

# KS Permaglide® Plain Bearings

Catalogue 2015



**Original**

**KS PERMAGLIDE®**

**Plain Bearings**



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# 1 | Overview of materials

## KS Permaglide® P1 plain bearings

- Maintenance-free
- Suitable for dry running

Characteristics & properties	Units	P10 P11	P14	P147*
lead-free	–	no	yes	yes
$p_{v\max}$	MPa · m/s	1.8	1.6	1.4
$p_{\max.\text{stat.}}$	MPa	250	250	250
$p_{\max.\text{dyn.}}$	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



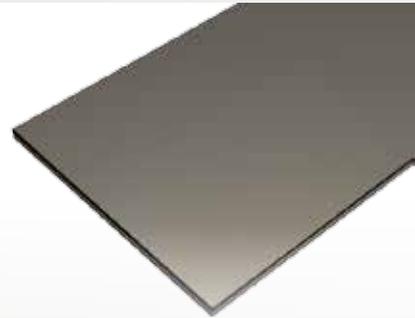
*PAP bushes*  
P10, P11, P14, P147\*



*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
$p v_{max}$	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

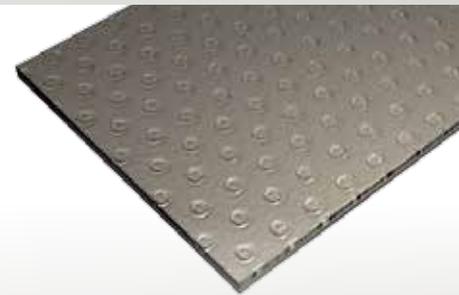
**Versions of the KS Permaglide® P2**



*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 <sub>i</sub>	mm	Usable strip width
C <sub>i</sub>	mm	Inside bevel of bush (bevelled edge)
C <sub>o</sub>	mm	Outside bevel of bush
D <sub>FL</sub>	mm	Collar diameter
D <sub>i</sub>	mm	Bush inside diameter Inside diameter of thrust washer
D <sub>ie</sub>	mm	Bush inside diameter in pressed-in state
D <sub>o</sub>	mm	Outside diameter of bush Outside diameter of thrust washer
d <sub>ch</sub>	mm	Diameter of test holder (adjusting mandrel)
d <sub>G</sub>	mm	Diameter of housing bore
d <sub>H</sub>	mm	Inside diameter of auxiliary ring
d <sub>K</sub>	mm	Diameter of calibrating mandrel
d <sub>L</sub>	mm	Oil hole diameter
d <sub>w</sub>	mm	Shaft diameter
d <sub>1</sub>	mm	Diameter of mounting hole in thrust washer
d <sub>6a</sub>	mm	Diameter of housing recess for thrust washer
F	N	Bearing load, press-in force
F <sub>ch</sub>	N	Test force
F <sub>E</sub>	N	Press-in force per mm of bush width
F <sub>Ges</sub>	N	Total press-in force
f <sub>G</sub>	mm	Chamfer width on housing
f <sub>A</sub>	–	Load type correction factor
f <sub>L</sub>	–	Linear movement correction factor
f <sub>p</sub>	–	Load correction factor
f <sub>R</sub>	–	Roughness depth correction factor
f <sub>T</sub>	–	Temperature correction factor
f <sub>v</sub>	–	Sliding speed correction factor
f <sub>w</sub>	–	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 <sub>N</sub>	h	Nominal service life
m	g	Weight
n	min <sup>-1</sup>	Speed
n <sub>osz</sub>	min <sup>-1</sup>	Oscillating frequency of oscillating movement
p	MPa	Specific bearing load
p <sub>v</sub>	MPa · m/s	p <sub>v</sub> value, product of specific bearing load and sliding speed
R, r	mm	Radius
R <sub>z</sub>	µm	Roughness depth
s <sub>1</sub>	mm	Thickness of steel or bronze back
s <sub>3</sub>	mm	Wall thickness of bush
s <sub>FL</sub>	mm	Collar thickness
T	°C	Temperature
t <sub>a</sub>	mm	Depth of housing recess
v	m/s	Sliding speed
x	mm	Measuring line distance
z	mm	Distance btwn. test holder halves
α <sub>Bz</sub>	K <sup>-1</sup>	Thermal expansion coefficient of bronze
α <sub>St</sub>	K <sup>-1</sup>	Thermal expansion coefficient of steel
Δs	mm	Theoretical bearing clearance
Δz	mm	Measured value in test holder
λ <sub>Bz</sub>	W(mK) <sup>-1</sup>	Coeff. of thermal conductivity, bronze
λ <sub>St</sub>	W(mK) <sup>-1</sup>	Coeff. of thermal conductivity, steel
μ	–	Coefficient of friction
τ <sub>s</sub>	N/mm <sup>2</sup>	Shear strength
φ	°	Swivel angle

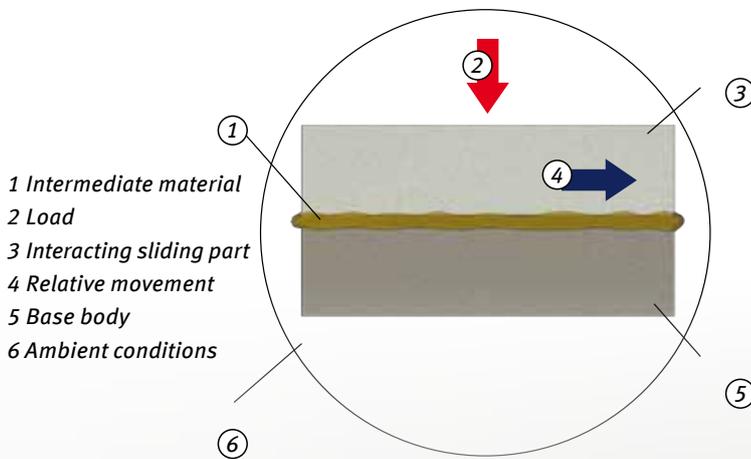
Plain bearings are used to absorb and convey forces between parts that move relative to one another. They determine the position of the moved components in relation to one another and ensure accuracy of the movement.

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**



**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

Fig. 1: Tribological system

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).

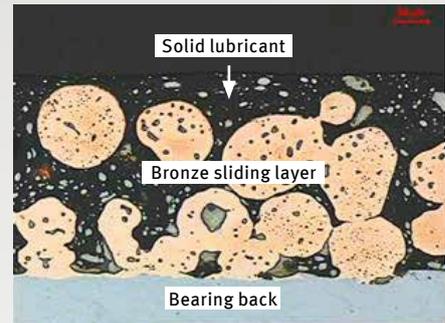
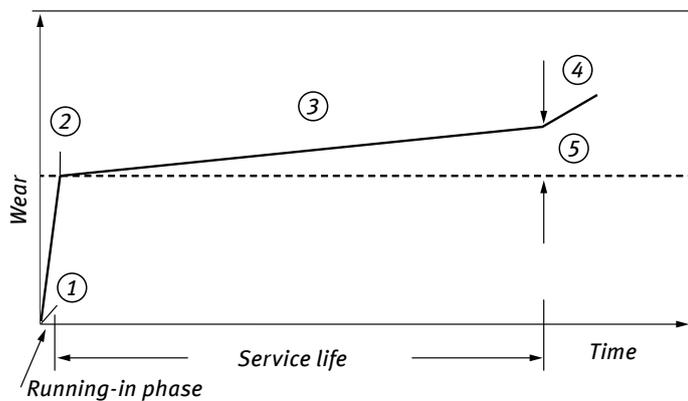


Fig. 2: P1 layer system

### 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**

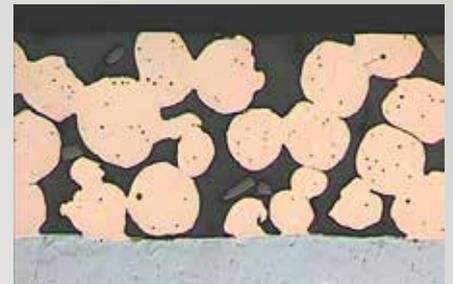
As the sliding movement commences, parts of the running-in layer are transferred to the moving interacting sliding part (Fig. 6). During this process, a sealed film of solid lubricant forms on the interacting sliding part, which considerably reduces the friction. This running-in process causes up to 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.

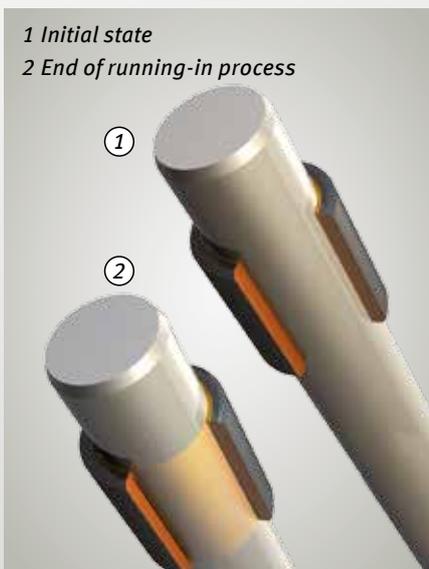
When the lubricant is used up, a new cycle commences. Fig. 7 shows a typical curve of this development. Fig. 8 illustrates the condition of the sliding surface during service life.



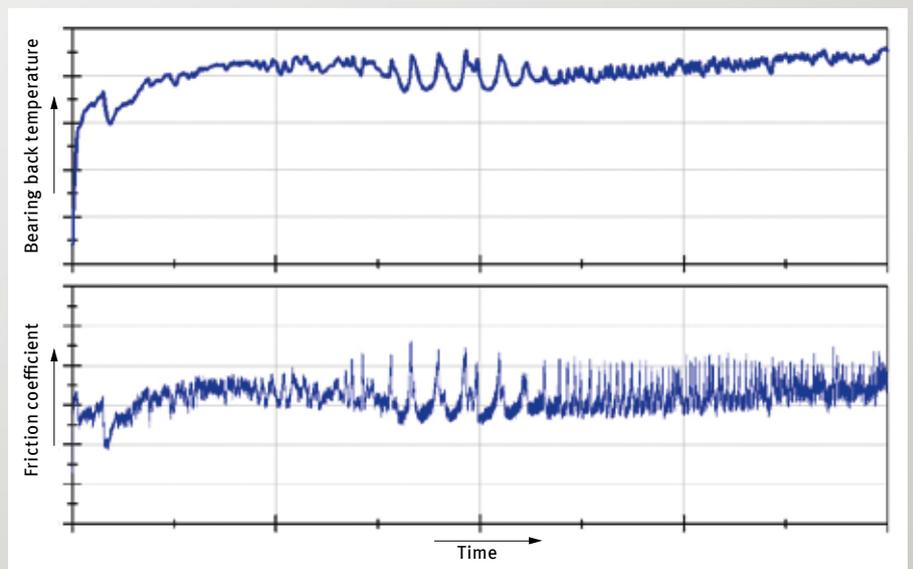
*Fig. 5: Condition of sliding surface at end of running-in process*



*Fig. 8: Condition of sliding surface during service life*



*Fig. 6: Material transfer*



*Fig. 7: Oscillation characteristic of friction coefficient and temperature*

### 3 | KS Permaglide® plain bearings

#### 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.

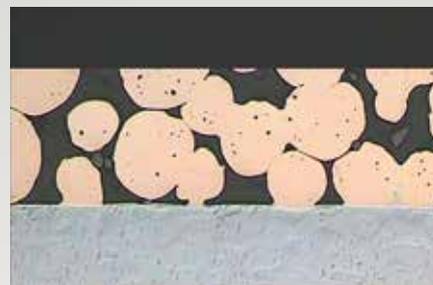


Fig. 9: Condition of sliding surface at end of service life

### 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	$< v \leq 2$ m/s
0.1 MPa	$< p \leq 56$ MPa
P14	
0.03 m/s	$< v \leq 1$ m/s
0.1 MPa	$< p \leq 56$ MPa
P147	
0.03 m/s	$< v \leq 0,8$ m/s
0.1 MPa	$< p \leq 56$ MPa

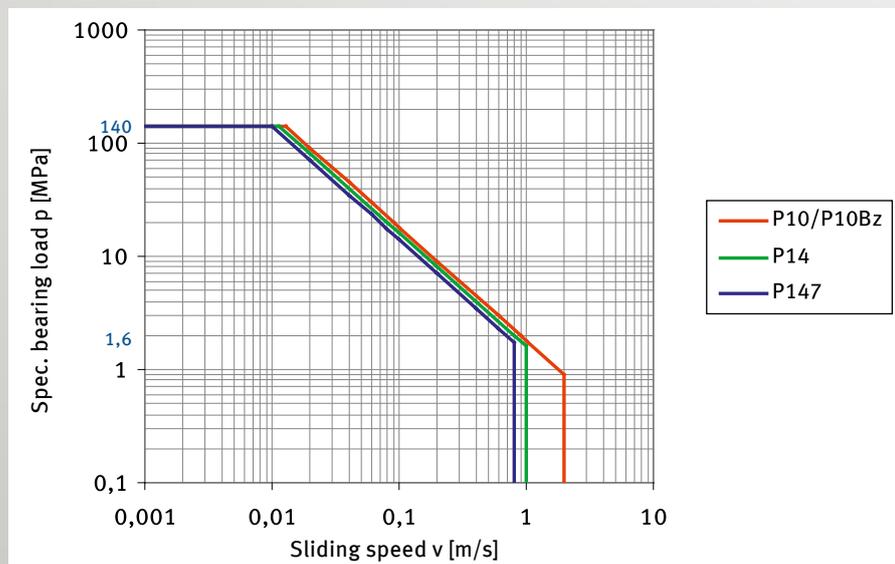


Fig. 10: pv value [MPa-m/s], limit curve (values apply at room temperature)

Here, the limit curve indicates that at the respective specific bearing load p<sub>max</sub> [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 v<sub>max.</sub> 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
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<sub>z</sub>0.8 to R<sub>z</sub>1.5. 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.

