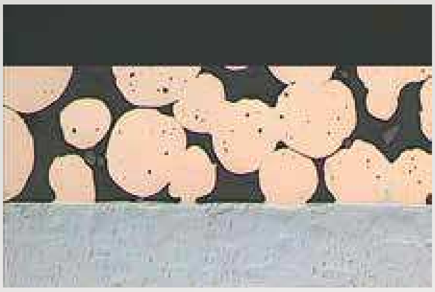


Fig. 9: Condition of sliding surface at end of service life

3.1.4 Limit values and influencing factors

Service life and operational reliability are determined by many different influences, which also interact with one another. The most important influencing factors and limit values are explained below.

Maximum permitted pv value

The pv value is the product of specific bearing load p [MPa] and sliding speed v [m/s]. These two variables interact with one another. Fig. 10 shows the maximum permitted pv value for P1 plain bearings in the form of a limit curve. If the specific bearing load and sliding speed lie within this limit curve, it is basically safe to assume that the P1 plain bearing is suitable for use.

Range of application of service life calculation:

P10, P11		
0.03 m/s	‹ v ≤	2 m/s
0.1 MPa	‹ p ≤	56 MPa
P14		
0.03 m/s	‹ v ≤	1 m/s
0.1 MPa	‹ p ≤	56 MPa
P147		
0.03 m/s	‹ v ≤	0,8 m/s
0.1 MPa	‹ p ≤	56 MPa

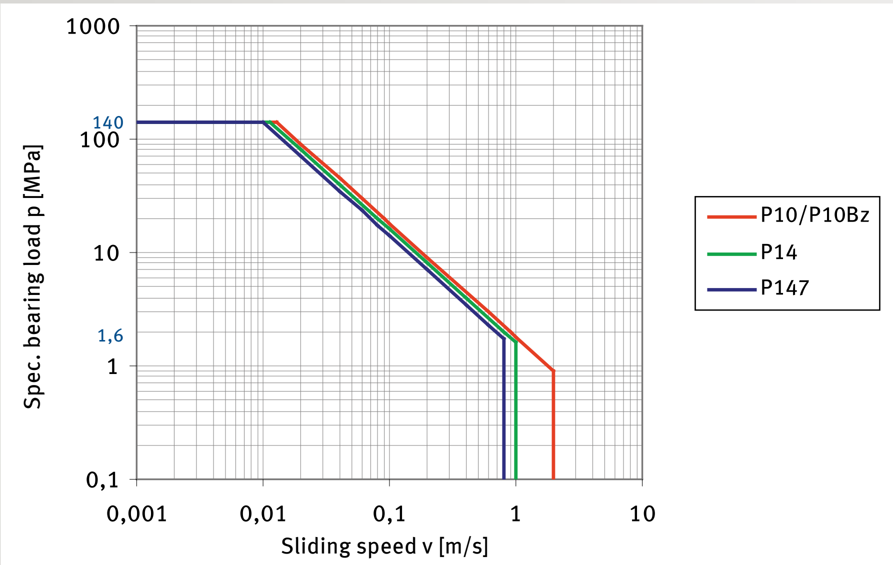


Fig. 10: pv value [MPa·m/s], limit curve (values apply at room temperature)

Here, the limit curve indicates that at the respective specific bearing load pmax. [MPa] and associated sliding speed v [m/s], thermal equilibrium is reached during operation, i.e. the plain bearing system still works reliably and safely. If the load or sliding speed increases beyond the limit curve, there is no thermal equilibrium. The wear intensity and temperature increase, and the bearing may fail within a short time.

Specific bearing load
At the maximum permitted specific bearing load and the respective maximum permitted sliding speed, the following threshold values apply to a maintenance-free, dry-running P1 plain bearing:

Maximum specific bearing load p [MPa]		Sliding speed v [m/s]		
		P10, P11	P14	P147
Static	250 MPa	–	–	
Concentrated load at rest, uniform movement	140 MPa	≤ 0.013 m/s	≤ 0.011 m/s	≤ 0.010 m/s
Concentrated load at rest, rotating, oscillating	56 MPa	≤ 0.032 m/s	≤ 0.029 m/s	≤ 0.025 m/s
Concentrated load, circumferential load, increasing, rotating, oscillating	28 MPa	≤ 0.064 m/s	≤ 0.057 m/s	≤ 0.050 m/s

Tab. 1: Threshold values of specific bearing load

Sliding speed
For maintenance-free, lead containing P1 plain bearings, the sliding speed v during dry running is limited to max. 2 m/s.
For lead-free P1 plain bearings, the maximum sliding speed vmax. is 1m/s for P14 and 0.8 m/s for P147. In a plain bearing assembly, the sliding speed is understood as the relative speed in m/s between the bearing and the shaft. It is of paramount importance in a tribological system, that the specific bearing load is a determining factor for the area of application of a plain bearing assembly (see Fig. 10: pv value limit curve). A high sliding speed exerts a particular influence on bearing wear. The long sliding distance during the operating period gives rise to correspondingly high wear. However, the bearing temperature is also dependent upon the sliding speed. If the tribological system no longer enjoys a state of thermal equilibrium as the result of an excessive sliding speed, the permitted load limit is exceeded.

Friction, bearing load, sliding speed
These three variables interact with one another. This relationship tends to manifest as follows:

Specific bearing load p [MPa]			Sliding speed v [m/s]			Coefficient of friction μ [1]		
140	to 250	high		up to 0.001	low	0.03		low
140	to 60	↑	0.001	to 0.005	↓	0.04	to 0.07	↓
60	to 10		0.005	to 0.05		0.07	to 0.1	
10	to 1		0.050	to 0.5		0.10	to 0.15	
	to 1	low	0.500	to 2	high	0.15	to 0.25	high

Tab. 2: Friction coefficient (all values apply at 20°C, interacting sliding surface steel, roughness depth Rz 0.8 to Rz 1.5)

Friction and interacting sliding parts (material and surface)
The operational reliability and service life of a maintenance-free bearing assembly depends not only on the load and sliding speed, but also on the material and surface of the interacting sliding part. The materials of the interacting sliding parts may exert a considerable influence on the wear behaviour and thus the service life of a maintenance-free, dry-running P1 plain bearing. It is basically advantageous in terms of service life to employ interacting sliding parts with a hardened sliding surface, or one featuring a special coating. This is particularly the case under higher loads or at higher sliding speeds.
The surface roughness of the interacting sliding part is also extremely important in respect of the reliability and service life of the tribological pairing.
The most favourable friction conditions are achieved with a surface roughness of R_z0.8 to R_z1.5. If the surface is excessively smooth, insufficient solid lubricant is deposited on the interacting sliding part. Adhesion repeatedly occurs during the sliding movement, resulting in stick-slip effects, squeaking noises and problems during operation.
If the surface of the interacting sliding part is too rough, on the other hand, the available solid lubricant in the plain bearing is no longer adequate for producing a sealed film of lubricant on the interacting part. The consequence is abrasion, together with increased friction, a rise in temperature and increased wear.

Friction and temperature (ambient temperature)

The operating temperature range within which a maintenance-free plain bearing system works is important for reliability and service life. This is particularly the case because the mechanical properties of the solid lubricant so vital to the performance of a plain bearing change with variations in temperature. Thus, the friction coefficient is slightly lower at an operating temperature of approx. 100 °C than at room temperature. If the operating temperature rises much over 100 °C, this effect is reversed. The friction coefficient rises and can be up to 50 % greater than the value at room temperature. This causes a change in the bearing temperature, and consequently the mechanical properties of the solid lubricant. The element of solid lubricant important for friction is the polymer PTFE. The shear strength of PTFE, above all, is responsible for forming and maintaining the lubricating film on the interacting sliding part. However, the shear strength of PTFE is temperature-dependent (Fig. 11). If the operating temperature rises, the shear strength diminishes proportionately. /2/
If the shear stress occurring in the contact zone due to the friction process is greater than the shear strength of PTFE, the lubricating film in the contact zone shears off, which can lead to rapid failure.

Sliding movement and type of load

The type of load – concentrated or circumferential – is also a factor in combination with rotating or swivelling motion. Concentrated load is the result of a moving shaft and stationary housing and bearing bush. With circumferential load, the housing and bearing bush move around the stationary shaft or axle. Rotating or swivelling movements under uniform load principally produce wear, whereby the wear rate for bearing assemblies with circumferential load can be much lower than for bearing assemblies subjected to concentrated load.
If the bearing assembly is subjected to high-frequency load changes or vibrations, this effect can intensify by material fatigue.
Where movements are linear, the bearing generally slides against a longer area of the interacting part. This causes more friction heat to be dissipated via the interacting sliding part. Therefore, higher sliding speeds are possible here than with rotating or swivelling movements.

Hydrodynamic operation

P1 plain bearings may also run under hydrodynamic conditions.
Motorservice offers the relevant calculations as a service.

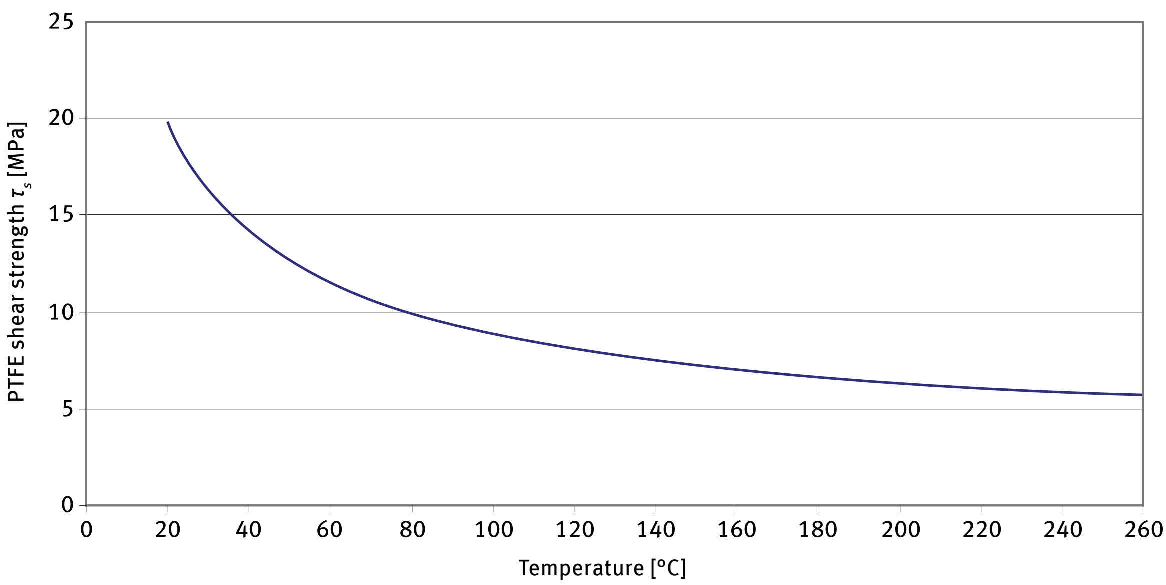


Fig. 11: PTFE shear strength τ_s versus temperature

4.1 P1 plain bearings

4.1.1 P10, P11 ... Sturdy and maintenance-free

Brief description
P10 and P11 are sturdy, lead containing sliding materials with superior tribological performance. They are designed for maintenance-free, dry-running applications, but can also be employed in systems with liquid lubrication. The use of grease as a lubricant with P10, P11 is only possible to a limited extent, and is not recommended.

Material manufacture
The solid lubricant mass is produced in a specially adapted mixing process. In a parallel, continuous sintering operation, bronze powder is sintered onto the steel or bronze back as a sliding layer. This produces a sliding layer with a thickness from 0.2 mm to 0.35 mm and a pore volume of approx. 30 %. Next, the cavities are filled with solid lubricant by means of impregnating rollers. This process step is controlled in such a way that a running-in layer of solid lubricant up to a max. thickness of 0.03 mm is produced above the sliding layer. In further thermal treatments, the characteristic properties of the material system are adjusted, and the required thickness tolerances of the composite material are produced using controlled roller pairs.

Plain bearing production
Sliding elements in a great variety of designs are produced from P10 and P11 in cutting, stamping and shaping processes. Standard designs are:
- Cylindrical bushes
- Collar bushes
- Thrust washers
- Strips

In a final step, plain bearings manufactured from P10 undergo anti-corrosion treatment on the bearing back, end faces and joint surfaces.
Standard version: Tin
Layer thickness: approx. 0.002 mm

Additionally, P10 plain bearings can be supplied with improved corrosion-protection coating “Zinc, transparent passivated”, on request.
P11 does not require any additional corrosion protection.