### 3 | KS Permaglide® plain bearings

#### 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.

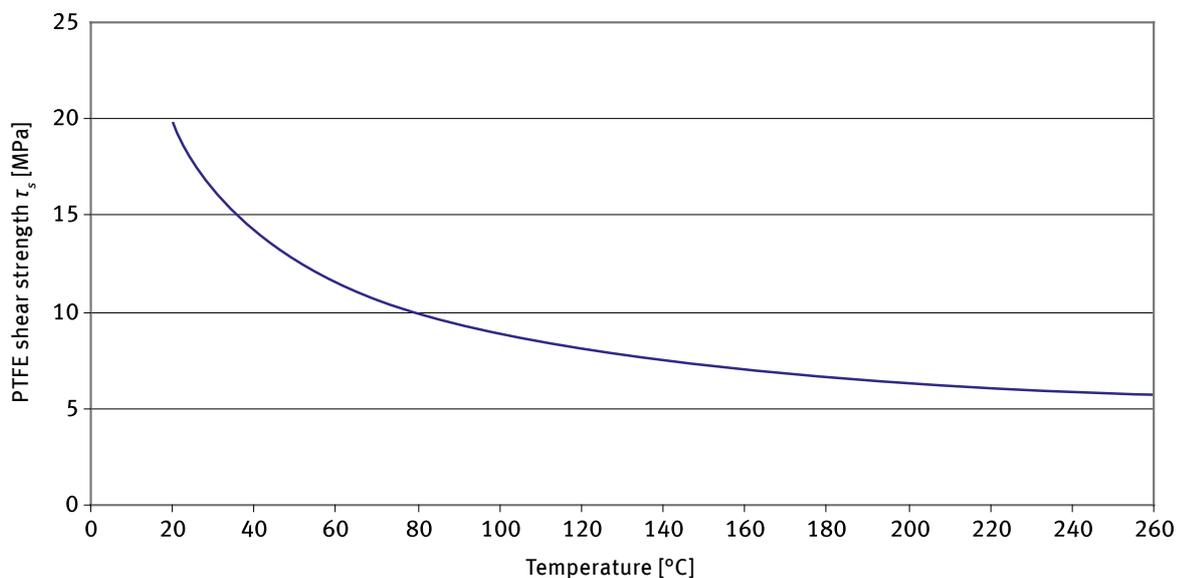


Fig. 11: PTFE shear strength  $\tau_s$  versus temperature

## 3.2 Introduction to material P2

### 3.2.1 Material composition

The material in P2 plain bearings consists of a steel back, a 0.2 mm to 0.35 mm thick bronze compound layer and a thermo-plastic resin with bulking agents as a sliding layer. The resin sliding layer is embedded in the cavities (pore volume ~ 50 %) of the bronze compound layer,

and forms a sliding surface 0.08 mm to 0.2 mm thick above the compound layer, depending on the intended purpose. Two different sliding layer compositions exist within the P2 material group: P20, P22, P23 with lead  
P200, P202, P203 lead-free

The thickness and contours of the sliding layer may also vary. Details on this subject can be found in the material data sheets of this catalogue.

### 3.2.2 Functional description

Low-maintenance P2 plain bearings are generally used in applications with life-time lubrication. For this purpose, the oil distributing pockets in the sliding surface are completely filled with lubricant (grease) during assembly.

#### Running-in process

At the beginning of the sliding movement, the grease in the sliding surface is transferred onto the interacting sliding part (shaft). The two sliding surfaces are therefore separated by a thin layer of lubricant.

The friction coefficient decreases during the sliding movement, assuming values of between 0.02 and 0.15. The sliding surfaces of the bearing and interacting sliding part simultaneously adapt accordingly, i.e. unevenness in the material is worked off. The material that is rubbed off, is largely deposited in the oil distributing pockets, and is initially no longer relevant to wear.

#### Continuous operation

Due to the design of the oil distributing

pockets (in conformity with DIN ISO 3547), sufficient lubricant is available for the expected period of operation. The friction coefficient and temperature remain virtually constant for a longer period. The wear rate is minimal. This applies to low to medium loads.

At higher loads or in difficult operating conditions, however, regular relubrication of the bearing assembly is recommended. Correctly timed relubricating intervals reduce the wear rate, and increase operational reliability and service life accordingly.

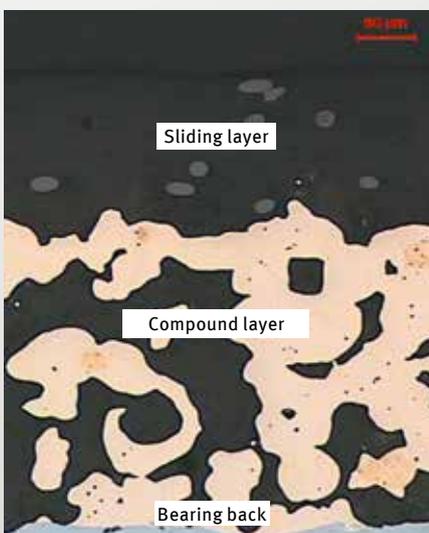


Fig. 12: P2 layer system

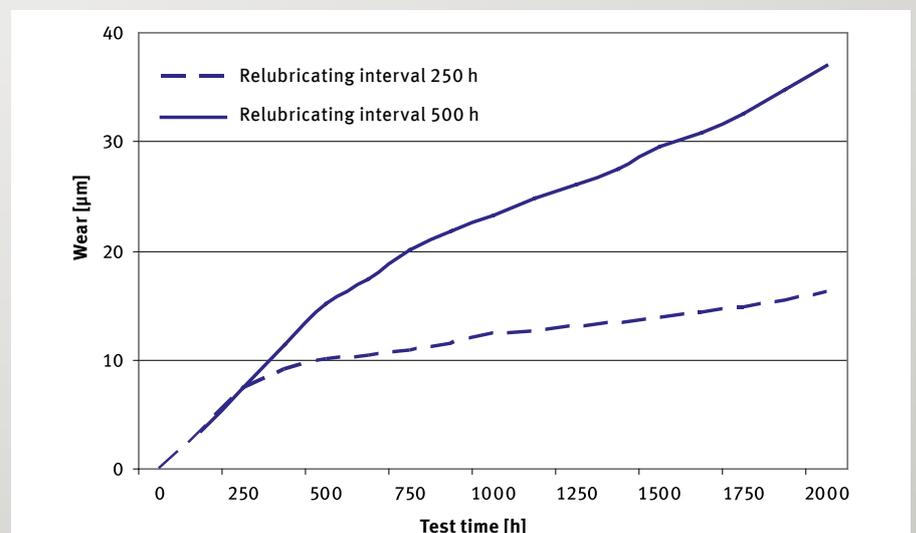


Fig. 13: Service life = f(lubricating interval)

## 3 | KS Permaglide® plain bearings

### End of service life

After a longer period of operation and corresponding depth of wear, the lubricant volume of plain bearing applications with lifetime lubrication is used up. The type of lubricating grease and ambient conditions may also adversely affect the performance of the lubricant (ageing). Consequently, the friction coefficient, bearing temperature and wear all rise disproportionately, and the bearing can overheat and fail.

Similar behaviour can also be expected in bearing assemblies requiring relubrication. Relubrication may considerably extend the service life of the bearing assembly, but even here, the depth of wear drastically reduces the capacity of the oil distributing pockets. Sufficient lubricant can then no longer be deposited. The effect is worsened by rubbed off material, which enters the oil distributing

pockets and further limits their volume. Failure symptoms similar to those of lifetime lubricated plain bearings can then occur.

### 3.2.3 Limit values and influencing factors

The service life and reliability of a low-maintenance plain bearing assembly are influenced not only by operating and ambient conditions, but also the lubricating conditions (grease, oil). As a rule, several influencing factors occur simultaneously and are also interdependent. The most important influencing factors and limit values are explained below.

#### Maximum permitted pv value

The pv value is the product of the specific bearing load  $p$  [MPa] and the sliding speed  $v$  [m/s]. These two variables interact with one another. Fig. 14 shows the maximum permitted pv value for P2 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 P2 plain bearing is suitable for use.

#### Range of application of service life calculation:

P20		
0.04 m/s	$< v \leq$	3 m/s
0.1 MPa	$< p \leq$	70 MPa
P200		
0.04 m/s	$< v \leq$	3.3 m/s
0.1 MPa	$< p \leq$	70 MPa

The limit curve indicates that at the respective specific bearing load  $p$  [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, no thermal equilibrium can be reached. The wear intensity and temperature increase and the bearing may fail within a short time.

P2 plain bearings must be lubricated. Depending on the lubricant, service life may be lengthened. The limit curve shown here applies to lithium-soap grease, mineral oil-based grease and a temperature of 20 °C.

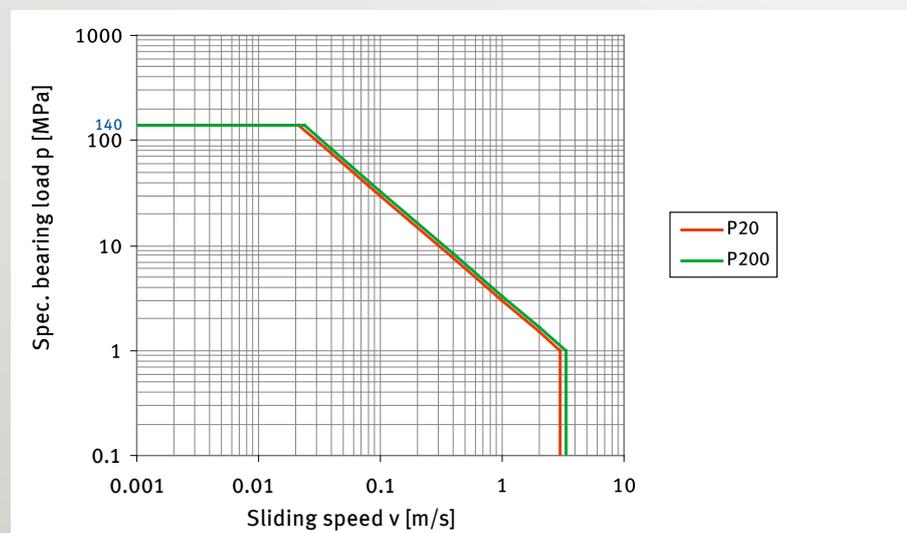


Fig. 14: pv values, limit curves for P20, P200, grease-lubricated at 20 °C

### Specific bearing load

At the maximum permitted specific bearing load and the respective maximum permitted sliding speed, the following threshold values apply to a low-maintenance P2 plain bearing:

Maximum specific bearing load p [MPa]		Sliding speed v [m/s]	
		P20, P22*, P23*	P200, P202*, P203*
Static	250 MPa	–	–
Concentrated load at rest, uniform movement	140 MPa	≤ 0.021 m/s	≤ 0.024 m/s
Concentrated load at rest, rotating, oscillating	70 MPa	≤ 0.043 m/s	≤ 0.047 m/s
Concentrated load, circumferential load, increasing, rotating, oscillating	35 MPa	≤ 0.086 m/s	≤ 0.094 m/s
Load limit (Fig. 14)	1.0 MPa	max. 3.0 m/s	max. 3.3 m/s

Tab. 3: Threshold values of spec. bearing load

### Sliding speed

For low-maintenance, lead containing P2 plain bearings, the maximum permitted sliding speed v with grease lubrication is limited to 3.0 m/s. For low-maintenance, lead-free P2 plain bearings, the maximum permitted sliding speed is 3.3 m/s. Here, the sliding speed is understood as the relative speed between the bearing and the interacting sliding part. It is of paramount importance in a tribological system, that the specific bearing load p is a determining factor for the area of application of a plain bearing. 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. If the sliding speed rises above the permitted value, the plain bearing system is no longer in a state of thermal equilibrium. Operational problems and even failure can arise.

### Grease lubrication

The service life of a P2 plain bearing is also influenced by the type of grease used. The friction coefficient, load carrying capacity and permitted operating temperature, in particular, are dependent upon the lubricating grease. Ageing resistance is also an important factor for problem-free function.

Types of grease that are basically suitable are:

- Lithium-soap grease (ageing-resistant)
- Barium-soap grease (good adhesion)
- Aluminium-soap grease (good wettability)

Correctly timed relubricating intervals extend service life and improve operational reliability (Fig. 13).

### Friction and interacting sliding parts (material and surface)

The operational reliability and service life of a low-maintenance bearing assembly depend not only on the load collective and lubricant, but also on the material and surface of the interacting sliding part.

The materials of the interacting sliding part may exert a considerable influence on service life (see Tab. 24). 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 conditions are created by a surface roughness of  $R_z$  0.8 to  $R_z$  1.5. If surface roughness exceeds this, abrasion and increased wear result, despite the presence of grease as a lubricant.

\* On request

### Temperature

P2 plain bearings are extremely insensitive to operating temperatures up to approx. 70 °C. If temperatures rise considerably above this level, however, the bearing's performance drops abruptly. The practical operating limit is reached at a temperature of 110 °C. An operating temperature of 140 °C is possible for brief periods, but only if bearing load is very low. The thermal resistance of the lubricant used (e.g. type of grease) must also be taken into consideration.

### Sliding movement and load

The type of load – concentrated or circumferential – is an important 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.

Rotating or swivelling movements under uniform load principally produce wear. If the bearing assembly is subjected to high-frequency load changes or vibrations, this effect can intensify 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.

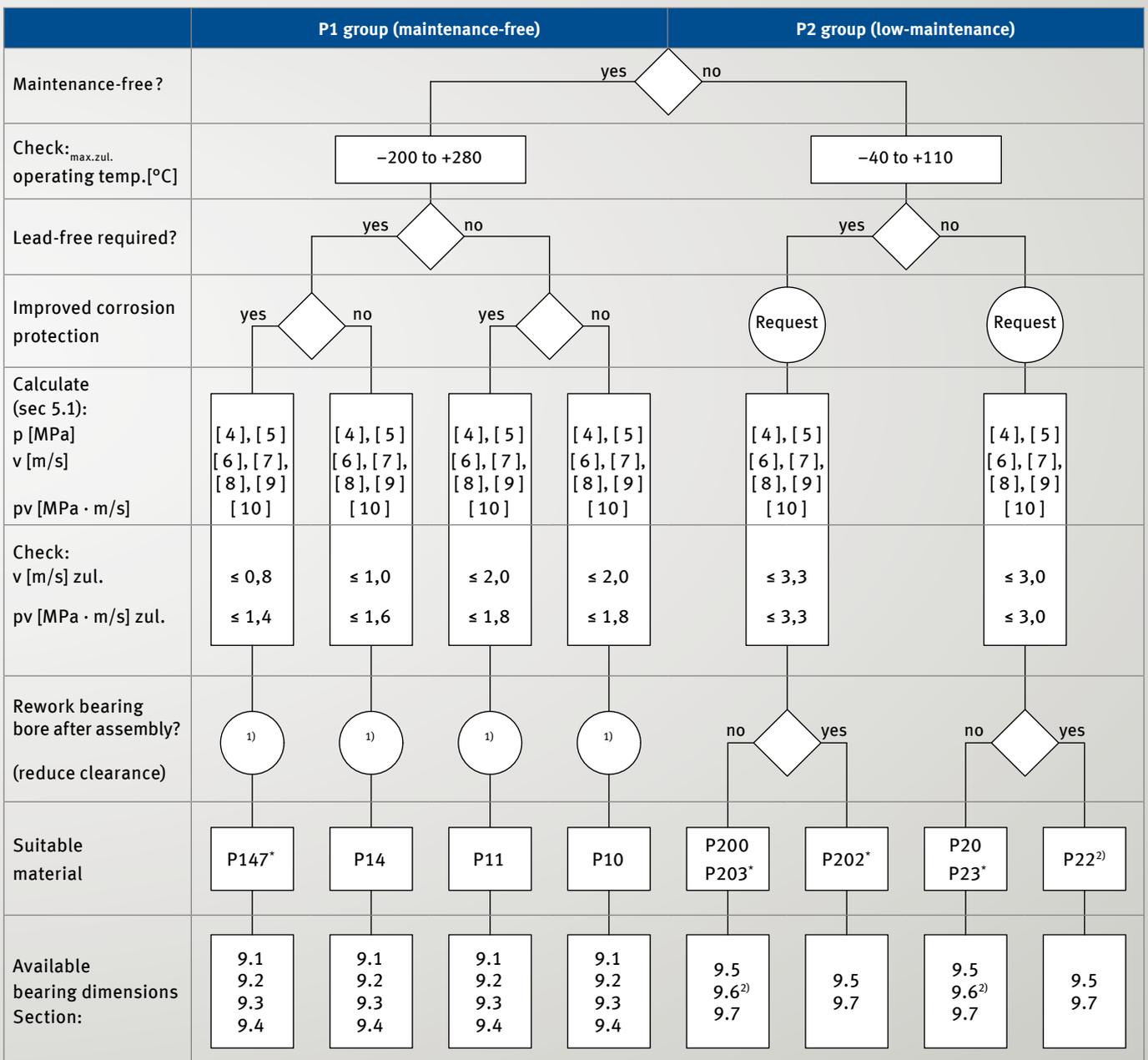
### Hydrodynamic operation

P2 plain bearings may also run under hydrodynamic conditions. In such application, a sliding layer without oil distributing pockets is required.

Plain bearings without oil distributing pockets can be supplied ready to install or, on request, the inside diameter of bearings can be machined accordingly. As calculation of hydrodynamic plain bearings is a complex task, Motorservice offers this service.

**Material selection plan. Applies to dry-running and grease-lubricated plain bearings.**  
 For hydrodynamic operation, Motorservice offers calculation and material selection as a service.

Input variables	
The adjacent input variables are normally set out in the specification or are calculated (shaft). As an initial approximation, the bearing width must be provisionally determined as a function of the shaft in this plan.	<ul style="list-style-type: none"> <li>• Bearing load [MPa]</li> <li>• Shaft diameter [mm]</li> <li>• Speed [rpm]</li> <li>• Swivel angle [°]</li> <li>• Oscillating frequency [rpm]</li> <li>• Bearing width [mm]</li> </ul>



<sup>1)</sup> P1 group bushes cannot be reworked.

They can be calibrated without cutting, but this reduces service life (Tab. 36)

<sup>2)</sup> Applies to P20/P200 material only

\* On request

### 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  $-200^{\circ}\text{C}$  to  $280^{\circ}\text{C}$

##### 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

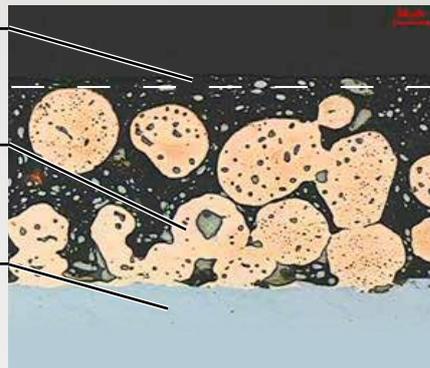
Use in hydrodynamic conditions is possible without problem up to a sliding speed of 3 m/s.

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**

<b>1</b>	<b>Running-in layer</b>	
	PTFE matrix with bulking agent <sup>1)</sup> Layer thickness [mm]:	max. 0.03
<b>2</b>	<b>Sliding layer</b>	
	Tin-lead-bronze Layer thickness [mm]: Pore volume [%]:	0.20–0.35 approx. 30
<b>3</b>	<b>Bearing back</b>	
	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	$p_{v_{zul.}}$	MPa·m/s	1.8
Permitted specific bearing load			
• Static	$p_{zul.}$	MPa	250
• Concentrated load, circumferential load at sliding speed $\leq 0.013$ m/s	$p_{zul.}$	MPa	140
• Concentrated load, circumferential load at sliding speed $\leq 0.032$ m/s	$p_{zul.}$	MPa	56
• Concentrated load, circumferential load, increasing at sliding speed $\leq 0.064$ 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	$\alpha_{St}$	K <sup>-1</sup>	$11 \cdot 10^{-6}$
Coeff. of thermal conductivity			
• Steel back	$\lambda_{St}$	W(mK) <sup>-1</sup>	40

Tab. 6: Material characteristics P10

<sup>1)</sup> The pores of the sliding layer are also filled with this lubricant mass.

## 4 | Material selection, material information

### Material composition of P11

1	Running-in layer	
	PTFE matrix with bulking agent <sup>1)</sup>	
	Layer thickness [mm]:	max. 0.03
2	Sliding layer	
	Tin-bronze	
	Layer thickness [mm]:	0.20–0.35
	Pore volume [%]:	approx. 30
3	Bearing back	
	Steel	
	Steel thickness [mm]:	Variable
	Steel hardness [HB]:	80–160

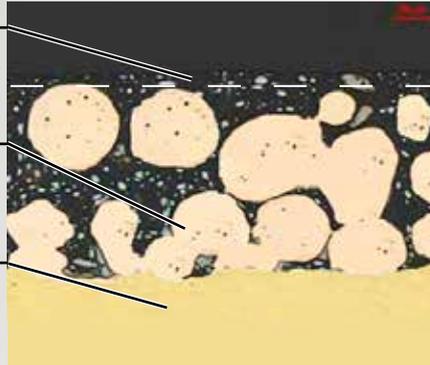


Fig. 16: Layer system P11

Tab. 7: System composition P11

### Chemical composition

Running-in layer	
Components	% Weight
PTFE	44
Pb	56
Sliding layer	
Components	% Weight
Sn	9 to 11
Cu	Remainder
Bearing back	
Material	Material information
Bronze	CuSn 6
	DIN 17662

Tab. 8: Chemical composition P11

### Material characteristics

Characteristics, load limit	Symbol	Unit	Value
Permitted pv value	$pV_{zul.}$	MPa * m/s	1,8
• Static	$p_{stat}$	MPa	250
• Dynamic	$p_{dyn}$	MPa	140
Speeds			
• Dry running	$v_{rot}$	[m/s]	2
• Hydrodynamic operation	$v_{lin}$	[m/s]	3
Continuous operation temperature			
• Min.	$T_{min}$	°C	-200
• Max.	$T_{max}$	°C	280
Temporary	$T_{short}$	°C	140
Thermal expansion coefficient	$\alpha_{Bronze}$	$10^{-5} 1/K$	1,7
Coefficient of thermal conductivity	$\lambda_{Bronze}$	W/m/K	$\leq 70$

Tab. 9: Material characteristics P11

<sup>1)</sup> The pores of the sliding layer are also filled with this lubricant mass.

## 4.1.2 P14 ... Maintenance-free and environmentally friendly

### Brief description

P14 is a lead-free standard sliding material with a high tribological performance. It is designed for maintenance-free, dry-running applications. It may also be employed in systems with liquid lubrication, however.

The use of grease as a lubricant with P14 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 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 produced using controlled roller pairs.