Important note:
Tin is used as temporary corrosion protection and an assembly aid.

Properties of P10
- Very low stick-slip tendency
- Low wear
- Good chemical resistance
- Low friction coefficient
- No tendency to fuse with metal
- Largely resistant to swelling
- Does not absorb water

Preferred areas of application
- Maintenance-free operation under dry-running conditions
- Rotating or oscillating movements up to a speed of 2 m/s
- Linear movements
- Temperature range –200 °C to 280 °C

Properties of P11
Material P11 is recommended for more stringent requirements in terms of corrosion resistance or for use in aggressive media. It has some advantages over P10 in this respect:
- Very good thermal conductivity and therefore increased reliability
- Anti-magnetic

Hydrodynamic operation
Use in hydrodynamic conditions is possible without problem up to a sliding speed of 3 m/s.
In continuous operation above 3 m/s, there is a risk of flow erosion or cavitation. Motorservice offers the calculation of hydrodynamic operating states as a service.

The materials P10 and P11 contain lead and must therefore not be used in applications involving food processing.

Material composition of P10

1	Running-in layer	
	PTFE matrix with bulking agent [1)] Layer thickness [mm]:	max. 0.03
2	**Sliding layer**	
	Tin-lead-bronze Layer thickness [mm]: Pore volume [%]:	0.20–0.35 approx. 30
3	**Bearing back**	
	Steel Steel thickness [mm]: Steel hardness [HB]:	Variable 100–180

Tab. 4: System composition P10

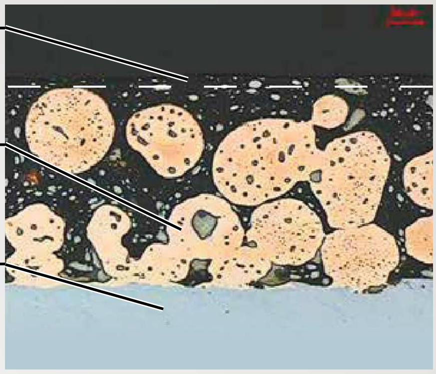


Fig. 15: Layer system P10

Chemical composition

Running-in layer	
Components	% Weight
PTFE	44
Pb	56
Sliding layer	
Components	% Weight
Sn	9 to 11
Pb	9 to 11
Cu	Remainder
Bearing back	
Material	Material information
Steel	DC04
	DIN EN 10130
	DIN EN 10139

Tab. 5: Chemical composition P10

Material characteristics

Characteristics, load limit	Symbol	Unit	Value
Permitted pv value	$pv_{zul.}$	MPa·m/s	1.8
Permitted specific bearing load			
• Static	$p_{zul.}$	MPa	250
• Concentrated load, circumferential load at sliding speed ≤0.013 m/s	$p_{zul.}$	MPa	140
• Concentrated load, circumferential load at sliding speed ≤0.032 m/s	$p_{zul.}$	MPa	56
• Concentrated load, circumferential load, increasing at sliding speed ≤0.064 m/s	$p_{zul.}$	MPa	28
Permitted sliding speed			
• Dry running	$v_{zul.}$	m/s	2
• Hydrodynamic operation	$v_{zul.}$	m/s	3
Permitted temperature	$T_{zul.}$	°C	−200 to +280
Thermal expansion coefficient			
• Steel back	α_{St}	K^{-1}	$11*10^{-6}$
Coeff. of thermal conductivity			
• Steel back	λ_{St}	$W(mK)^{-1}$	40

Tab. 6: Material characteristics P10

[1)] The pores of the sliding layer are also filled with this lubricant mass.

5.1 Service life calculation formulae

Based on the information from the previous pages the influences on the service life and reliability of KS Permaglide® plain bearings, the equations below can be used to achieve an estimate of expected service life.

Nominal service life L_N for maintenance-free P1 plain bearings

[1] Movement: rotating, oscillating $$L_N = \frac{400}{(pv)^{1,2}} f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R \quad [h]$$

[2] Movement: linear $$L_N = \frac{400}{(pv)^{1,2}} f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R \cdot f_L \quad [h]$$

Nominal service life L_N for low-maintenance, grease-lubricated P2 plain bearings

[3] Movement: rotating, oscillating $$L_N = \frac{2000}{(pv)^{1,5}} f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R \quad [h]$$

Movement: linear

Since the effect of influences (e.g. dirt, lubricant ageing, etc.) cannot be ascertained with precision, a calculation of service life where linear movement and grease lubrication are involved is not feasible. Motorservice offers an advisory service here, based on practical experience.

[4] Specific bearing load, bush $$p = \frac{F}{D_i \cdot B} \quad [MPa]$$

[5] Specific bearing load, thrust washer $$p = \frac{4 \cdot F}{(D_o^2 - D_i^2) \cdot \pi} \quad [MPa]$$

[6] Sliding speed, bush, rotating $$v = \frac{D_i \cdot \Pi \cdot n}{60 \cdot 10^3} \quad [m/s]$$

[7] Sliding speed, thrust washer, rotating $$v = \frac{D_o \cdot \Pi \cdot n}{60 \cdot 10^3} \quad [m/s]$$

[8] Sliding speed, bush, oscillating

$$v = \frac{D_i \cdot \pi}{60 \cdot 10^3} \cdot \frac{2\varphi \cdot n_{osz}}{360°} \quad [m/s]$$

[9] Sliding speed, thrust washer, oscillating

$$v = \frac{D_o \cdot \pi}{60 \cdot 10^3} \cdot \frac{2\varphi \cdot n_{osz}}{360°} \quad [m/s]$$

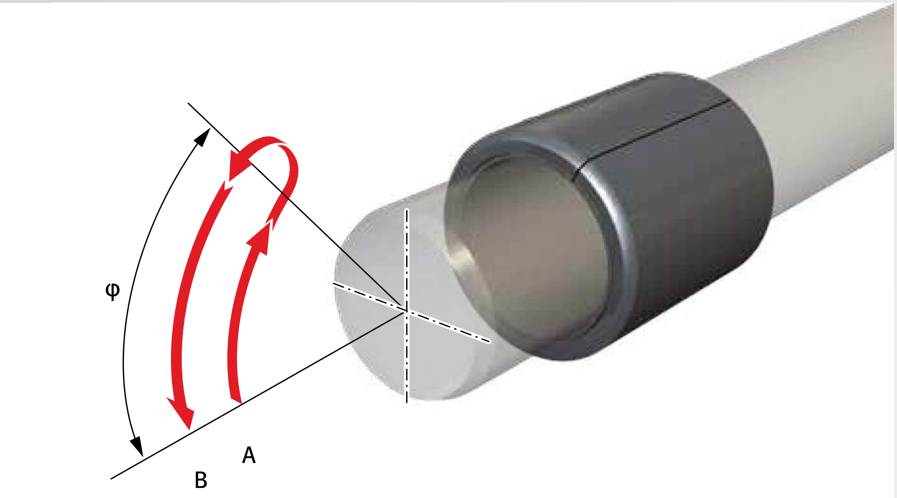


Fig. 23: Swivel angle φ
The oscillating frequency n_{osz} is the number of movements from A to B per minute.

[10] Calculation of pv value

$$pv = p\,[MPa] \cdot v\,[m/s] \quad [MPa \cdot m/s]$$

$pv_{zul.}$ for
P10, P11 ..... ≤ 1.8 MPa · m/s
P14 ..... ≤ 1.6 MPa · m/s
P147 ..... ≤ 1.4 MPa · m/s
P20 ..... ≤ 3.0 MPa · m/s
P200 ..... ≤ 3.3 MPa · m/s

Correction factors	P1	P2
f_p = specific bearing load	Fig. 24	Fig. 28
f_t = temperature	Fig. 25	Fig. 29
f_v = sliding speed	Fig. 26	Fig. 30
f_R = roughness depth	Fig. 27	Fig. 31
f_A = type of load	Fig. 32	Fig. 32
f_w = material	Tab. 24	Tab. 24
f_L = linear movement [11]	Fig. 33	---