### Plain bearing production

Sliding elements in a great variety of designs are produced from P14 in cutting, stamping and shaping processes.

Standard designs are:

- Cylindrical bushes
- Collar bushes
- Thrust washers
- Strips

In a final step, plain bearings manufactured from P14 undergo anti-corrosion treatment on the bearing back, end faces and joint surfaces.

Standard version: Tin

Layer thickness: approx. 0.002 mm

### Properties of P14

- Lead-free
- Very low stick-slip tendency
- Low wear
- Low friction coefficient
- No tendency to fuse with metal
- Very low tendency to swell

### Preferred areas of application

- Maintenance-free operation in dry-running conditions where lead-free parts are required
- Rotating or oscillating movements up to a speed of 1 m/s
- Linear movements
- Temperature range  $-200^{\circ}\text{C}$  to  $280^{\circ}\text{C}$

### 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.

### Important note:

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

**P14 cannot be used in water  
(Alternative: P10, P11, P147)**

## 4 | Material selection, material information

### Material composition of P14

1 Running-in layer		
PTFE matrix with bulking agent <sup>1)</sup>	Layer thickness [mm]:	max. 0,03
2 Sliding layer		
Tin-bronze	Layer thickness [mm]:	0,20–0,35
	Pore volume [%]:	approx. 30
3 Bearing back		
Steel	Steel thickness [mm]:	Variable
	Steel hardness [HB]:	100–180

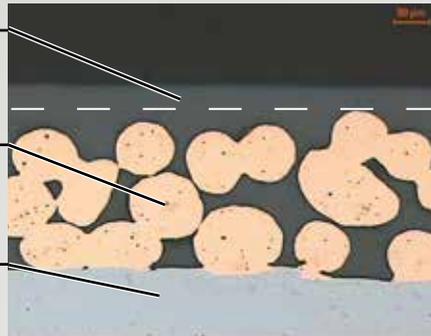


Fig. 17: Layer system

Tab. 10: System composition

### Chemical composition

Running-in layer	
Components	% Weight
PTFE	62
ZnS	38
Sliding Layer	
Components	% Weight
Sn	9 to 11
Cu	Remainder
Bearing back	
Material	Material information
Steel	DC04
	DIN EN 10130
	DIN EN 10139

Tab. 11: Chemical composition

### Material characteristics

Characteristics, load limit	Symbol	Unit	Value
Permitted pv value	$p_{v_{zul.}}$	MPa·m/s	1.6
Permitted specific bearing load			
• Static	$p_{zul.}$	MPa	250
• Concentrated load, circumferential load at sliding speed $\leq 0.011$ m/s	$p_{zul.}$	MPa	140
• Concentrated load, circumferential load at sliding speed $\leq 0.029$ m/s	$p_{zul.}$	MPa	56
• Concentrated load, circumferential load, increasing at sliding speed $\leq 0.057$ m/s	$p_{zul.}$	MPa	28
Permitted sliding speed			
• Dry running	$v_{zul.}$	m/s	1
• Hydrodynamic operation	$v_{zul.}$	m/s	3
Permitted temperature	$T_{zul.}$	°C	–200 to +280
Thermal expansion coefficient			
• Steel back	$\alpha_{St}$	K <sup>-1</sup>	$11 \cdot 10^{-6}$
Coeff. of thermal conductivity			
• Steel back	$\lambda_{St}$	W(mK) <sup>-1</sup>	40

Tab. 12: Material characteristics

<sup>1)</sup> The pores of the sliding layer are also filled with this lubricant mass.

## 4.1.2 P147 ... Maintenance-free and corrosion-resistant

### Brief description

P147 is a lead-free special sliding material with a high tribological performance. It is designed for maintenance-free, dry-running applications, particularly in areas subject to increased corrosion. It may also be used in systems with liquid lubrication. The use of grease as a lubricant with P147 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 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 produced using controlled roller pairs.

### Plain bearing production

Sliding elements in a great variety of designs are produced from P147 in cutting, stamping and shaping processes.

Standard designs are:

- Cylindrical bushes
- Collar bushes
- Thrust washers
- Strips

In a final step, plain bearings manufactured from P147 undergo special anti-corrosion treatment on the bearing back, end faces and joint surfaces.

Standard version: tin

Layer thickness: approx. 0.002 mm

- Higher corrosion protection requirements (on request).

Version: Zinc, transparent passivated

Layer thickness: 0.008 mm to 0.012 mm

Greater layer thickness is available on request.

### Properties of P147

- Lead-free
- Very low stick-slip tendency
- Low wear
- Good chemical resistance
- Low friction coefficient
- No tendency to fuse with metal
- Very low tendency to swell
- Does not absorb water
- Very good corrosion resistance

### Preferred areas of application

- In aggressive media<sup>1)</sup>
- Outside machines and systems<sup>1)</sup>
- Maintenance-free operation in dry-running conditions where lead-free parts are required
- Rotating or oscillating movements up to a speed of 0.8 m/s
- Linear movements
- Temperature range –200 °C to 280 °C

### 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.



#### Important note:

Transparent passivated zinc is an especially effective anti-corrosion agent. An inclined position of the bush must be avoided during installation (force-fitting) of the bearing bushes. As this carries a risk of damaging the zinc coating.



#### Important note:

The material P147 is available on request.

<sup>1)</sup> P147 satisfies the requirements of the salt spray test to DIN 50021

## 4 | Material selection, material information

### Material composition of P147

1	Running-in layer	
	PTFE matrix with bulking agent <sup>1)</sup> Layer thickness [mm]:	max. 0.03
2	Sliding layer	
	Tin-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

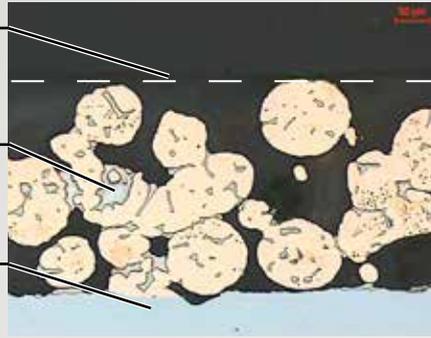


Fig. 18: Layer system

Tab. 13: System composition

### Chemical composition

Running-in layer	
Components	% Weight
PTFE	82
BaSO <sub>4</sub>	18
Sliding layer	
Components	% Weight
Sn	9 to 11
Cu	Remainder
Material	Material information
Steel	DC04
	DIN EN 10130
	DIN EN 10139

Tab. 14: Chemical composition

### Material characteristics

Characteristics, load limit	Symbol	Unit	Value
Permitted pv value	$p_{v_{zul.}}$	MPa·m/s	1,4
Permitted specific bearing load			
• Static	$p_{zul.}$	MPa	250
• Concentrated load, circumferential load at sliding speed $\leq 0.010$ m/s	$p_{zul.}$	MPa	140
• Concentrated load, circumferential load at sliding speed $\leq 0.025$ m/s	$p_{zul.}$	MPa	56
• Concentrated load, circumferential load, increasing at sliding speed $\leq 0.050$ m/s	$p_{zul.}$	MPa	28
Permitted sliding speed			
• Dry running	$v_{zul.}$	m/s	0.8
Permitted temperature	$T_{zul.}$	°C	-200 to +280
Thermal expansion coefficient			
• Steel back	$\alpha_{St}$	K <sup>-1</sup>	$11 \cdot 10^{-6}$
Coeff. of thermal conductivity			
• Steel back	$\lambda_{St}$	W(mK) <sup>-1</sup>	40

Tab. 15: Material characteristics

<sup>1)</sup> The pores of the sliding layer are also filled with this lubricant mass.

## 4.2 P2 plain bearings

### 4.2.1 P20, P22, P23 ... Low-maintenance standard solutions

#### Brief description

P20, P22 and P23 are lead containing standard sliding materials with a high performance. They are designed for low-maintenance grease or liquid-lubricated applications. The standard P20 version features oil distributing pockets to DIN ISO 3547 in the sliding surface and a pre-finished wall thickness. The P22 versions (smooth sliding surface, suitable for reworking) and P23 (smooth sliding surface, ready to install) are also available on request.

#### Material manufacture

The bronze compound layer is sintered onto a prepared steel surface in a continuous sintering process in such a way as to produce a pore volume of around 50% at a layer thickness of approx. 0.3 mm. Next, the sliding layer is applied in powder form and rolled into the cavities in the compound layer under a high temperature. The result is a sliding layer thickness of approx. 0.08 mm or approx. 0.2 mm above the compound layer, depending on the intended purpose. At the same time, the oil distributing pockets are produced, if required. A further rolling calibration process ensures the necessary thickness tolerance of the composite.

#### Plain bearing production

Sliding elements in a great variety of designs are produced from the composite material in cutting, stamping and shaping processes.

Standard designs are:

- Cylindrical bushes
- Thrust washers
- Strips

In a final step, plain bearings manufactured from P20, P22 or P23 undergo anti-corrosion treatment on the bearing back, end faces and joint surfaces.

Standard version: Tin

Layer thickness [mm]: approx. 0.002



#### Important note:

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

#### Properties

- Lifetime lubrication possible
- Low wear
- Low sensitivity to edge loading
- Good damping characteristic
- Insensitive to impact
- Good chemical resistance

#### Preferred areas of application

- Low-maintenance operation with lubrication
- Rotating and oscillating movements up to a speed of 3 m/s
- Linear movements up to 6 m/s
- Temperature range –40°C to 110°C

**The materials P20, P22 and P23 contain lead and must therefore not be used in applications involving food processing.**



Fig. 19: P20 plain bearing with oil distributing pockets and oil hole

P22 and P23 feature smooth sliding surfaces and can be used under hydrodynamic conditions. The bearing bore of P22 is suitable for reworking.

Motorservice offers the calculation of hydrodynamic operating states as a service.



#### Important note:

Materials P22 and P23 are available on request.

Material	Version		
	Ready to install	Oil distributing pockets	Machining allowance
P20	•	•	
P22			•
P23	•		

Tab. 16: Material versions P22 and P23 available on request

## 4 | Material selection, material information

### Material composition of P20, P22, P23

1 Sliding layer		
PVDF matrix with bulking agents <sup>1)</sup>	Layer thickness [mm]:	0.08–0.20
2 Intermediate layer		
Tin-bronze	Layer thickness [mm]:	0.20–0.35
	Pore volume [%]:	approx. 50
3 Bearing back		
Steel	Steel thickness [mm]:	Variable
	Steel hardness [HB]:	100–180

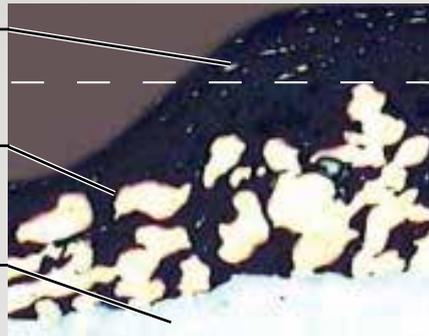


Fig. 20: Layer system

Tab. 17: System composition

### Chemical composition

Sliding layer	
Components	% Weight
PVDF	51
PTFE	8
Pb	41
Intermediate layer	
Components	% Weight
Sn	9 to 11
Cu	Remainder
Bearing back	
Material	Material information
Steel	DC04
	DIN EN 10130
	DIN EN 10139

Tab. 18: Chemical composition

### Material characteristics

Characteristics, load limit	Symbol	Unit	Value
Permitted pv value	$p_{v_{zul.}}$	MPa·m/s	3
Permitted specific bearing load			
• Static	$p_{zul.}$	MPa	250
• Concentrated load, circumferential load at sliding speed $\leq 0.021$ m/s	$p_{zul.}$	MPa	140
• Concentrated load, circumferential load at sliding speed $\leq 0.043$ m/s	$p_{zul.}$	MPa	70
• Concentrated load, circumferential load, increasing at sliding speed $\leq 0.086$ m/s	$p_{zul.}$	MPa	35
Permitted sliding speed			
• Grease-lubricated, rotating, oscillating	$v_{zul.}$	m/s	3
• Grease-lubricated, linear	$v_{zul.}$	m/s	6
• Hydrodynamic operation	$v_{zul.}$	m/s	6
Permitted temperature	$T_{zul.}$	°C	-40 to +110
Thermal expansion coefficient			
• Steel back	$\alpha_{St}$	K <sup>-1</sup>	$11 \cdot 10^{-6}$
Coeff. of thermal conductivity			
• Steel back	$\lambda_{St}$	W(mK) <sup>-1</sup>	40

Tab. 19: Material characteristics

1) The cavities of the intermediate sliding layer are also filled with this mass.