Correction factors for P10 P11, P14 and P147*

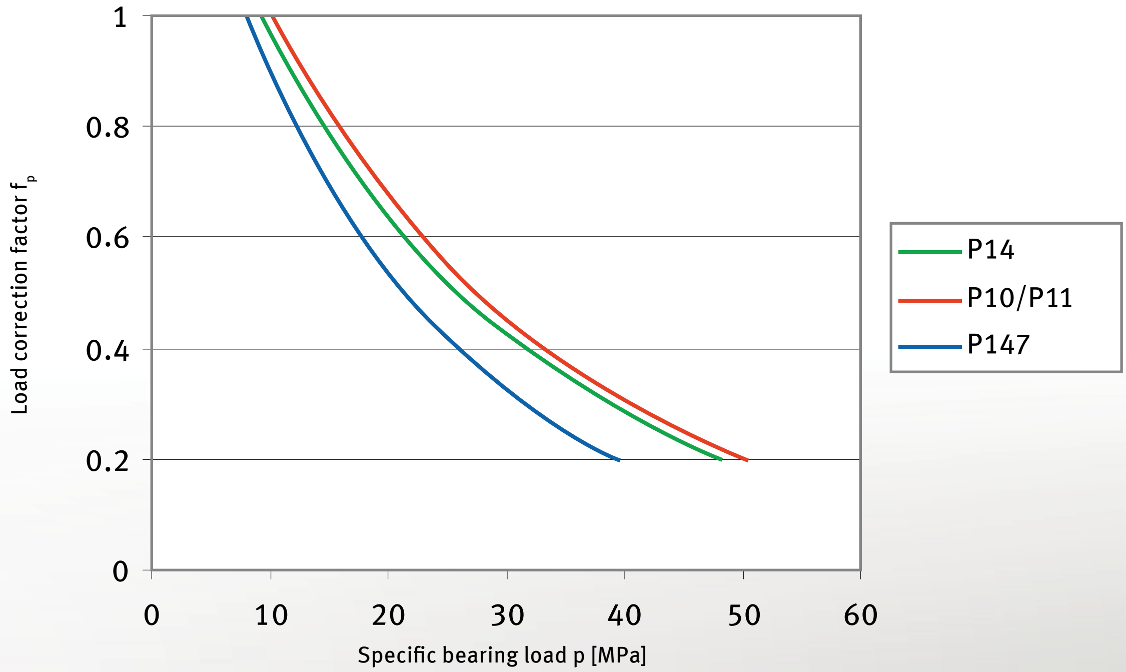


Fig. 24: Load correction factor f_p

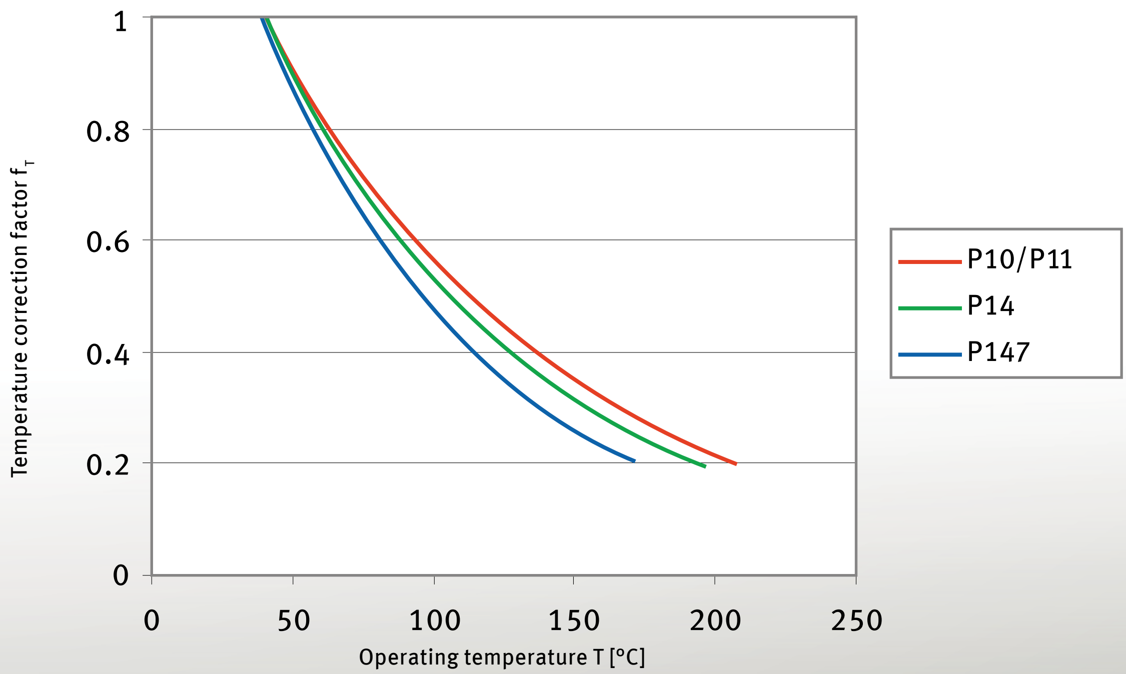


Fig. 25: Temperature correction factor f_T

* On request

Correction factors for P10, P11, P14 and P147*

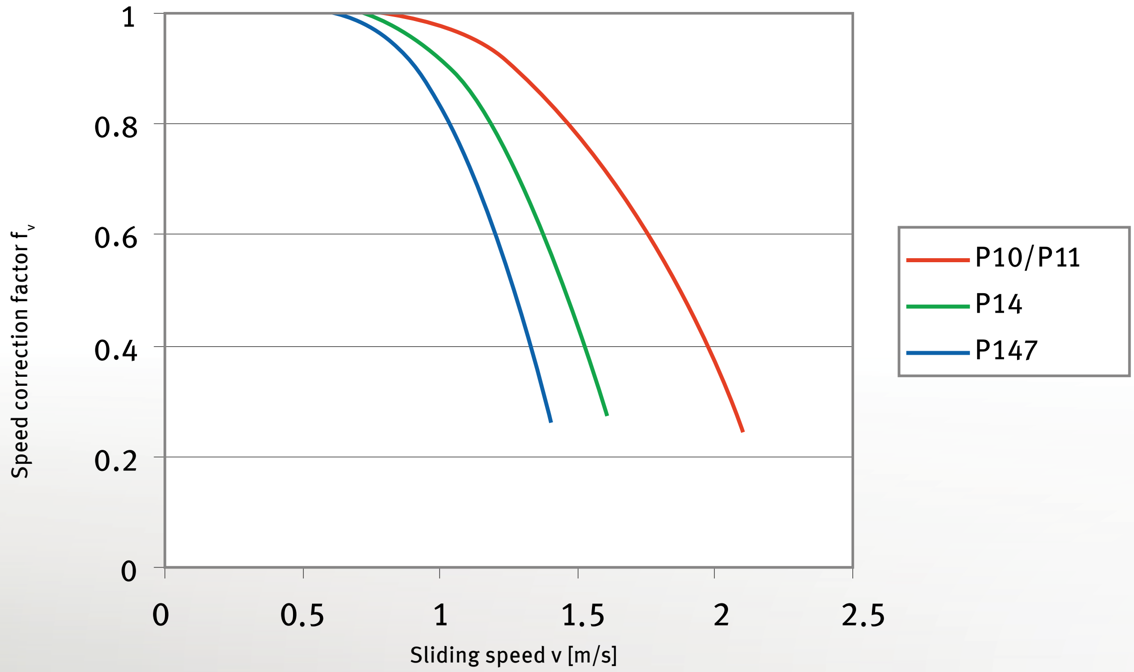


Fig. 26: Sliding speed correction factor f_v

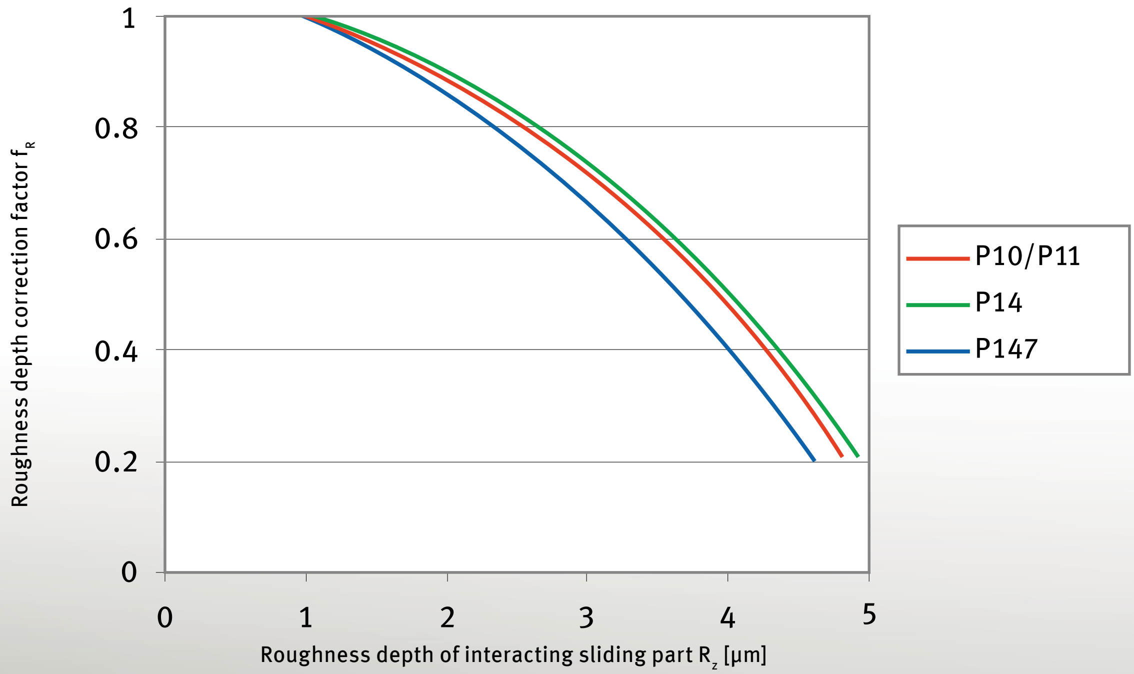


Fig. 27: Roughness depth correction factor f_R

Load type correction factor

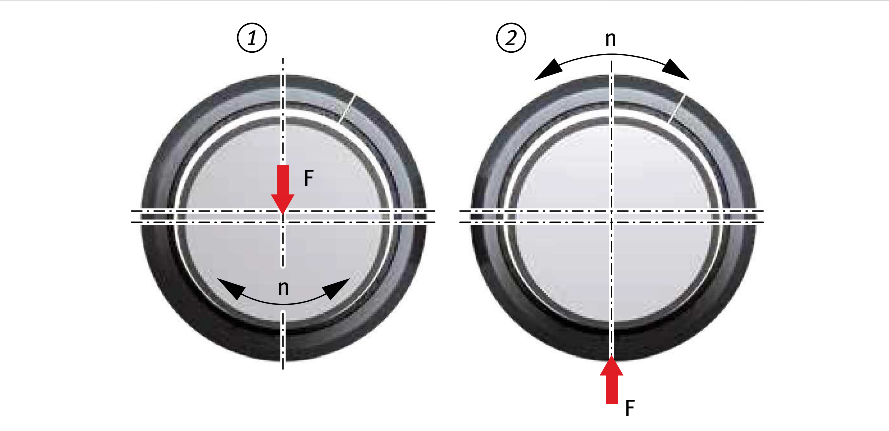


Fig. 32: Load correction factor f_A

No. (see Fig. 32)	Type of load	f_A
1	*Concentrated load*	1
2	*Circumferential load*	2
–	*Axial load*	1
–	*Linear movement*	1

Linear movement correction factor

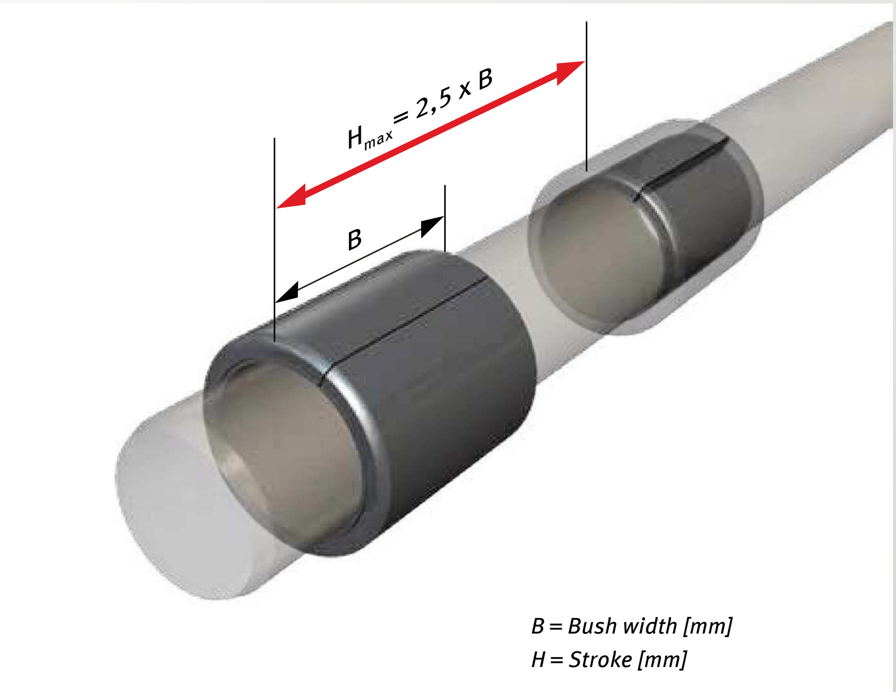


Fig. 33: Linear movement, stroke $H_{max.}$

Correction factor for material of interacting sliding part

Material of interacting sliding surface	f_w
Steel	1
Nitrided steel	1
Corrosion-resistant steel	2
Hard chrome-plated steel (min. layer thickness 0.013 mm)	2
Galvanised steel (min. layer thickness 0.013 mm)	0.2
Phosphated steel (min. layer thickness 0.013 mm)	0.2
Grey cast iron R_z2	1
Anodised aluminium	0.4
Hard anodised aluminium (hardness 450 +50 HV; 0.025 mm thick)	2
Copper-based alloys	0.1 to 0.4
Nickel	0.2

Tab. 24: Material correction factor f_w (with roughness depth R_z 0.8 to R_z 1.5)

[11] Calculating the linear movement correction factor f_L:

$$f_L = 0,65 \frac{B}{H + B} \qquad [1]$$

Special operating conditions
Special operating conditions can both lengthen and shorten the calculated service life. The impact of such influences can often only be estimated. Table 25 shows some typical values based on experience.

Evaluating calculated service life
As already discussed in the section on Basics, the calculation of the service life of P1/P2 plain bearings is still subject to uncertainty. On the one hand, it depends on numerous influencing factors and the interactions between them. On the other hand, the influence of corrosion, lubricant ageing, the action of chemicals, dirt, etc. on expected service life cannot be mathematically calculated with precision.

Important note:
The calculated service life can therefore only be a rough guide. We recommend verifying the use of KS Permaglide® plain bearings through field-oriented tests.

Operating conditions	Influence on service life	Reason
Dry running, sometimes interrupted	Lengthens service life	The bearing assembly occasionally has time to cool down. This has a positive effect on expected service life.
Alternately dry running and running in water	Reduces service life	Hydrodynamic conditions can only be achieved to a limited extent in water. This and the changeover to dry running increases wear.
Continuous operation in liquid lubricants	Greatly lengthens service life	Here, mixed friction or hydrodynamic conditions predominate. The lubricant conveys the frictional heat out of the contact zone. In the hydrodynamic state, the plain bearing runs practically without wear.
Continuous operation in lubricating grease (KS Permaglide® P1 materials)	Reduces or lengthens service life	Solid additives such as MoS_2 or ZnS encourage the formation of paste, and can shorten service life. Nominal service life can be increased through design measures (bore/grooves in the run-out zone) and through regular relubrication (also see “Lubrication” in section 6).

Tab. 25: Special operating conditions

7.1 Housing

Bushes

KS Permaglide® bushes are pressed into the housing and fixed radially and axially. No further measures are required.

For the housing bore, we recommend:

- Roughness depth $R_z 10$
- Chamfer f_G 20° ±5°
  This chamfer facilitates press-fitting.

Bore diameter d_G	Chamfer width f_G
$d_G \leq 30$	0.8 ± 0.3
$30 < d_G \leq 80$	1.2 ± 0.4
$80 < d_G \leq 180$	1.8 ± 0.8
$180 < d_G$	2.5 ± 1.0

Tab. 26: Chamfer width f_G in the housing bore for bushes (Fig. 39)

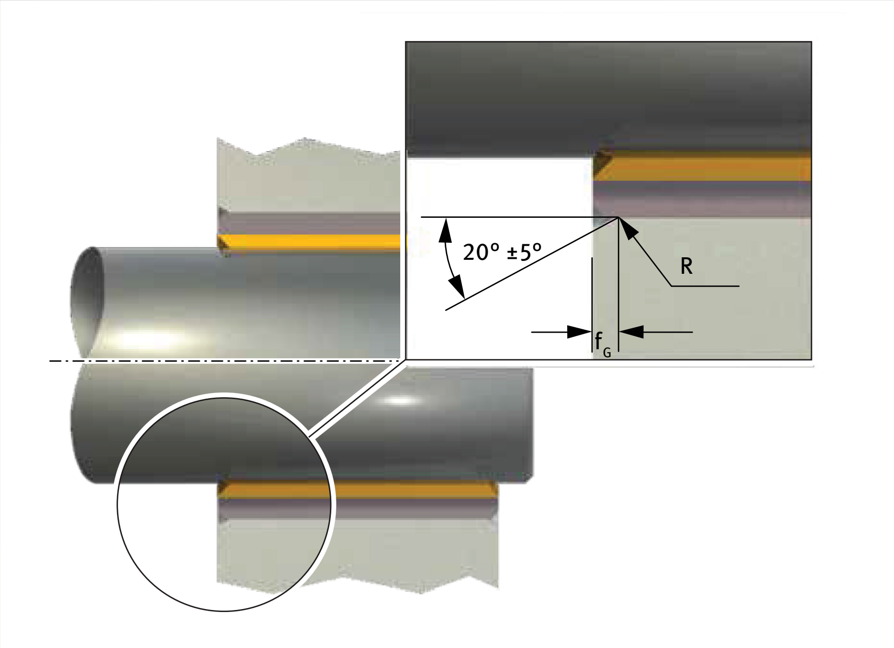


Fig. 39: Chamfer in housing for PAP bush

Collar bushes

In the case of collar bushes, the radius on the transition from the radial to the axial part must be borne in mind.

- Collar bushes must not be in contact in the radius area.
- The collar must have sufficient support when under axial loads.

Bore diameter d_G	Chamfer width f_G
$d_G \leq 10$	1.2 ± 0.2
$10 < d_G$	1.7 ± 0.2

Tab. 27: Chamfer width f_G in the housing bore for collar bushes (Fig. 40)

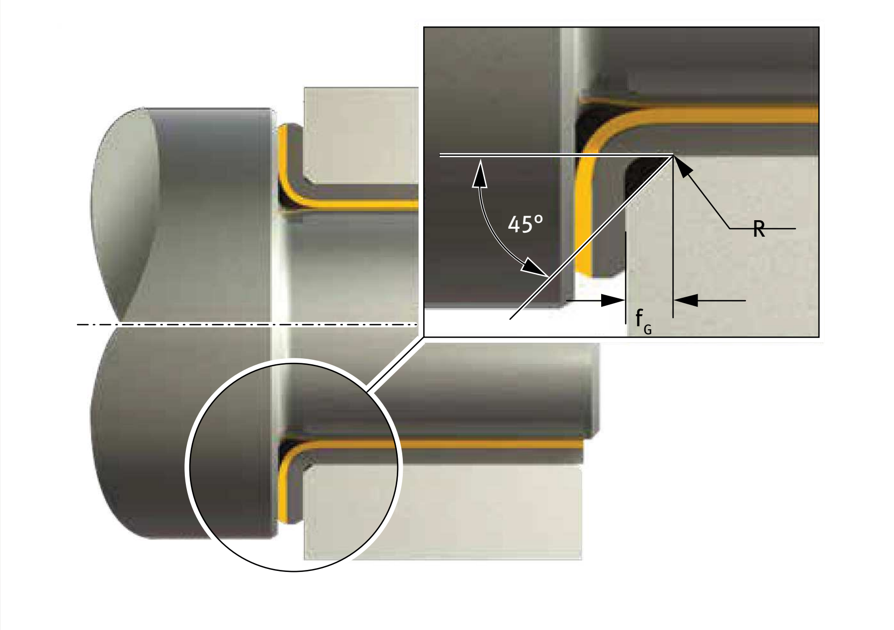


Fig. 40: Chamfer in housing for PAF bush

Securing thrust washers
Recommendation:

- A concentric fit is ensured by the recess in the housing (Fig. 41)
  - See dimension tables for the diameter and depth of free cuts
- Unwanted rotation with the shaft is prevented by means of a dowel pin or countersunk screw (Figs. 41 and 42)
  - The screw head or dowel pin must be recessed by min. 0.25 mm from the sliding surface (Figs. 41 and 42)
  - See dimension tables for size and position of drill holes.
- If no recess can be made in the housing:
  - Secure with several dowel pins or screws (Fig. 42)
  - Use other methods for fastening

Rotation prevention is not always required. In various cases, the static friction between the back of the washer and the housing is sufficient.

Other fastening methods
If the press fit of the bush is insufficient or pinning or screwing is uneconomical, low-cost fastening methods can be used as an alternative:

- Laser welding
- Soft-soldering
- Sticking, please observe information below.

Caution:
The temperature of the running-in or sliding layer must not exceed +280 °C for the KS Permaglide® P1 and +140 °C for the KS Permaglide® P2. Adhesive must not reach the running-in or sliding layer.
Recommendation: Obtain information from adhesive manufacturers, particularly concerning the choice of adhesive, preparing the surface, setting, strength, temperature range and strain characteristics.

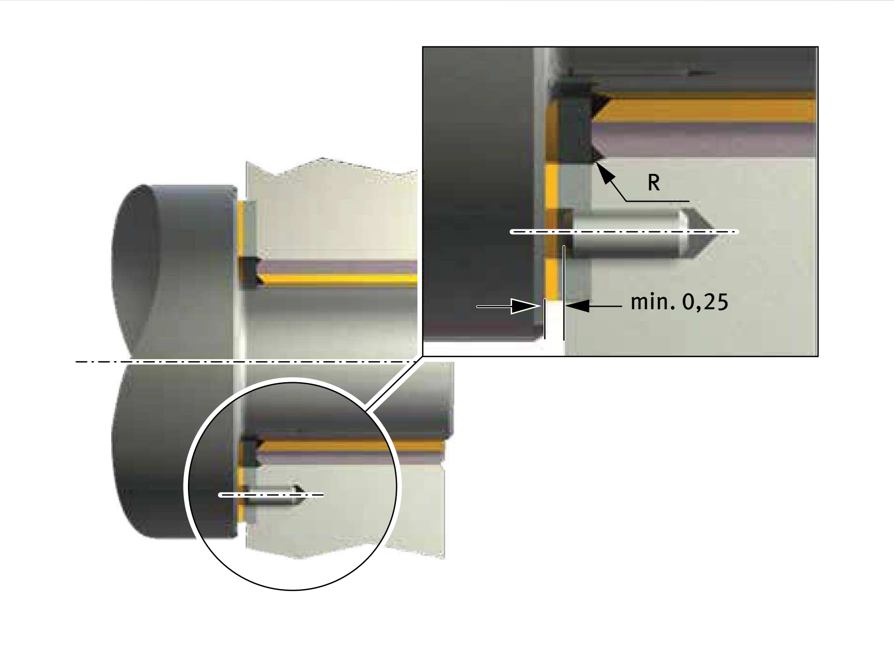


Fig. 41: Securing a PAW thrust washer in a recess in the housing

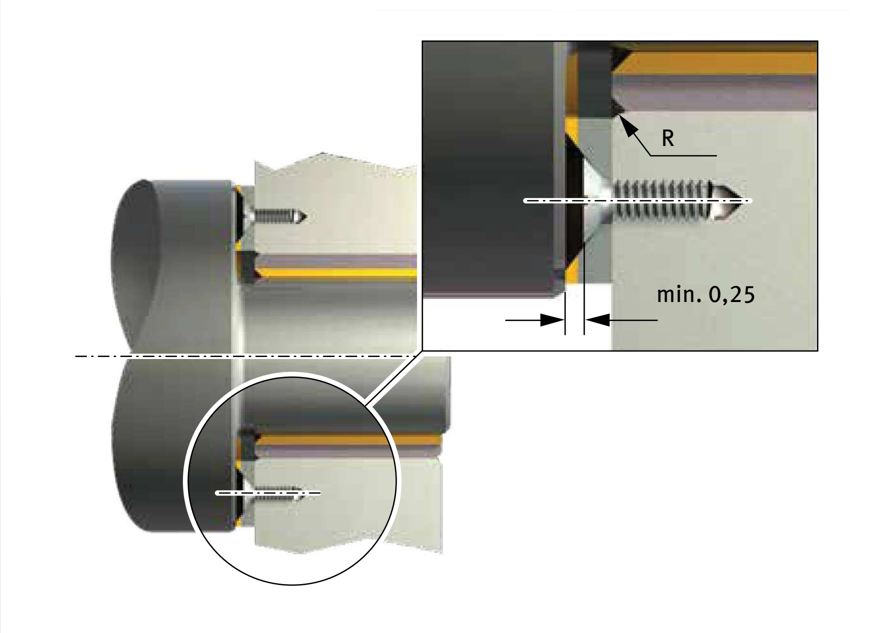


Fig. 42: Securing a PAW thrust washer without a recess in the housing

7.2 Design of the interacting sliding part

The following generally applies:
In a tribological system with a radial bearing, the shaft must project beyond the sliding surface. With an axial bearing, the pressure shoulder must project beyond the sliding surface. This allows the maximum contact ratio to be achieved and avoids offsets in the sliding layer.

Shaft
Shafts must be chamfered and all sharp edges rounded, which:

- Simplifies assembly
- Prevents damage to the bush sliding layer

Shafts must never have grooves or pricks in the area of the sliding zone.

Interacting sliding surface
Optimum service life thanks to correct roughness depth

- Optimum service life is achieved when the interacting sliding surface has a roughness depth of R_z0.8 to R_z1.5:
  - with dry-running KS Permaglide® P1
  - with lubricated KS Permaglide® P2

Caution:
Smaller roughness depths do not increase service life and may even lead to adhesion wear. Larger roughness depths considerably reduce it.

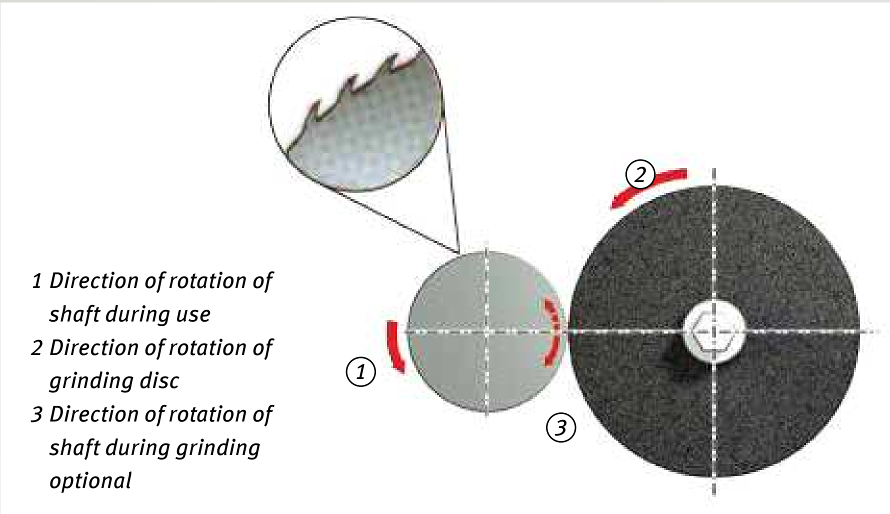


Fig. 43: Grinding a cast shaft

- With KS Permaglide® P1 and P2, corrosion of the interacting sliding surface is prevented by:
  - Sealing
  - The use of corrosion-resistant steel
  - Suitable surface treatment.

With KS Permaglide® P2, the lubricant is also effective against corrosion.