### 4.2.2 P200, P202, P203 ... Low-maintenance, universal

**Brief description**

P200, P202 and P203 are lead-free, environmentally friendly sliding materials with a very high performance. Thanks to a special combination of bulking agents, high resistance is achieved with simultaneously very good dry-running behaviour. They are therefore ideally suited to low-maintenance grease or liquid-lubricated applications subject to more stringent requirements. The standard P200 version features oil distributing pockets to DIN ISO 3547 in the sliding surface and a pre-finished wall thickness. The P202 versions (smooth sliding surface, suitable for reworking) and P203 (smooth sliding surface, ready to install) are also available on request.

**Material manufacture**

The bronze compound layer is sintered onto a prepared steel surface in a continuous sintering process in such a way as to produce a pore volume of around 50% at a layer thickness of approx. 0.3 mm. Next, the sliding layer is applied in powder form and rolled into the cavities in the compound layer under a high temperature. The result is a sliding layer thickness of approx. 0.08 mm or approx. 0.2 mm above the compound layer, depending on the intended purpose. At the same time, the oil distributing pockets are produced, if required. A further rolling calibration process ensures the necessary thickness tolerance of the composite.

**Plain bearing production**

Sliding elements in a great variety of designs are produced from the composite material in cutting, stamping and shaping processes.

Standard designs are:

- Cylindrical bushes
- Thrust washers
- Strips

In a final step, plain bearings manufactured from P200, P202 or P203 undergo anti-corrosion treatment on the bearing back, end faces and joint surfaces.

Standard version: Tin

Layer thickness [mm]: approx. 0.002

Additionally, the plain bearings can be supplied with improved corrosion-protection coating “Zinc, transparent passivated”, on request.



**Important note:**

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

**Properties**

- Lifetime lubrication
- Low wear
- Very good dry-running properties
- Insensitive to edge loading and impacts
- Good damping characteristic
- Good chemical resistance

**Preferred areas of application**

- Food sector
- Special requirements for environmental protection
- Low-maintenance operation with lubrication, more stringent requirements
- Rotating and oscillating movements up to a sliding speed of 3.3 m/s
- Linear movements up to 6 m/s
- Temperature range –40°C to 110°C



Fig. 21: P200 plain bearing with oil distributing pocket and oil hole

P202 and P203 feature smooth sliding surfaces and can be used under hydrodynamic conditions. P202 is suitable for reworking.

Motorservice offers the calculation of hydrodynamic operating states as a service.



**Important note:**

Materials P202 and P203 are available on request.

Material	Version		
	Ready to install	Oil distributing pockets	Machining allowance
P200	•	•	
P202			•
P203	•		

Tab. 20: Material versions P202 and P203 available on request

## 4 | Material selection, material information

### Material composition of P200, P202, P203

1	Sliding layer	
	PVDF matrix with bulking agents <sup>1)</sup> Layer thickness [mm]:	0.08–0.20
2	Intermediate layer	
	Tin-bronze Layer thickness [mm]: Pore volume [%]:	0.20–0.35 approx. 50
3	Bearing back	
	Steel Steel thickness [mm]: Steel hardness [HB]:	Variable 100–180

Tab. 21: System composition

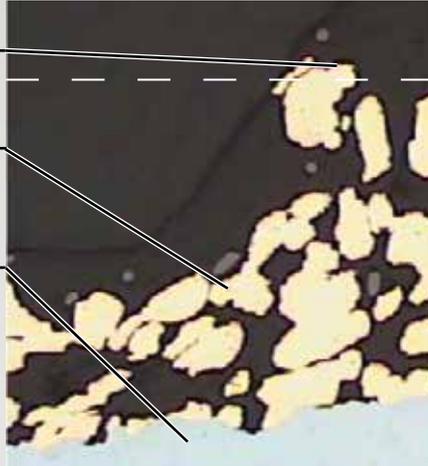


Fig. 22: Layer system

### Chemical composition

Sliding layer	
Components	% Weight
PTFE	9 to 12
Wear and friction-reducing bulking agents	22 to 26
PVDF	Rest
Intermediate layer	
Components	% Weight
Sn	9 to 11
P	max. 0.05
Other	max. 0.05
Cu	Remainder
Bearing back	
Material	Material information
Steel	DC04
	DIN EN 10130
	DIN EN 10139

Tab. 22: Chemical composition

### Material characteristics

Characteristics, load limit	Symbol	Unit	Value
Permitted pv value	$p_{v_{zul.}}$	MPa·m/s	3.3
Permitted specific bearing load			
• Static	$p_{zul.}$	MPa	250
• Concentrated load, circumferential load at sliding speed $\leq 0.024$ m/s	$p_{zul.}$	MPa	140
• Concentrated load, circumferential load at sliding speed $\leq 0.047$ m/s	$p_{zul.}$	MPa	70
• Concentrated load, circumferential load, increasing at sliding speed $\leq 0.094$ m/s	$p_{zul.}$	MPa	35
Permitted sliding speed			
• Grease-lubricated, rotating, oscillating	$v_{zul.}$	m/s	3.3
• Grease-lubricated, linear	$v_{zul.}$	m/s	6
• Hydrodynamic operation	$v_{zul.}$	m/s	6
Permitted temperature	$T_{zul.}$	°C	-40 to +110
Permitted temperature			
• Steel back	$\alpha_{St}$	K <sup>-1</sup>	$11 \cdot 10^{-6}$
• Steel back			
• Steel back	$\lambda_{St}$	W(mK) <sup>-1</sup>	40

Tab. 23: Material characteristics

<sup>1)</sup> The cavities of the intermediate sliding layer are also filled with this 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 
$$v = \frac{D_o \cdot \pi \cdot n}{60 \cdot 10^3} \quad [m/s]$$

## 5 | Nominal service life calculation

[ 8 ] Sliding speed, bush,  
oscillating

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

[ 9 ] Sliding speed, thrust washer,  
oscillating

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

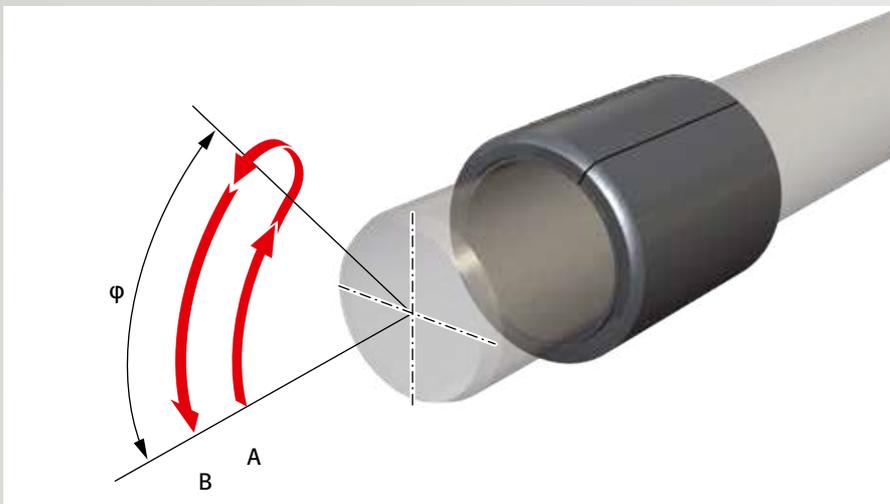


Fig. 23: Swivel angle  $\varphi$

The oscillating frequency  $n_{osz}$  is the number of movements from A to B per minute.

[ 10 ] Calculation of pv value

$$pv = p \text{ [MPa]} \cdot v \text{ [m/s]} \quad [\text{MPa} \cdot \text{m/s}]$$