Surface quality

- Ground or drawn surfaces are preferable
- Precision-turned or precision-turned and roller burnished surfaces, even with R_z0.8 to R_z1.5, can cause greater wear (precision turning produces spiral scores)

- Sphero cast (GGG) has an open surface structure, and can therefore be ground to R_z2 or better.
  Figure 43 shows the direction of rotation of cast shafts in use. This should be the same as the direction of rotation of the grinding disc, as more wear will occur in the opposite direction.

Hydrodynamic operation
For hydrodynamic operation, the roughness depth R_z of the interacting sliding surface should be less than the smallest thickness of the lubricating film.
Motorservice offers hydrodynamic calculation as a service.

Seals

Protecting the bearing assembly is recommended in the event of greater exposure to dirt in an aggressive environment.

Figure 44 shows recommended seal types:

- The surrounding seal (1)
- A gap seal (2)
- A shaft seal (3)
- A ring of grease

Heat dissipation

Thorough heat dissipation must be assured.

- In hydrodynamic operation, heat is overwhelmingly conveyed away by the lubricating liquid.
- In dry and grease-lubricated plain bearings, the heat is also dissipated by the housing and shaft.

Machining the bearing elements

- KS Permaglide® plain bearings can be cut and machined in other ways (e.g. shortening, bending or drilling)
- KS Permaglide® plain bearings should preferably be cut from the PTFE side. The burrs produced during cutting would impair the sliding surface
- Bearing elements must be cleaned after machining
- Bare steel surfaces (cut edges) must be protected against corrosion with:
  - Oil, or
  - Galvanic protective layers At higher flow densities or with longer coating times, the sliding layers must be covered to prevent deposits.

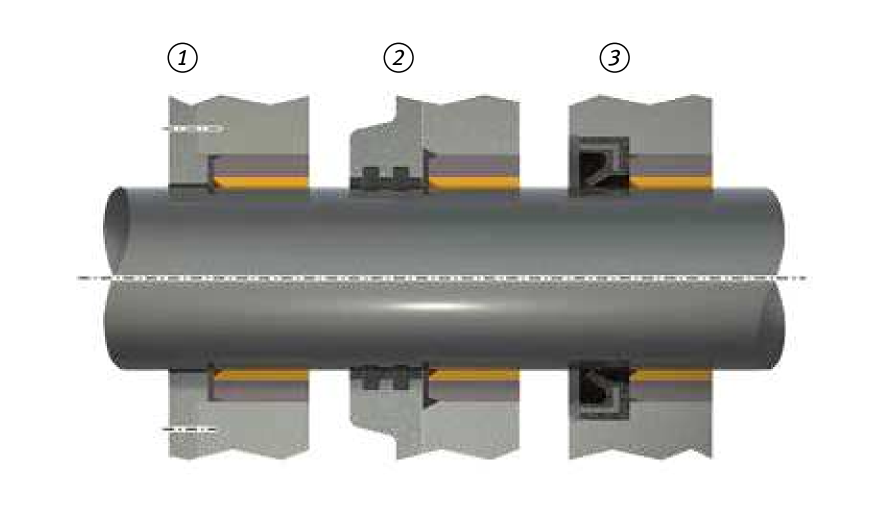


Fig. 44: Seals

Caution:

Machining temperatures, that exceed the following limits are hazardous to health:
+280 °C with the KS Permaglide® P1
+140 °C with the KS Permaglide® P2
Burrs may contain lead.

Axial orientation (precise alignment)
Precise alignment is important for all radial and axial plain bearings. This is particularly the case for dry-running plain bearings, in which the load cannot be distributed via the lubricating film.
Misalignment over the entire width of the bush must not exceed 0.02 mm (see Fig. 45). This figure also applies to the overall width of bushes arranged in pairs, and of thrust washers.
Bushes arranged one behind the other may need to have the same width. The joints must be flush on assembly.

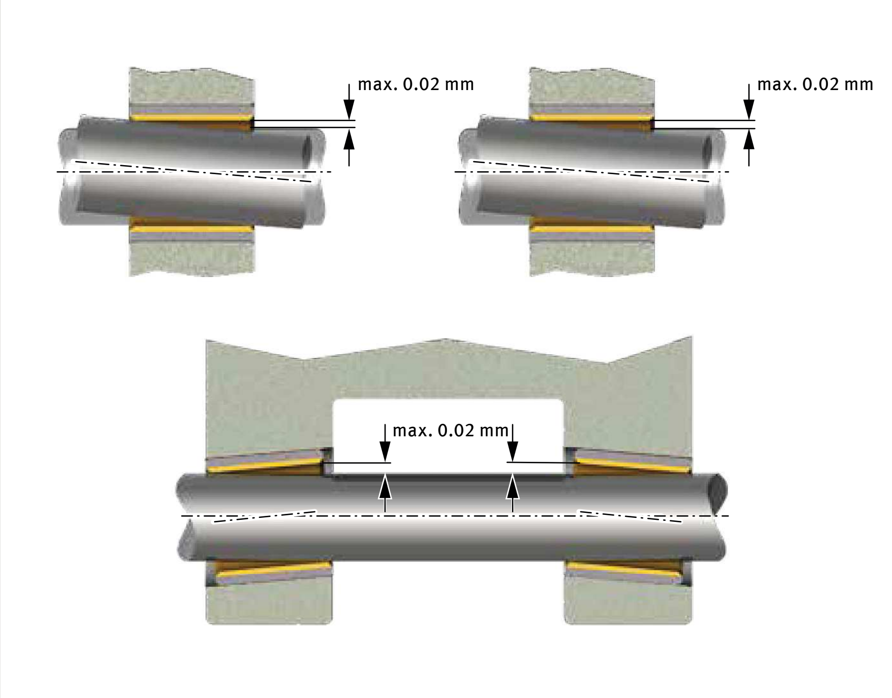


Fig. 45: Permitted misalignment

Edge load on an installed plain bearing
Excessively high load around the edges of the plain bearing may occur as the result of geometric inaccuracies or under special operating conditions. This type of "edge loading" can cause the bearing assembly to jam. This load can be reduced through design measures (Fig. 46).

- Enlarged chamfers on housing
- Enlarged bore diameter in edge region of housing bore
- Allow width of bush to project beyond width of housing.

In addition, edge loading can be relieved by housing with an elastic design.

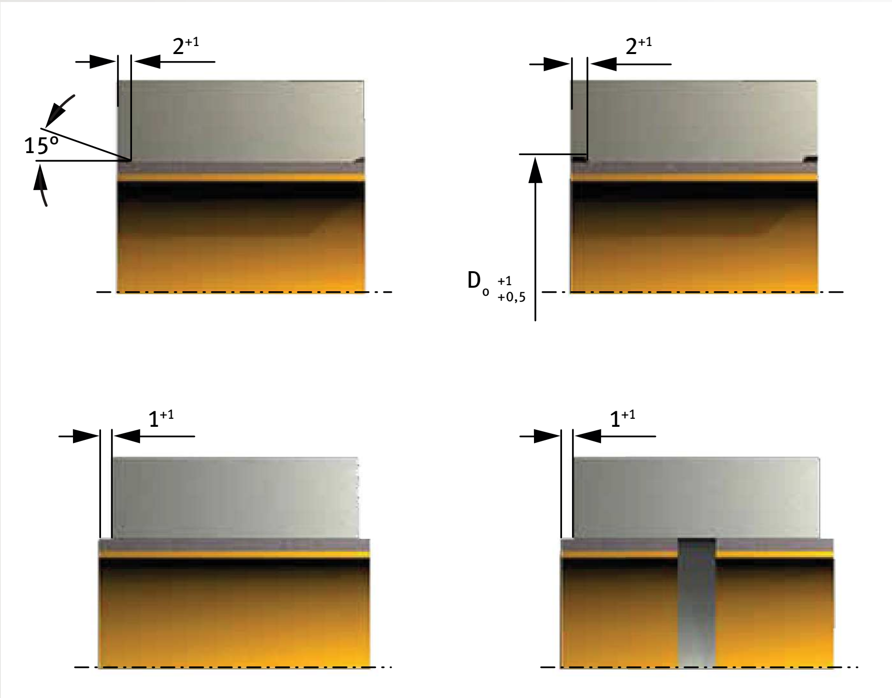


Fig. 46: Reducing excessive stress on edges

7.3 Bearing clearance, press fit

Theoretical bearing clearance
Bushes of KS Permaglide® P1 and P2 are pressed into the housing and fixed in place radially and axially.
No further measures are required. With the fitting tolerances from Table 28 and rigid housings and shafts, the following are achieved:
- A press-fit bearing
- Bearing clearance as per Table 33

The theoretical bearing clearance is calculated as follows:

[12]	$\Delta s_{max} = d_{Gmax} - 2 \cdot s_{3min} - d_{Wmin}$
[13]	$\Delta s_{min} = d_{Gmin} - 2 \cdot s_{3max} - d_{Wmax}$

Δs_{max}	[mm]	Maximum bearing clearance
Δs_{min}	[mm]	Minimum bearing clearance
d_{Gmax}	[mm]	Maximum diameter of housing bore
d_{Gmin}	[mm]	Minimum diameter of housing bore
d_{Wmax}	[mm]	Maximum shaft diameter
d_{Wmin}	[mm]	Minimum shaft diameter
s_{3max}	[mm]	Maximum wall thickness
s_{3min}	[mm]	Minimum wall thickness (see Tab. 31)

Caution:
Widening the housing bore is not taken into consideration in the bearing clearance calculation.

For calculating the press fit U, the tolerances of the housing bore are stated in Table 28 and the dimensions of the bush outside diameter D_o in Table 29.

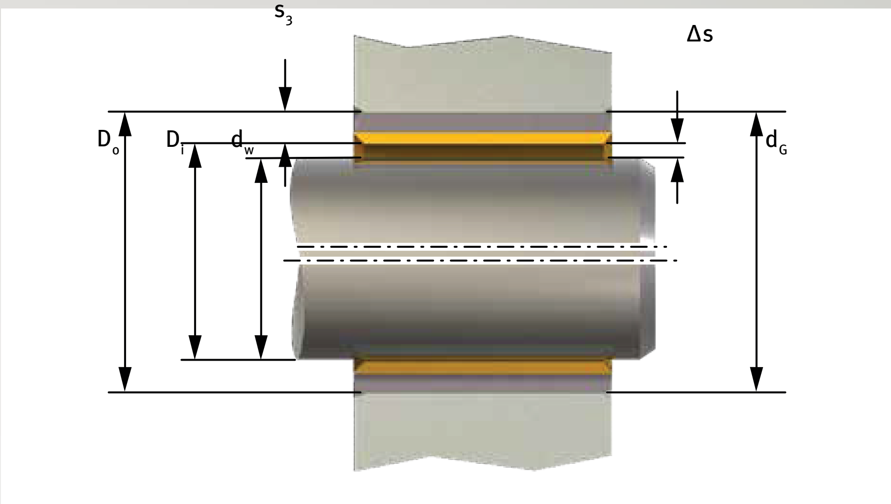


Fig. 47: Theoretical bearing clearance Δs

Press fit and bearing clearance
The bearing clearance and press fit can be influenced by the measures shown in Tab. 34:
- At high ambient temperatures
- Depending on the housing material
- Depending on the housing wall thickness.

Smaller clearance tolerances require narrower tolerances for the shaft and bore.

Caution:
When using shafts with tolerance zone position h, the bearing play for $5 \leq d_W < 80$ (P10, P14, P147) and $d_W < 80$ (P11) must be verified using equations [12] for Δs_{max} and [13] for Δs_{min}.