$pv_{zul.}$ 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\*

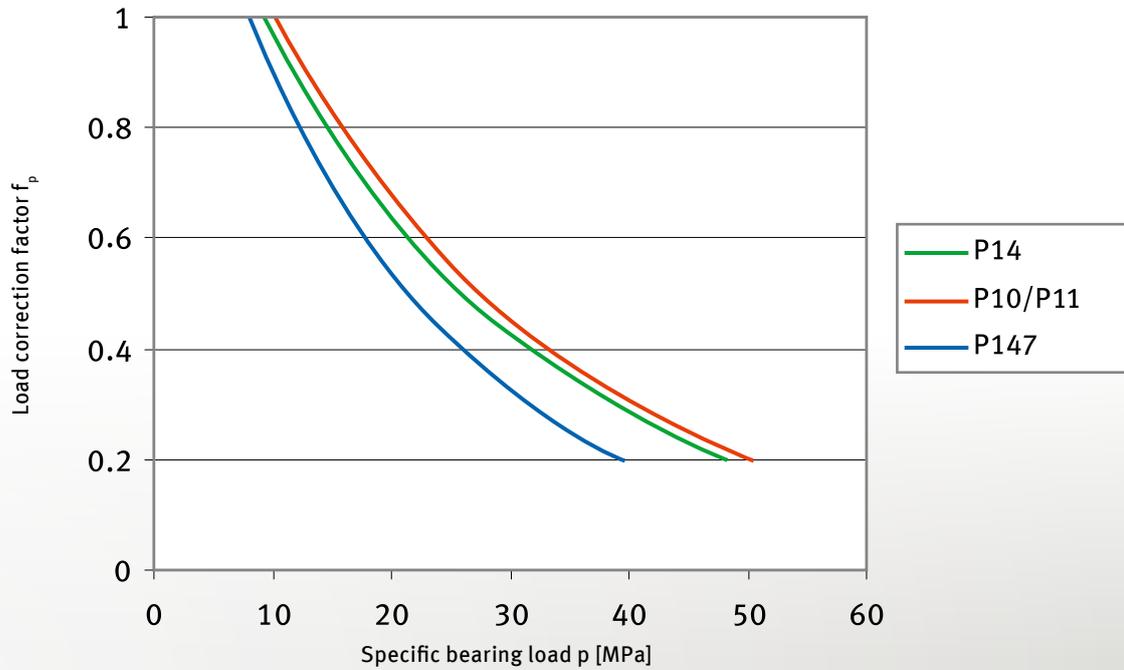


Fig. 24: Load correction factor  $f_p$

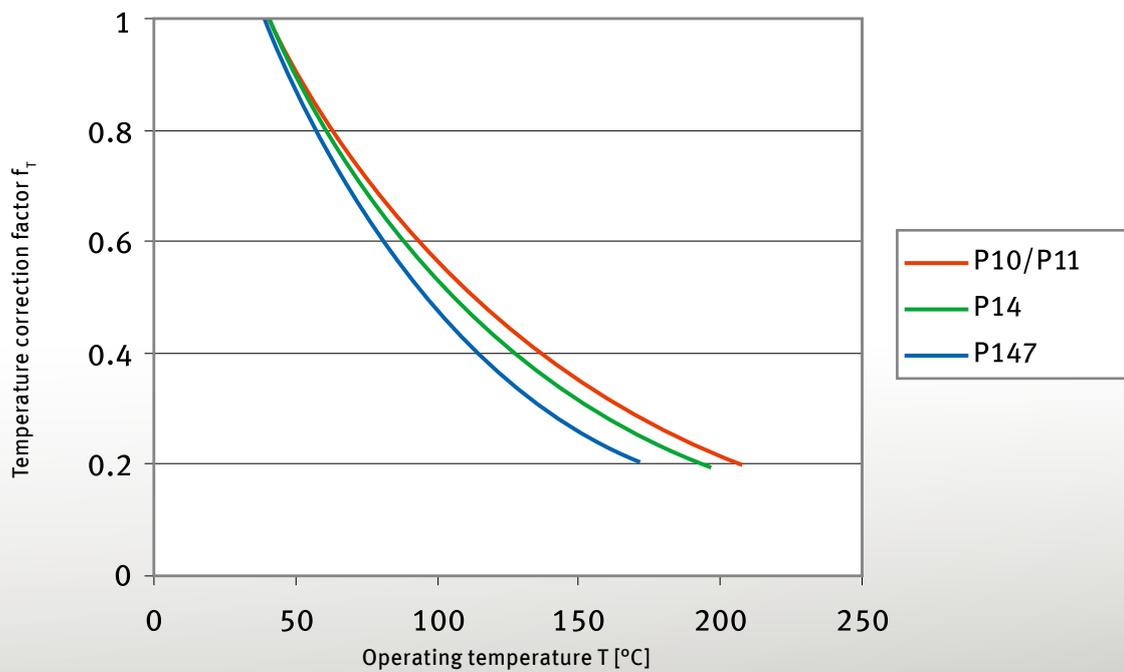


Fig. 25: Temperature correction factor  $f_T$

\* On request

## 5 | Nominal service life calculation

Correction factors for P10, P11, P14 and P147\*

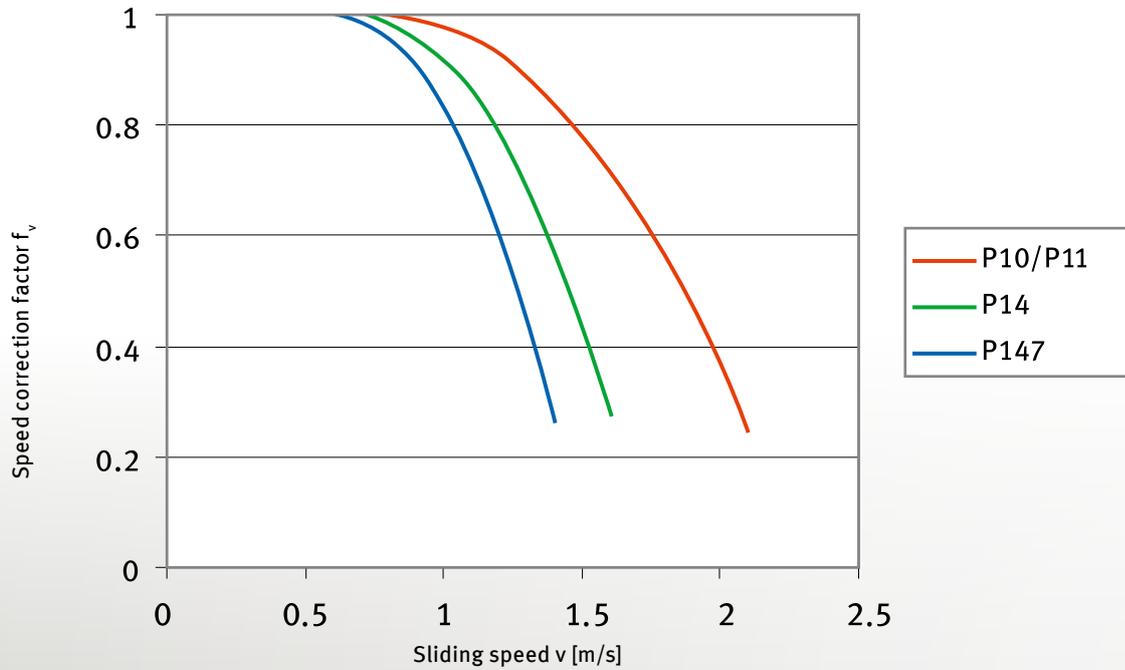


Fig. 26: Sliding speed correction factor  $f_v$

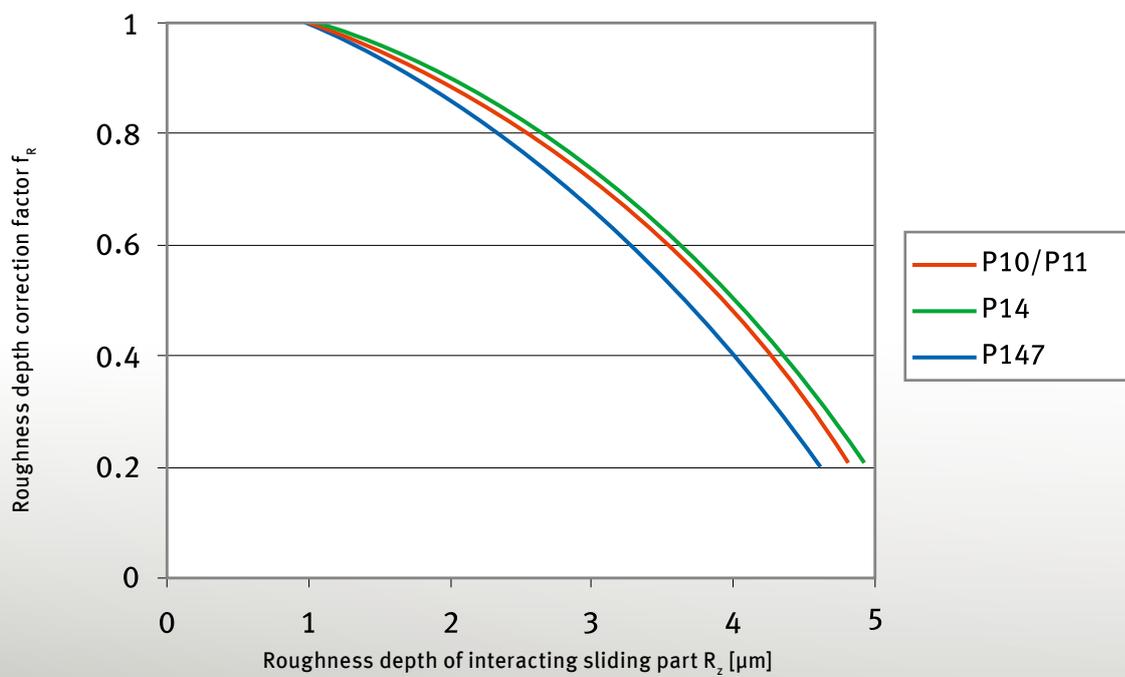


Fig. 27: Roughness depth correction factor  $f_R$

Correction factors for P20, P22\*, P23\* and P200, P202\*, P203\*

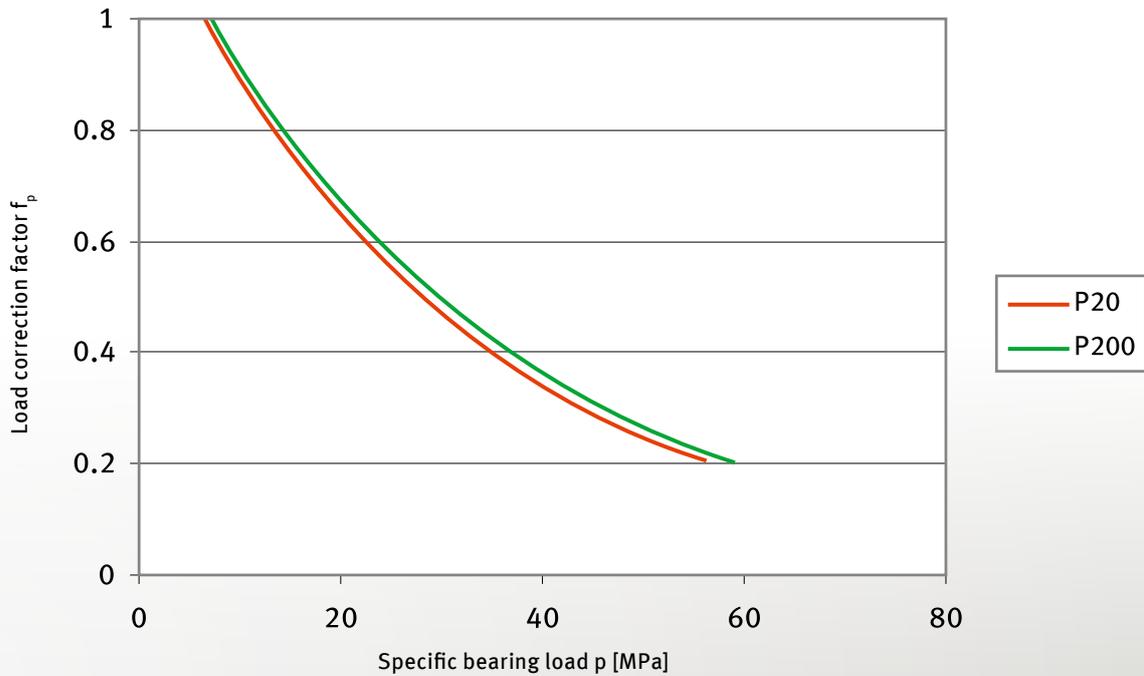


Fig. 28: Load correction factor  $f_p$

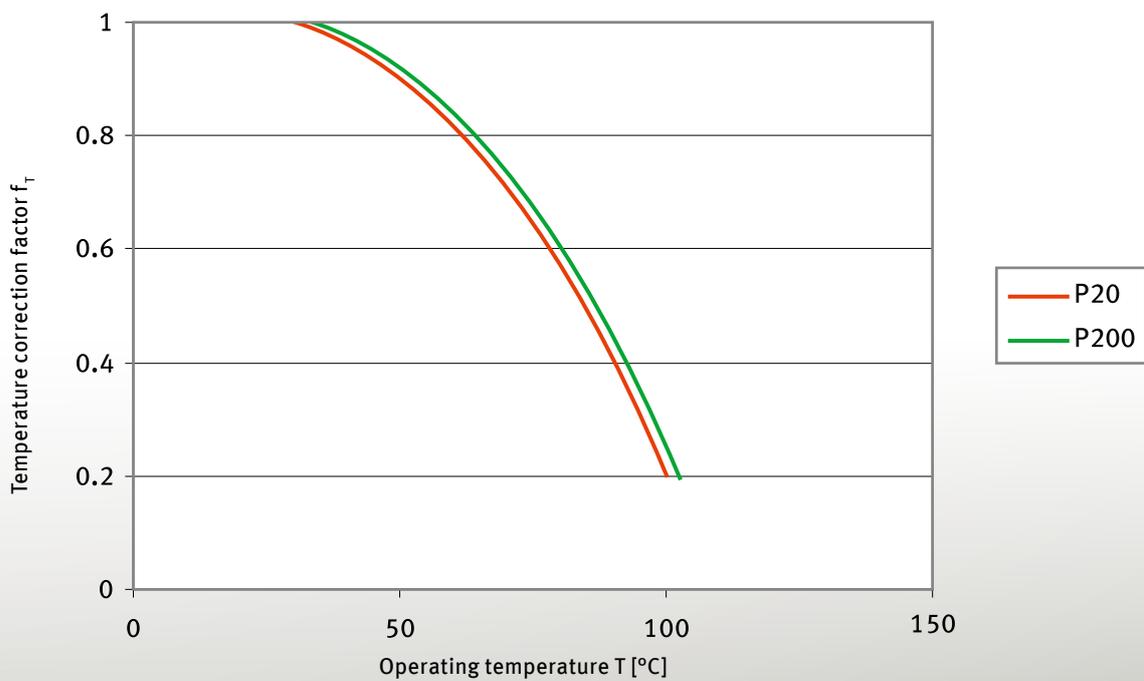


Fig. 29: Temperature correction factor  $f_T$

\* On request

## 5 | Nominal service life calculation

Correction factors for P20, P22\*, P23\* and P200, P202\*, P203\*

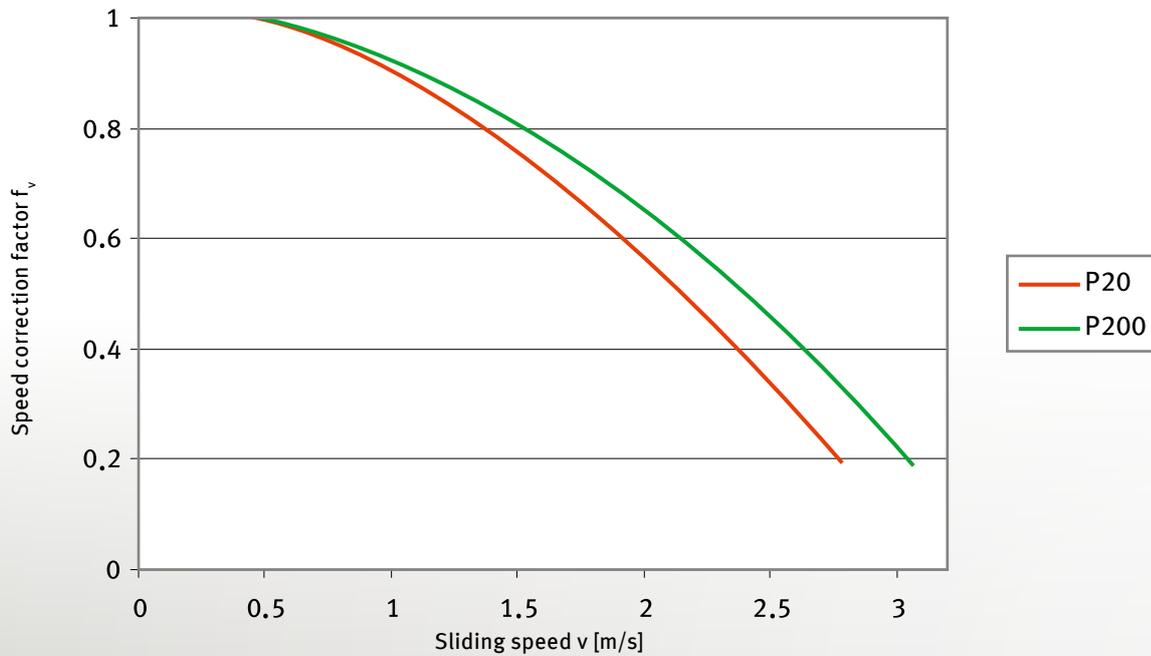


Fig. 30: Sliding speed correction factor  $f_v$

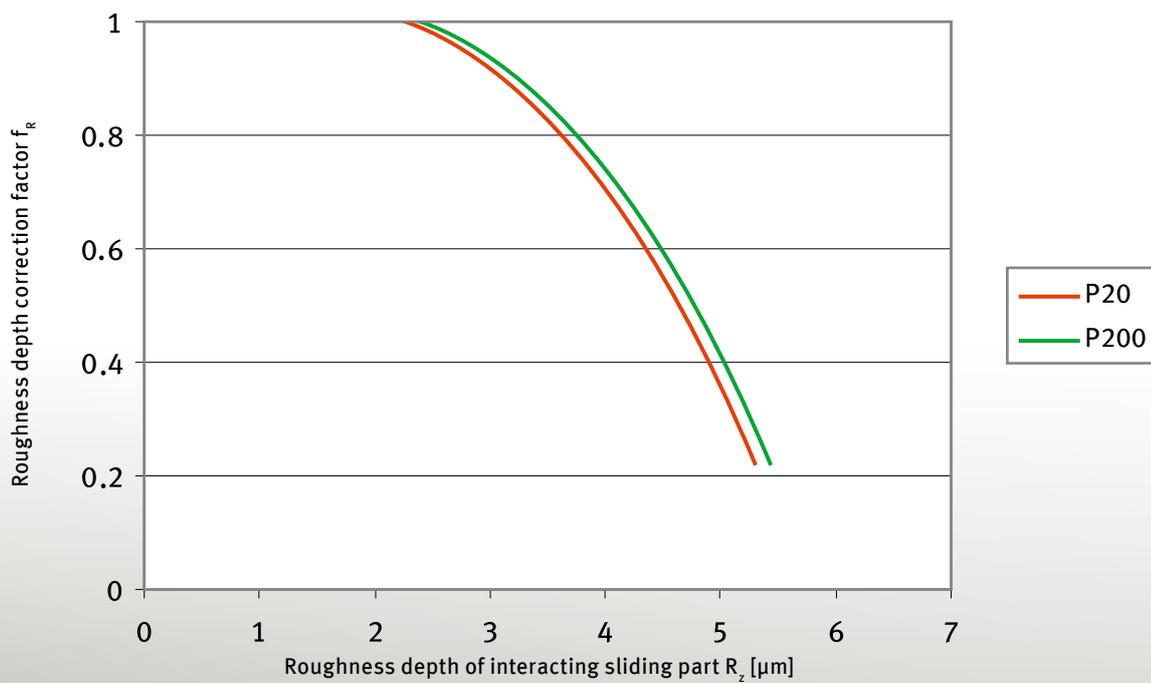


Fig. 31: Roughness depth correction factor  $f_R$

**Load type correction factor**

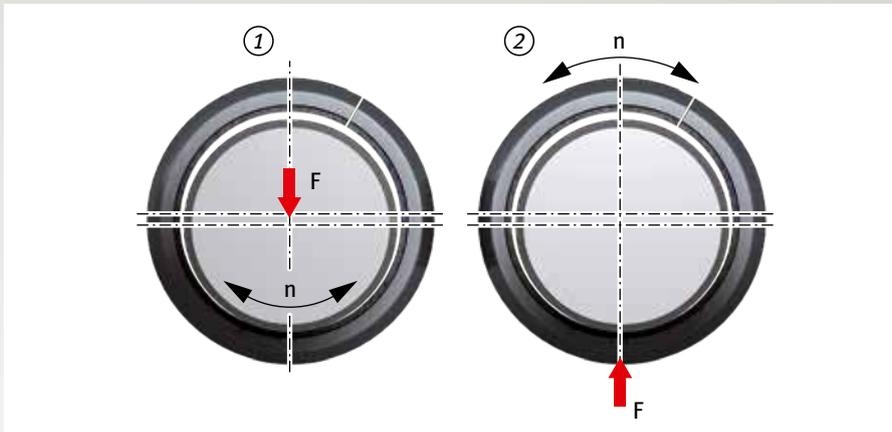


Fig. 32: Load correction factor  $f_A$

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**

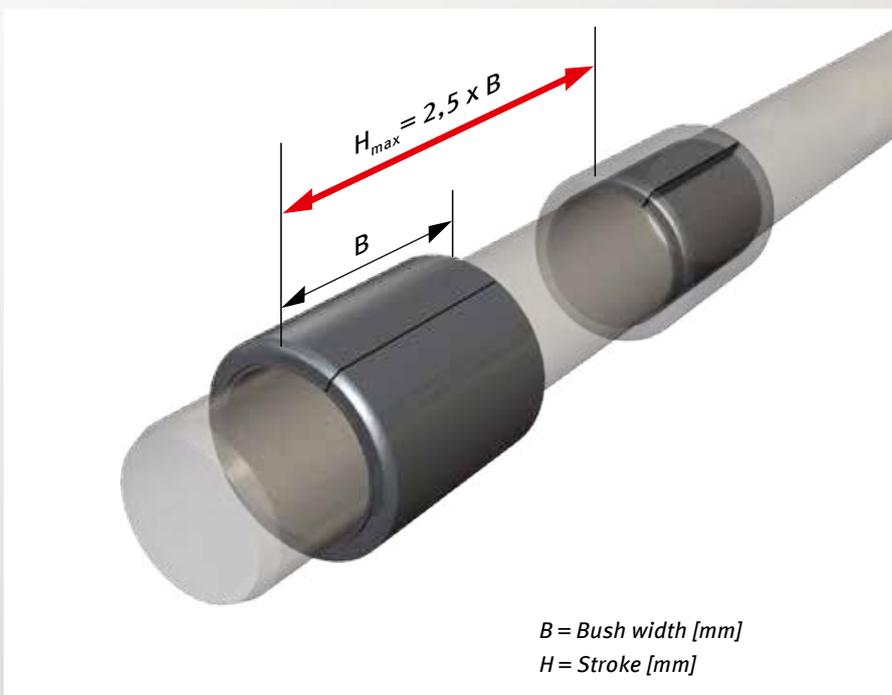


Fig. 33: Linear movement, stroke  $H_{max}$ .

**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 <sub>z</sub> 2	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  $f_L$ :

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

## 5 | Nominal service life calculation

### 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 <sub>2</sub> 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

## 5.2 Example calculations

### Estimate of service life

Example calculation: P14 bush with a required service life of >1200 h

#### Given:

Operating data		Design data		Other conditions
Rotating shaft (continuous operation)				
Dry running		Bearing diameter	$D_1 = 20 \text{ mm}$	Lead-free
Concentrated load	$F = 270 \text{ N}$	Bearing width	$W = 15 \text{ mm}$	
Speed	$n = 325 \text{ rpm}$	Shaft material	Steel	
Temperature	$T = 70 \text{ °C}$	Shaft roughness depth	$R_z = 2 \text{ }\mu\text{m}$	

#### Wanted: Nominal service life $L_N$

##### 1. Specific bearing load $p$

$$[4] \quad p = \frac{F}{D_1 \cdot W} = \frac{270 \text{ N}}{20 \text{ mm} \cdot 15 \text{ mm}} = 0.9 \text{ N/mm}^2 \rightarrow \text{MPa}$$

##### 2. Sliding speed $v$

$$[6] \quad v = \frac{D_1 \cdot \pi \cdot n}{60 \cdot 10^3} = \frac{20 \text{ mm} \cdot \pi \cdot 325 \text{ rpm}}{60 \cdot 10^3} = 0.34 \text{ m/s}$$