Diameter range	KS Permaglide®		
	P10, P14, P147*	P11	P20, P200
Shaft			
$d_W < 5$	h6	f7	h8
$5 \leq d_W < 80$	f7	f7	h8
$80 \leq d_W$	h8	h8	h8
Housing bore			
$d_G \leq 5.5$	H6	–	–
$5.5 < d_G$	H7	H7	H7

Tab. 28: Recommended fitting tolerances

* On Request

Outside diameter of bush D_o			Dimensions (test A to DIN ISO 3547-2)			
			P10, P14, P147*, P20, P200		P11	
			Upper	Lower	Upper	Lower
	$D_o \leq$	10	+0.055	+0.025	+0.075	+0.045
10	$< D_o \leq$	18	+0.065	+0.030	+0.080	+0.050
18	$< D_o \leq$	30	+0.075	+0.035	+0.095	+0.055
30	$< D_o \leq$	50	+0.085	+0.045	+0.110	+0.065
50	$< D_o \leq$	80	+0.100	+0.055	+0.125	+0.075
80	$< D_o \leq$	120	+0.120	+0.070	+0.140	+0.090
120	$< D_o \leq$	180	+0.170	+0.100	+0.190	+0.120
180	$< D_o \leq$	250	+0.210	+0.130	+0.230	+0.150
250	$< D_o \leq$	305	+0.260	+0.170	+0.280	+0.190

Tab. 29: Dimensions for outside diameter D_o

Inside diameter			Wall thickness	Dimensions to DIN ISO 3 547-1, Table 3, row D, P20, P200	
D_i			s_3	Upper	Lower
8	$\leq D_i <$	20	1	−0.020	−0.045
20	$\leq D_i <$	28	1.5	−0.025	−0.055
28	$\leq D_i <$	45	2	−0.030	−0.065
45	$\leq D_i <$	80	2.5	−0.040	−0.085
80	$\leq D_i$		2.5	−0.050	−0.115

Tab. 31: Wall thickness s_3 for bushes of KS Permaglide® P20/P200

Bush inside diameter D_i			Wall thick-ness s_3	Dimensions to DIN ISO 3 547–1, Table 3, row B			
				P10, P14, P147*		P11	
				Upper	Lower	Upper	Lower
	$D_i <$	5	0.75	0	−0.020	–	–
			1	–	–	+0.005	−0.020
5	$\leq D_i <$	20	1	+0.005	−0.020	+0.005	−0.020
20	$\leq D_i <$	28	1.5	+0.005	−0.025	+0.005	−0.025
28	$\leq D_i <$	45	2	+0.005	−0.030	+0.005	−0.030
45	$\leq D_i <$	80	2.5	+0.005	−0.040	+0.005	−0.040
80	$\leq D_i <$	120	2.5	−0.010	−0.060	−0.010	−0.060
120	$\leq D_i$		2.5	−0.035	−0.085	−0.035	−0.085

Tab. 30: Wall thickness s_3 for P1 bushes and collar bushes

Wall thickness s_3	Outside bevel, without cutting C_o	Inside bevel C_i	
		min.	max.
0.75	0.5±0.3	0.1	0.4
1	0.6±0.4	0.1	0.5
1.5	0.6±0.4	0.1	0.7
2	1.0±0.4	0.1	0.7
2.5	1.2±0.4	0.2	1.0

Tab. 32: Outside bevel C_o and inside bevel C_i (Fig. 48) for bushes with metric dimensions to DIN ISO 3 547-1, Table 2

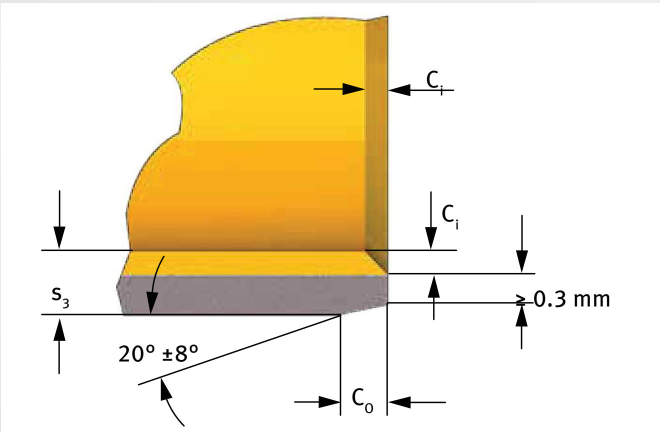


Fig. 48: Outside bevel C_o and inside bevel C_i with metric dimensions

* Auf Anfrage

Theoretical bearing clearance

Bush diameter		Bearing clearance Δs			
		P10. P11. P14. P147*		P20. P200	
D_i (mm)	D_o (mm)	Δs_{min} (mm)	Δs_{max} (mm)	Δs_{min} (mm)	Δs_{max} (mm)
2	3.5	0	0.054	–	–
3	4.5	0	0.054	–	–
4	5.5	0	0.056	–	–
5	7	0	0.077	–	–
6	8	0	0.077	–	–
7	9	0.003	0.083	–	–
8	10	0.003	0.083	0.040	0.127
10	12	0.003	0.086	0.040	0.130
12	14	0.006	0.092	0.040	0.135
13	15	0.006	0.092	–	–
14	16	0.006	0.092	0.040	0.135
15	17	0.006	0.092	0.040	0.135
16	18	0.006	0.092	0.040	0.135
18	20	0.006	0.095	0.040	0.138
20	23	0.010	0.112	0.050	0.164
22	25	0.010	0.112	0.050	0.164
24	27	0.010	0.112	0.050	0.164
25	28	0.010	0.112	0.050	0.164
28	32	0.010	0.126	0.060	0.188
30	34	0.010	0.126	0.060	0.188
32	36	0.015	0.135	0.060	0.194
35	39	0.015	0.135	0.060	0.194
40	44	0.015	0.135	0.060	0.194
45	50	0.015	0.155	0.080	0.234
50	55	0.015	0.160	0.080	0.239
55	60	0.020	0.170	0.080	0.246
60	65	0.020	0.170	0.080	0.246
65	70	0.020	0.170	–	–
70	75	0.020	0.170	0.080	0.246
75	80	0.020	0.170	0.080	0.246
80	85	0.020	0.201	0.100	0.311
85	90	0.020	0.209	–	–
90	95	0.020	0.209	0.100	0.319
95	100	0.020	0.209	–	–
100	105	0.020	0.209	0.100	0.319
105	110	0.020	0.209	–	–

Bush diameter		Bearing clearance Δs			
		P10. P11. P14. P147*		P20. P200	
D_i (mm)	D_o (mm)	Δs_{min} (mm)	Δs_{max} (mm)	Δs_{min} (mm)	Δs_{max} (mm)
110	115	0.020	0.209	–	–
115	120	0.020	0.209	–	–
120	125	0.070	0.264	–	–
125	130	0.070	0.273	–	–
130	135	0.070	0.273	–	–
135	140	0.070	0.273	–	–
140	145	0.070	0.273	–	–
150	155	0.070	0.273	–	–
160	165	0.070	0.273	–	–
180	185	0.070	0.279	–	–
200	205	0.070	0.288	–	–
220	225	0.070	0.288	–	–
250	255	0.070	0.294	–	–
300	305	0.070	0.303	–	–

Tab. 33: Theoretical bearing clearance after press-fitting bushes or collar bushes with metric dimensions, without consideration of possible widening of the bore

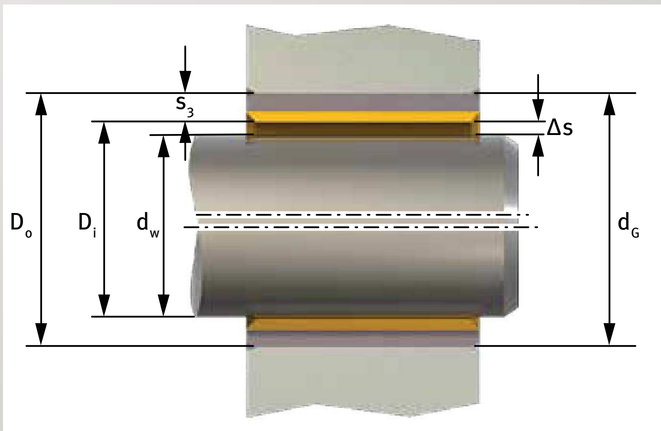


Fig. 49: Theoretical bearing clearance Δs

* On request

Press fit and bearing clearance

Design and environmental influences	Consequence	Measure	Note
Alloy or thin-walled housing	Extensive widening Excessive clearance	Reduce housing bore d_G	The housing is under greater stress; the permitted housing tension must not be exceeded .
Steel or cast iron housing at high ambient temperatures	Smaller clearance	Reduce shaft diameter d_W by 0.008 mm per 100 °C above room temperature	
Bronze or copper alloy housing at high ambient temperatures	Poor press fit	Reduce housing bore d_G, recommended change to diameter per 100 °C above room temperature: d_G −0.05 %	Reduce shaft diameter d_W by the same value, in order to retain the same bearing clearance.
Aluminium alloy housing at high ambient temperatures	Poor press fit	Reduce housing bore d_G, recommended change to diameter per 100 °C above room temperature: d_G −0.1 %	Reduce shaft diameter d_W by the same value, in order to retain the same bearing clearance. The housing is under greater stress at temperatures below 0 °C; the permitted housing tension must not be exceeded.
Bushes with thicker layer of corrosion protection	Outside diameter D_o too large Insufficient clearance	Enlarge housing bore d_G Example: Layer thickness 0.015±0.003 mm producing d_G +0.03 mm	The bush and housing are subject to greater stress unless appropriate measures are taken.

Tab. 34: Errors, consequences and measures in relation to press fit and bearing clearance at high ambient temperatures, with special housing materials or housing wall thicknesses

KS Permaglide® bushes can simply be pressed into the housing bore. Applying a little oil to the back of the bush or the housing bore facilitates the press-fitting operation.

Recommended press-fitting methods

For outside diameters D_o up to around 55 mm:

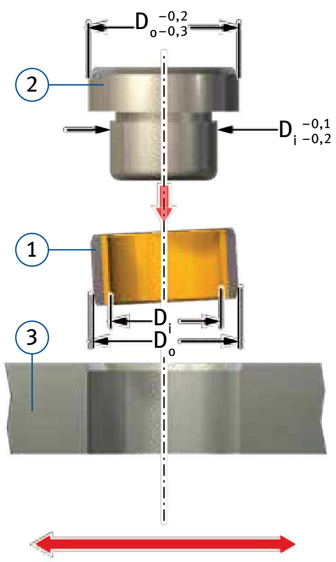
- Flush press-fitting with mandrel, without auxiliary ring, as per Fig. 51
- Recessed press-fitting with mandrel, without auxiliary ring, as per Fig. 52

For outside diameters D_o from around 55 mm and over:

- Press-fitting with mandrel and auxiliary ring as per Fig. 53.

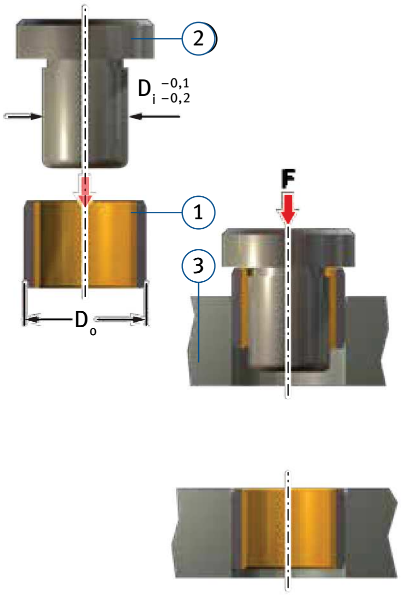
Caution:
Ensure cleanliness during installation. Dirt reduces the service life of the bearing assembly.
Take care not to damage the sliding layer.
Note the installation position, if given.
Do not position the joint in the main load zone.

Avoid an inclined position or axis offset



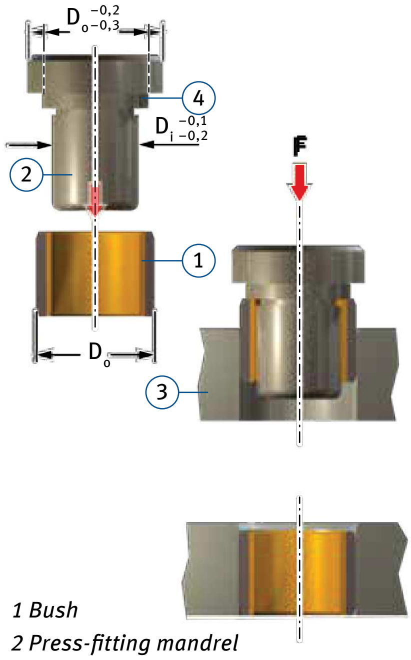
1 Bush
2 Press-fitting mandrel
3 Housing

Fig. 50: Press-fitting with moving housing



1 Bush
2 Press-fitting mandrel
3 Housing

Fig. 51: Flush press-fitting $D_o \leq 55$ mm



1 Bush
2 Press-fitting mandrel
3 Housing
4 System diameter

Fig. 52: Recessed press-fitting $D_o \geq 55$ mm

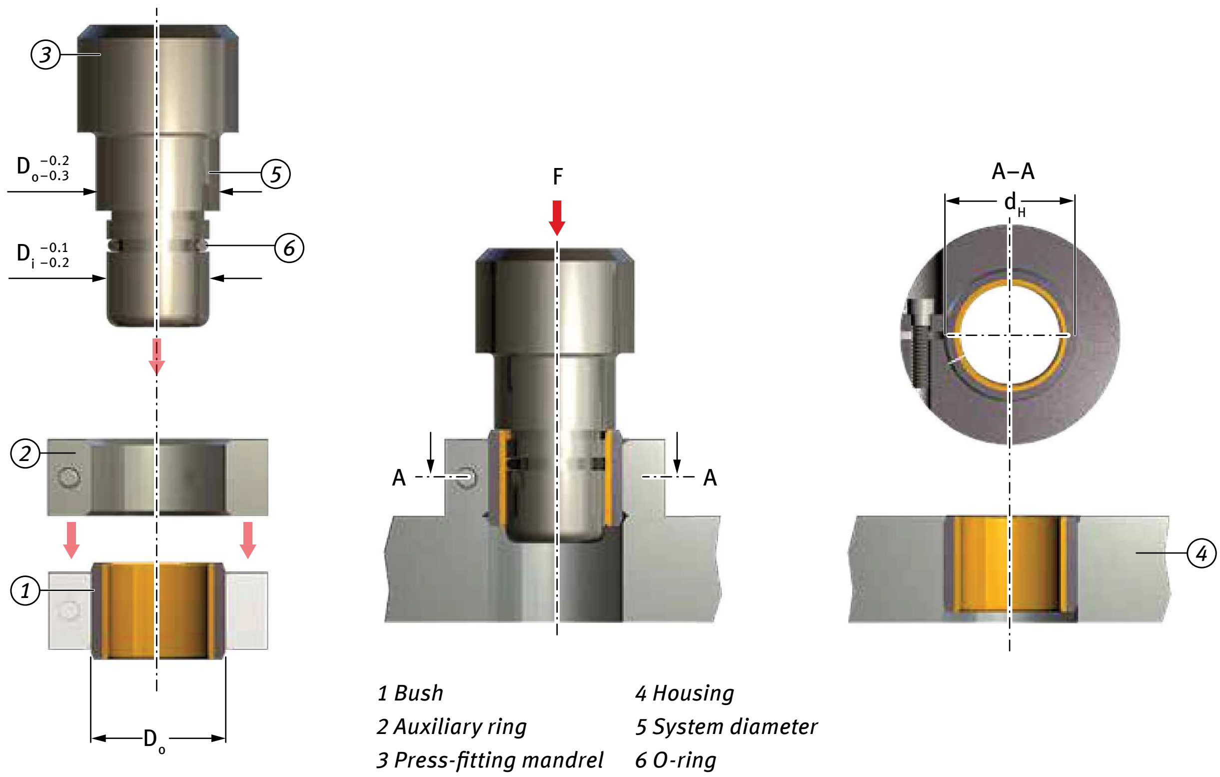


Fig. 53: Press-fitting bushes, $D_o \geq 55$ mm, with auxiliary ring

Table 35 allows you to calculate the required inside diameter d_H of the auxiliary ring on the basis of the stated outside diameter D_o of the bush.

D_o (mm)	d_H (mm)	
$55 \leq D_o \leq 100$	D_o	+0.28
		+0.25
$100 < D_o \leq 200$	D_o	+0.40
		+0.36
$200 < D_o \leq 305$	D_o	+0.50
		+0.46

Tab. 35: Inside diameter d_H of auxiliary ring

Calibration of bearing bore after installation (applies to P1 plain bearings only)

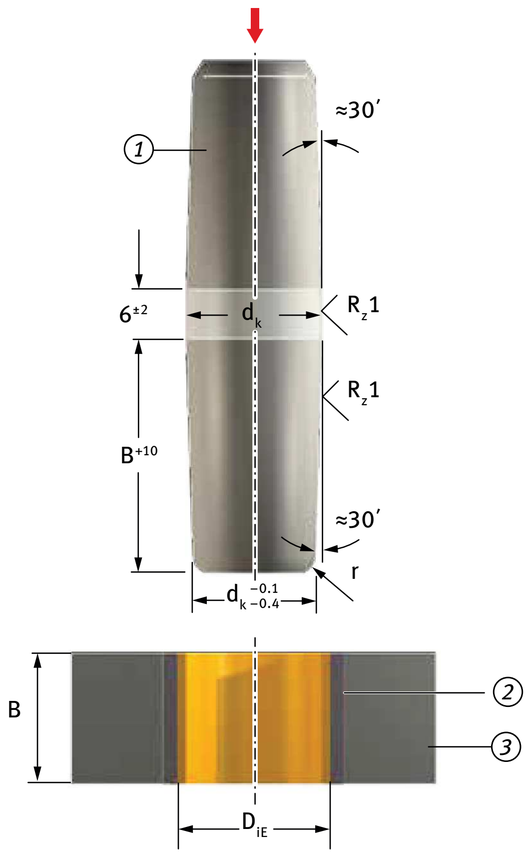
Calibration
KS Permaglide® plain bearings are ready to install on delivery, and should only be calibrated if a bearing clearance with a narrower tolerance cannot otherwise be reached.

Caution:
Calibration considerably shortens the service life of P1 KS Permaglide® bushes (see Tab. 36).

Figure 53 shows calibration using a mandrel. Table 36 contains approximate values for the diameter of the calibrating mandrel d_K. Precise values can only be ascertained through tests.

Better possibilities
The bearing clearance tolerance can be reduced through the following measures, which do not adversely affect service life:

- Narrower tolerances for housing bore
- Narrower shaft tolerances.



1 Calibrating mandrel, case hardening depth Eht>0.6, HRC 56 to 64
2 P10 KS Permaglide® bush
3 Housing
B Bush width
D_{iE} Bush diameter in press-fit state
d_K Diameter of calibrating mandrel
r Rounded edge

Fig. 54: Calibration

Desired inside diameter of bush	Diameter of calibrating mandrel[1] d_K	Service life[2]
D_{iE}	–	100% L_N
D_{iE} +0.02	D_{iE} +0.06	80% L_N
D_{iE} +0.03	D_{iE} +0.08	60% L_N
D_{iE} +0.04	D_{iE} +0.10	30% L_N

Tab. 36: Approximate values for the calibration mandrel diameter and the reduction in service life

D_{iE} Inside diameter of bush in press-fit state.
[1] Approximate value, based on steel housing.
[2] Approximate value for dry running.

Press-in force and joint pressure

Press-in force and joint pressure are interdependent. The joint pressure occurs between the housing bore and the surface of the bush jacket. It can be understood as a measure of how securely the bush fits in the housing. Together with other factors, the joint pressure influences the amount of press-in force.

Calculating the press-in force

The press-in force depends upon many factors, which can only be estimated, for example:

- Actual press-fit
- Coefficient of friction
- Scoring
- Press-in speed.

Motorservice offers the calculation of the press-in force as a service. In most cases, the estimate of press-in force as per Fig. 55 is sufficient.

Determining the bush press-in force

Figure 55 below shows the maximum required press-in force per mm of bush width. The curves represent the bush outside diameter D_O and the bush wall thickness $_3$ to DIN ISO 3547.

This calculation assumes a steel housing, with a diameter D_G that has been adapted in relation to the bush outside diameter D_O. The selected ratio is $D_G : D_O \approx 1.5...2$.

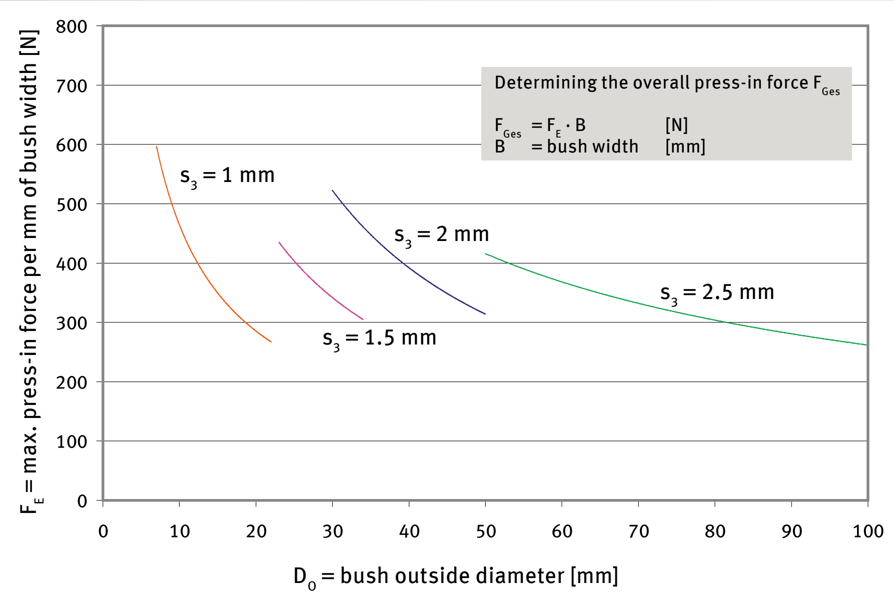


Fig. 55: Press-in force FE

Example of estimate of press-in force F_{Ges}

Given:	Bush		PAP 4030 P14
	Bush outside diameter	D_O =	44 mm
	Bush width	B =	30 mm
	Bush wall thickness	s_3 =	2 mm

[14]	$F_{Ges} = F_E - B$	= 340 N/mm – 30 mm	= 10200 N

F_E = 340 N/mm (from Fig. 55, D_O = 44 mm, s_3 = 2mm)

Bushes

Fig. 56: Bushes

P10, P14, P147*
- For shafts from 2 mm to 300 mm

P11
- For shafts from 4 mm to 100 mm

P20, P22*, P23*, P200, P202*, P203*
- For shafts from 8 mm to 100 mm

Maintenance-free KS Permaglide® plain bearings P10, P11, P14, P147*

Technical data		P10, P11	P14	P147*
Symbol	Unit			
$pv_{max.}$	[MPa · m/s]	1.8	1.6	1.4
$p_{stat.}$	[MPa]	250	250	250
$p_{dyn.}$	[MPa]	56	56	56
$v_{max.}$	[m/s]	2	1	0.8
T	[°C]	−200 to +280	−200 to +280	−200 to +280

KS Permaglide® P10 with steel back, KS Permaglide® P11 with bronze back

Low-maintenance KS Permaglide® plain bearings P20, P22*, P23*, P200, P202*, P203*

Technical data		P20, P22*, P23*	P200, P202*, P203*
Symbol	Unit		
$pv_{max.}$	[MPa · m/s]	3	3.3
$p_{stat.}$	[MPa]	250	250
$p_{dyn.}$	[MPa]	70	70
$v_{max.}$	[m/s]	3	3.3
T	[°C]	−40 to +110	−40 to +110

Collar bushes

Fig. 57: Collar bushes

P10, P11, P14, P147*
- For shafts from 6 mm to 40 mm

Thrust washers

Fig. 58: Thrust washers

P10, P11, P14, P147*
- With inside diameter from 10 mm to 62 mm

P20, P22*, P23*, P200, P202*, P203*
- With inside diameter from 12 mm to 52 mm

Strips

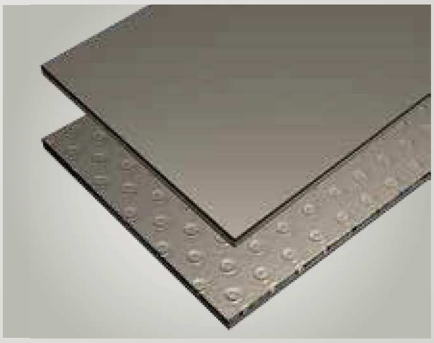


Fig. 59: Strips

P10, P11, P14, P147*
- Length 500 mm
- For widths see dimension tables
- For wall thicknesses see dimension tables

P20, P22*, P23*, P200, P202*, P203*
- Length 500 mm
- Width 250 mm
- For wall thicknesses see dimension tables

* On request

Example order and example designation

Bush of KS Permaglide® P10 with steel back:

Inside diameter (D_i)	16 mm
Width (B)	25 mm
Order designation:	PAP 1625 P10

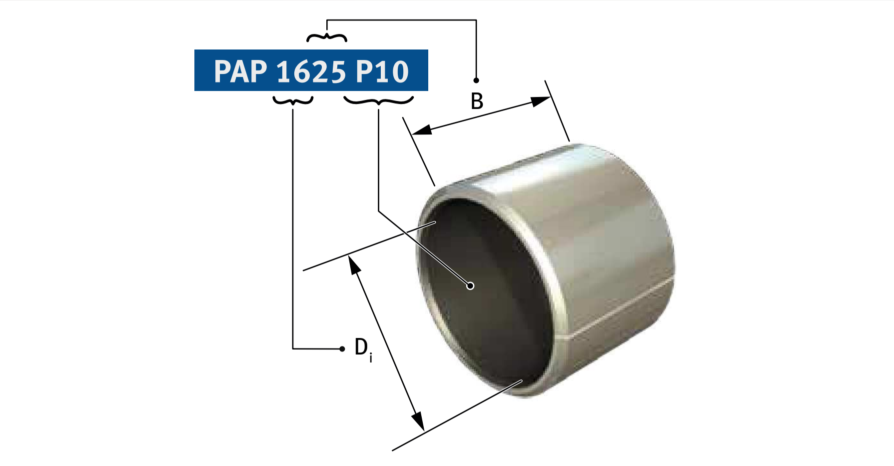


Fig. 60: Example order, P10 bush

Strips of KS Permaglide® P20:

Width (B)	180 mm
Wall thickness (s_3)	1 mm
(Order code: $s_3 \cdot 10$)	
Order designation:	PAS 10180 P20

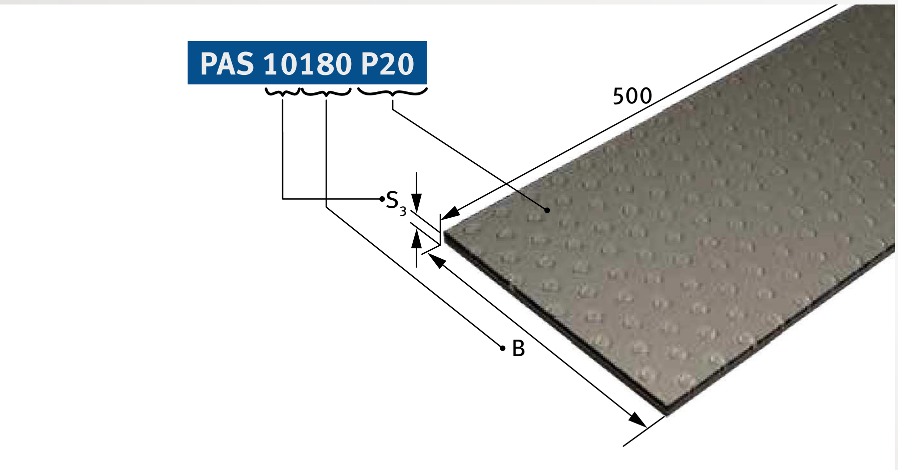


Fig. 61: Example order, P20 strip

Thrust washers of KS Permaglide® P20:

Inside diameter (D_i)	12 mm
Order designation:	PAW 12 P20

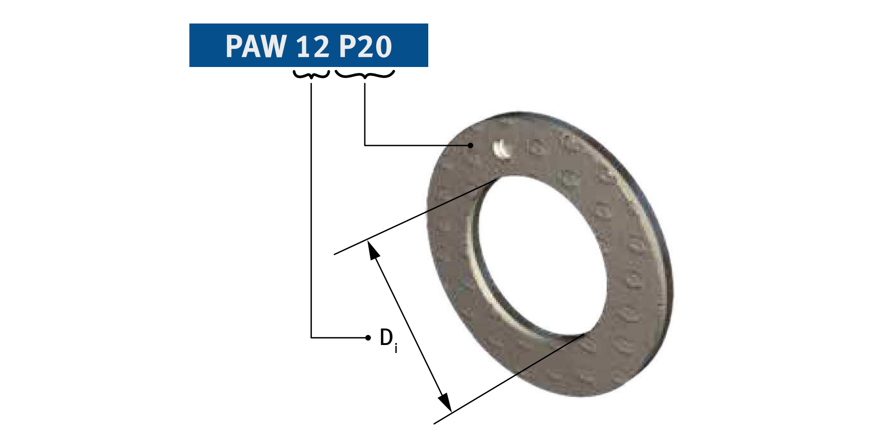


Fig. 62: Example order, P20 thrust washer

9.1 KS Permaglide® bushes, maintenance-free

9.1.1 Series P10, P14, P147* with steel back

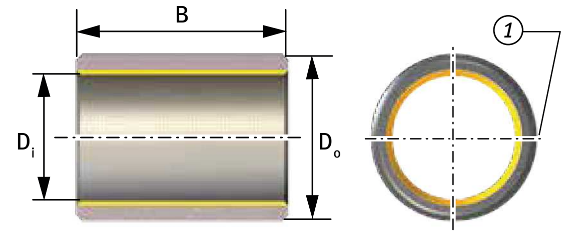
Recommended fitting tolerance:

Shaft	
$d_W < 5$	h6
$5 \le d_W < 80$	f7
$80 \le d_W$	h8

House bore	
$d_G \le 5.5$	H6
$5.5 < d_G$	H7

For bearing clearances, wall thicknesses and chamfer tolerances, see section 7, “Design and layout of bearing assembly”, “Theoretical bearing clearance”.

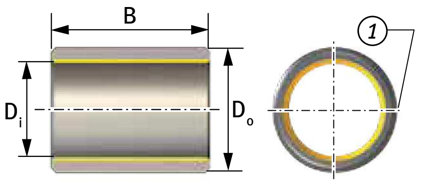
Bushes in special dimensions available on request.



1 Joint

Dimension table (dimensions in mm)					
Shaft	Order designation	Weight	Dimensions		
diameter	……. P10, P14, P147*	g	D_i	D_o	B ±0.25
2	PAP 0203 ….	0.15	2	3.5	3
	PAP 0205 ….	0.25	2	3.5	5
3	PAP 0303 ….	0.2	3	4.5	3
	PAP 0304 ….	0.26	3	4.5	4
	PAP 0305 ….	0.33	3	4.5	5
	PAP 0306 ….	0.4	3	4.5	6
4	PAP 0403 ….	0.25	4	5.5	3
	PAP 0404 ….	0.33	4	5.5	4
	PAP 0406 ….	0.5	4	5.5	6
	PAP 0410 ….	0.84	4	5.5	10
5	PAP 0505 ….	0.72	5	7	5
	PAP 0508 ….	1.1	5	7	8
	PAP 0510 ….	1.4	5	7	10
6	PAP 0606 ….	1	6	8	6
	PAP 0608 ….	1.3	6	8	8
	PAP 0610 ….	1.7	6	8	10
7	PAP 0710 ….	1.9	7	9	10
8	PAP 0808 ….	1.7	8	10	8
	PAP 0810 ….	2.1	8	10	10
	PAP 0812 ….	2.6	8	10	12
10	PAP 1008 ….	2.1	10	12	8
	PAP 1010 ….	2.6	10	12	10
	PAP 1012 ….	3.1	10	12	12
	PAP 1015 ….	3.9	10	12	15
	PAP 1020 ….	5.3	10	12	20
12	PAP 1208 ….	2.5	12	14	8
	PAP 1210 ….	3.1	12	14	10
	PAP 1212 ….	3.7	12	14	12
	PAP 1215 ….	4.7	12	14	15
	PAP 1220 ….	6.2	12	14	20
	PAP 1225 ….	7.8	12	14	25
13	PAP 1310 ….	3.3	13	15	10

* On request



1 Joint

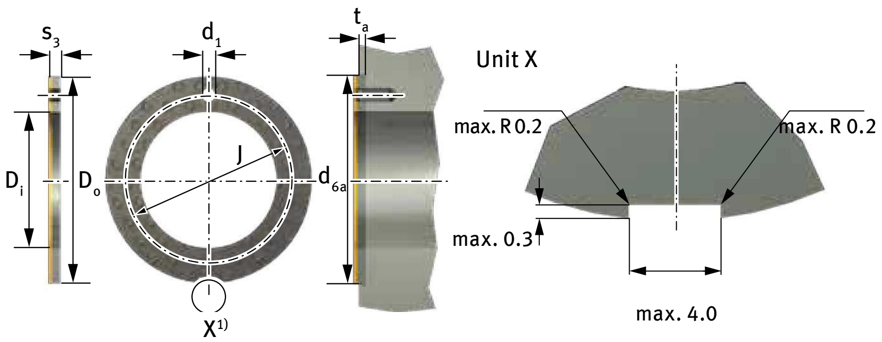
Dimension table · continued (dimensions in mm)					
Shaft diameter	Order designation P10, P14, P147*	Weight g	Dimensions		
			D_i	D_o	B ±0.25
14	PAP 1410	3.6	14	16	10
	PAP 1412	4.3	14	16	12
	PAP 1415	5.4	14	16	15
	PAP 1420	7.1	14	16	20
	PAP 1425	9	14	16	25
15	PAP 1510	3.8	15	17	10
	PAP 1512	4.6	15	17	12
	PAP 1515	5.7	15	17	15
	PAP 1520	7.6	15	17	20
	PAP 1525	9.5	15	17	25
16	PAP 1610	4	16	18	10
	PAP 1612	4.9	16	18	12
	PAP 1615	6.1	16	18	15
	PAP 1620	8.1	16	18	20
	PAP 1625	10.1	16	18	25
18	PAP 1810	4.5	18	20	10
	PAP 1815	6.8	18	20	15
	PAP 1820	9.1	18	20	20
	PAP 1825	11.3	18	20	25
20	PAP 2010	7.8	20	23	10
	PAP 2015	11.7	20	23	15
	PAP 2020	15.6	20	23	20
	PAP 2025	19.5	20	23	25
	PAP 2030	23.4	20	23	30
	PAP 2040	31.2	20	23	40
22	PAP 2215	12.7	22	25	15
	PAP 2220	17	22	25	20
	PAP 2225	21.3	22	25	25
	PAP 2230	25.5	22	25	30
24	PAP 2415	13.8	24	27	15
	PAP 2420	18.5	24	27	20
	PAP 2425	23.1	24	27	25
	PAP 2430	27.7	24	27	30
25	PAP 2510	9.6	25	28	10
	PAP 2515	14.4	25	28	15
	PAP 2520	19.2	25	28	20
	PAP 2525	24	25	28	25
	PAP 2530	28.8	25	28	30
	PAP 2540	38.4	25	28	40
	PAP 2550	48	25	28	50
28	PAP 2820	29.1	28	32	20
	PAP 2830	43.7	28	32	30

* On request

9.3 KS Permaglide® thrust washers, maintenance-free

9.3.1 Series P10, P14, P147* with steel back – Series P11 with bronze back

Thrust washers in special dimensions available on request.



1) Maximum 4 free cuts on outside diameter, location optional

Dimension table (dimensions in mm)								
Order designation P10, P11, P14, P147*	Weight g	Dimensions					Connection dimensions	
		D_i +0.25	D_o −0.25	s_3 −0.05	J ±0.12	d_1 +0.4 +0.1	t_a ±0.2	d_{6a} +0.12
PAW 10	2.7	10	20	1.5	15	1.5	1	20
PAW 12	3.9	12	24	1.5	18	1.5	1	24
PAW 14	4.3	14	26	1.5	20	2	1	26
PAW 16	5.8	16	30	1.5	22	2	1	30
PAW 18	6.3	18	32	1.5	25	2	1	32
PAW 20	8.1	20	36	1.5	28	3	1	36
PAW 22	8.7	22	38	1.5	30	3	1	38
PAW 26	11.4	26	44	1.5	35	3	1	44
PAW 28	13.7	28	48	1.5	38	4	1	48
PAW 32	17.1	32	54	1.5	43	4	1	54
PAW 38	21.5	38	62	1.5	50	4	1	62
PAW 42	23.5	42	66	1.5	54	4	1	66
PAW 48	38.5	48	74	2	61	4	1.5	74
PAW 52	41	52	78	2	65	4	1.5	78
PAW 62	52	62	90	2	76	4	1.5	90

* On request