##### 3. $pv$ value

$$[10] \quad pv = p \text{ [MPa]} \cdot v \text{ [m/s]} = 0.9 \text{ MPa} \cdot 0.34 \text{ m/s} \approx 0.31 \text{ MPa} \cdot \text{m/s}$$

##### 4. Check: $pv$ value acceptable?

Fig. 10

$$pv \text{ } 0.31 \text{ MPa} \cdot \text{m/s} < pv_{zul.} \text{ } 1.6 \text{ MPa} \cdot \text{m/s}$$

##### 5. Determine correction factors

• Load type for concentrated load	Fig. 32	$f_A = 1$
• Load	Fig. 24	$f_p = 1$
• Sliding speed	Fig. 26	$f_v = 1$
• Temperature (70 °C)	Fig. 25	$f_T = 0.65$
• Roughness depth ( $R_z \text{ } 2 \text{ }\mu\text{m}$ )	Fig. 27	$f_R = 0.9$
• Shaft material (steel)	Tab. 24	$f_w = 1$

##### 6. Nominal service life $L_N$

$$[1] \quad L_N = \frac{400}{(pv)^{1.2}} \cdot f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R = \frac{400}{0.31^{1.2}} \cdot 1 \cdot 1 \cdot 1 \cdot 0.65 \cdot 1 \cdot 0.9 = 954 \text{ h}$$

**Result:** With  $L_N = 954 \text{ h}$ , the requirement  $L_N > 1200 \text{ h}$  is not met.

## 5 | Nominal service life calculation

### New calculation with bearing width enlarged to 20 mm

#### 1. Specific bearing load p

$$[4] \quad p = \frac{F}{D_i \cdot W} = \frac{270 \text{ N}}{20 \text{ mm} \cdot 20 \text{ mm}} = 0.675 \text{ N/mm}^2 \rightarrow \text{MPa}$$

#### 2. Sliding speed v

$$[6] \quad v = \frac{D_i \cdot \pi \cdot n}{60 \cdot 10^3} = \frac{20 \text{ mm} \cdot \pi \cdot 325 \text{ rpm}}{60 \cdot 10^3} = 0.34 \text{ m/s}$$

#### 3. pv value

$$[10] \quad pv = p [\text{MPa}] \cdot v [\text{m/s}] = 0.675 \text{ MPa} \cdot 0.34 \text{ m/s} \approx 0.23 \text{ MPa} \cdot \text{m/s}$$

#### 4. Check: pv value acceptable?

Fig. 10

$$pv \ 0.23 \text{ MPa} \cdot \text{m/s} < pv_{zul.} \ 1.6 \text{ MPa} \cdot \text{m/s}$$

#### 5. Determine correction factors

• Load type for concentrated load	Fig. 32	$f_A = 1$
• Load	Fig. 24	$f_p = 1$
• Sliding speed	Fig. 26	$f_v = 1$
• Temperature (70 °C)	Fig. 25	$f_T = 0.65$
• Roughness depth ( $R_z \ 2 \ \mu\text{m}$ )	Fig. 27	$f_R = 0.9$
• Shaft material (steel)	Fig. 22	$f_w = 1$

#### 6. Nominal service life $L_N$

$$[1] \quad L_N = \frac{400}{(pv)^{1,2}} f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R = \frac{400}{0.23^{1,2}} \cdot 1 \cdot 1 \cdot 1 \cdot 0.65 \cdot 1 \cdot 0.9 = 1365 \text{ h}$$

**Result:** With  $L_N = 1365 \text{ h}$ , the requirement  $L_N > 1200 \text{ h}$  is met.

Selected: Bush PAP 2020 P14

**Estimate of service life**
**Example calculation: P200 thrust washer PAW 32 P200 with a required service life of >1500 h**

Given:

Operating data		Design data		Other conditions
Rotating shaft (continuous operation)				
Axial load	F = 2000 N	Thrust washer	D <sub>i</sub> = 32 mm	Lead-free, therefore selected material P200 (with oil distributing pockets)
Speed	n = 300 rpm	Outside diameter	D <sub>o</sub> = 54 mm	
Temperature	T = 50 °C	Shaft material	Steel	
Greased lubrication		Shaft roughness depth	R <sub>z</sub> = 3 μm	

 Wanted: Nominal service life L<sub>N</sub>
**1. Specific bearing load p**

$$[4] \quad p = \frac{4 \cdot F}{(D_o^2 - D_i^2) \cdot \pi} = \frac{4 \cdot 2000 \text{ N}}{(54^2 - 32^2) \cdot \pi} \approx 1.35 \text{ N/mm}^2 \rightarrow \text{MPa}$$

**2. Sliding speed v**

$$[6] \quad v = \frac{D_o \cdot \pi \cdot n}{60 \cdot 10^3} = \frac{54 \text{ mm} \cdot \pi \cdot 300 \text{ rpm}}{60 \cdot 10^3} \approx 0.85 \text{ m/s}$$

**3. pv value**

$$[10] \quad pv = p [\text{MPa}] \cdot v [\text{m/s}] = 1.35 \text{ MPa} \cdot 0.85 \text{ m/s} \approx 1.15 \text{ MPa} \cdot \text{m/s}$$

**4. Check: pv value acceptable?**

Fig. 14

 pv 1.15 MPa · m/s < pv<sub>zul.</sub> 3.3 MPa · m/s

**5. Determine correction factors**

• Load type for axial load	Fig. 32	f <sub>A</sub> = 1
• Load	Fig. 28	f <sub>p</sub> = 1
• Sliding speed	Fig. 30	f <sub>v</sub> = 1
• Temperature (50 °C)	Fig. 29	f <sub>T</sub> = 0.92
• Roughness depth (R <sub>z</sub> 3 μm)	Fig. 31	f <sub>R</sub> = 0.9
• Shaft material (steel)	Tab. 24	f <sub>w</sub> = 1

**6. Nominal service life L<sub>N</sub>:**

$$[1] \quad L_N = \frac{2000}{(pv)^{1.5}} f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R = \frac{2000}{1,15^{1,5}} \cdot 1 \cdot 1 \cdot 1 \cdot 0,92 \cdot 1 \cdot 0,9 = 1343 \text{ h}$$

**Result:** With L<sub>N</sub> = 1343 h, the requirement L<sub>N</sub> > 1500 h is not met.

## 5 | Nominal service life calculation

### New calculation with larger thrust washer PAW 38 P200

#### 1. Specific bearing load p

$$[4] \quad p = \frac{4 \cdot F}{(D_o^2 - D_i^2) \cdot \pi} = \frac{4 \cdot 2000 \text{ N}}{(62^2 - 38^2) \cdot \pi} \approx 1,06 \text{ N/mm}^2 \rightarrow \text{MPa}$$

#### 2. Sliding speed v

$$[6] \quad v = \frac{D_o \cdot \pi \cdot n}{60 \cdot 10^3} = \frac{62 \text{ mm} \cdot \pi \cdot 300 \text{ min}^{-1}}{60 \cdot 10^3} \approx 0,97 \text{ m/s}$$

#### 3. pv value

$$[10] \quad pv = p [\text{MPa}] \cdot v [\text{m/s}] = 1,06 \text{ MPa} \cdot 0,97 \text{ m/s} \approx 1,03 \text{ MPa} \cdot \text{m/s}$$

#### 4. Check: pv value acceptable?

Fig. 14

$$pv \ 1.03 \text{ MPa} \cdot \text{m/s} < pv_{\text{zul.}} \ 3.3 \text{ MPa} \cdot \text{m/s}$$

#### 5. Determine correction factors

• Load type for axial load	Fig. 32	$f_A = 1$
• Load	Fig. 28	$f_p = 1$
• Sliding speed	Fig. 30	$f_v = 1$
• Temperature (50 °C)	Fig. 29	$f_T = 0.92$
• Roughness depth ( $R_z \ 3 \ \mu\text{m}$ )	Fig. 31	$f_R = 0.9$
• Shaft material (steel)	Tab. 24	$f_w = 1$

#### 6. Nominal service life $L_N$ :

$$[1] \quad L_N = \frac{2000}{(pv)^{1,5}} f_A \cdot f_p \cdot f_v \cdot f_T \cdot f_w \cdot f_R = \frac{2000}{1,03^{1,5}} \cdot 1 \cdot 1 \cdot 1 \cdot 0,92 \cdot 1 \cdot 0,9 = 1584 \text{ h}$$

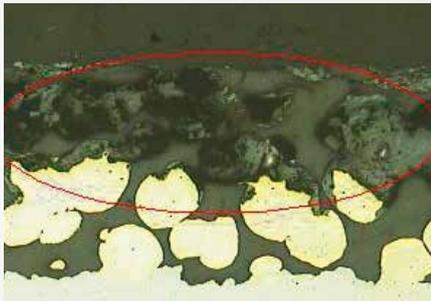
**Result:** With  $L_N = 1584 \text{ h}$ , the requirement  $L_N > 1500 \text{ h}$  is met.

**Selected:** Thrust washer PAW 38 P200

**In addition to the wear factors of bearing load, sliding speed, temperature, shaft material and shaft surface, plain bearings are subject to further stresses arising from the operating conditions, which may have a considerable impact on reliability and service life.**

**Tribochemical reaction, corrosion**

KS Permaglide® plain bearings are basically resistant to water (except P14), alcohol, glycol and many mineral oils. However, some media have an aggressive effect on the composite, particularly the bronze components. This risk mainly comes into play at operating temperatures in excess of 100 °C. This can have adverse effects on function.



*Fig. 34: Damage due to the action of chemicals*

The P1 material group is not resistant to acidic media (PH < 3) and alkaline media (pH > 12).

Oxidising acids and gases such as free halides, ammonia or hydrogen sulphide damage the bronze back of P11.

If corrosion would pose a risk to the sliding surface of the interacting sliding part (shaft), the following materials are recommended:

- Corrosion-resistant steel
- Hard chrome-plated steel
- Hard anodised aluminium

These corrosion-resistant materials also lower the wear rate.

**Tendency to swell**

In the P1 material group, the running-in layer (solid lubricant) can swell in the presence of certain media and at operating temperatures > 100 °C. Depending on the medium, the wall thickness of the plain bearing may increase by up to 0.03 mm.

**Remedy:**

- Increase bearing clearance
- Use plain bearings made of P14/P147. Here, the tendency to swell is much lower, at < 0.01 mm.

Please note that P14 should only be used at sliding speeds of up to 1 m/s and P147 up to sliding speeds of 0.8 m/s.

**Electrochemical contact corrosion**

Local elements may form under unfavourable conditions, reducing operational reliability.

**Remedy:**

Select appropriate material pairings

**Micro-sliding movements**

If very small sliding distances take place during swivelling or linear movements, a film of lubricant is unable to form on P1 bearings. Consequently, after the running-in process, metal contact zones are produced between the bronze sliding layer and the surface of the shaft. This results in increased wear, with a risk of shaft seizure.

**Remedy:**

Lubricate the bearing assembly. Please note the following section, “Lubrication”.

**Lubrication**

In certain applications, it may be necessary to provide grease or oil lubrication for the contact surface between the P1 plain bearing and the interacting sliding part. This may result in considerable deviations from the expected service life.

The use of grease or oil can both lengthen and shorten service life (Tab. 25: Special operating conditions).

Firstly, service life is shortened by the transfer of solid lubricant during the running-in process. Secondly, the presence of grease or oil gives rise to the formation of a so-called paste. This paste consists of an accumulation of grease or smaller quantities of oil together with material removed from the contact zone. This paste deposits itself on the run-out zone in the direction of rotation, hampering the dissipation of heat. Some of the paste is carried back into the contact zone, where it encourages wear. Solid lubricants with zinc sulphide or molybdenum disulphide additives increase the tendency towards paste formation. In cases where lubrication of

P1 plain bearings with grease cannot be avoided, the following steps can be taken to counter paste formation:

- Regular relubrication (e.g. with lithium-soap grease)
- Insert bores or grooves in the run-out zone, so that the paste can deposit itself there.

**Caution:**

Bores or grooves reduce the cross sectional area of the bush wall. If they amount to > 10 %, this must be taken into account in the calculation (secure fit, press-fit).

P2 plain bearings must be lubricated. For suitable types of grease, see section 3.2 “Low-maintenance KS Permaglide® P2 plain bearings”, “Grease lubrication” section.

## 6 | Typical plain bearing damage

### Cavitation, erosion

KS Permaglide® plain bearings can run under hydrodynamic conditions.

#### Advantages:

- Higher sliding speeds are possible than with dry running or grease lubrication.
- Virtually wear-free operation, as above the transition speed the two sliding surfaces are separated by the lubricating fluid. Conditions of pure liquid friction prevail.
- Plain bearings have a self-lubricating effect during mixed friction (below transition speed).

Despite this, the sliding surface of the plain bearing can suffer particular damage under hydrodynamic conditions, caused above all by cavitation and erosion.

Cavitation and erosion mostly occur simultaneously. These damage symptoms are particularly evident at a high sliding speed.

#### Remedy:

- Lower the sliding speed (if possible)
- Use a different lubricant (viscosity, load carrying capacity in relation to temperature)
- Avoid flow disruptions in the lubricating gap provoked by oil grooves, oil bores, oil pockets, etc.).

Motorservice offers the calculation of hydrodynamically operated KS Permaglide® plain bearings as a service.

### Cavitation damage

Cavitation damage is local destruction of the sliding surface due to pressure. In plain bearings that run hydrodynamically, vapour bubbles may be produced in the fast moving lubricating film as the result of a drop in pressure. When pressure increases in the fluid, the vapour bubbles break down. The released energy aggressively attacks the sliding surface and hollows out the sliding material in places.



Fig. 35: Local damage caused by cavitation

### Erosion damage

Erosion is mechanical damage to the sliding surface due to the rinsing action of a liquid, which may also contain solid particles. The distribution of pressure in the lubricating film of a hydrodynamic bearing assembly is disturbed by turbulence and narrowing of the cross section, resulting in mechanical damage to the sliding surface.



Fig. 36: Damage due to erosion in the running-in layer of a P1 plain bearing

**Damaged caused by dirt**

If dirt particles enter the contact zone between the bearing and the shaft, the sliding surface of the bearing is damaged by the formation of grooves. This has a negative effect on service life and reliability.

**Remedy:**

- Seal the bearing
- Place a filter upstream if using liquid lubrication

**Damage due to installation errors**

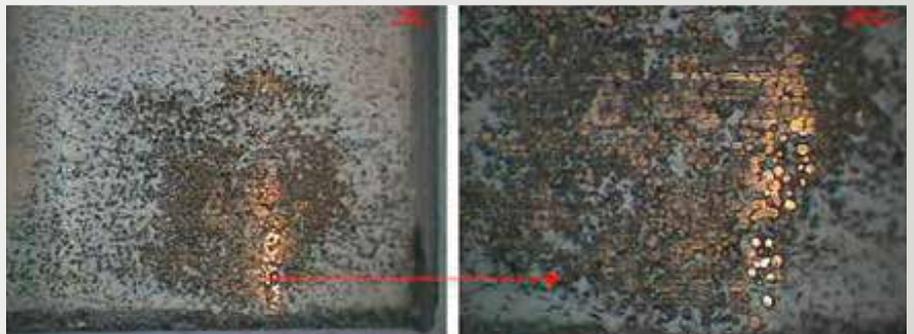
The sliding surface may be damaged when a bush is press fit. In addition, seizures frequently occur between the surface of the bearing jacket and the housing bore. This leads to local bulges in the sliding surface of the bearing. Both the above types of damage can considerably shorten service life.

**Remedy:**

- Force-fitting device with pre-centring (auxiliary ring)
- Optimised press-fit between housing bore and bearing outside diameter
- Avoid dirt
- Make sure bush is not inclined when force-fitting
- Use suitable lubricant



*Fig. 37: P2 plain bearing, grooves in the sliding surface*



*Fig. 38: Local extreme wear due to installation errors*

## 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  $f_G 20^\circ \pm 5^\circ$

This chamfer facilitates press-fitting.

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

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

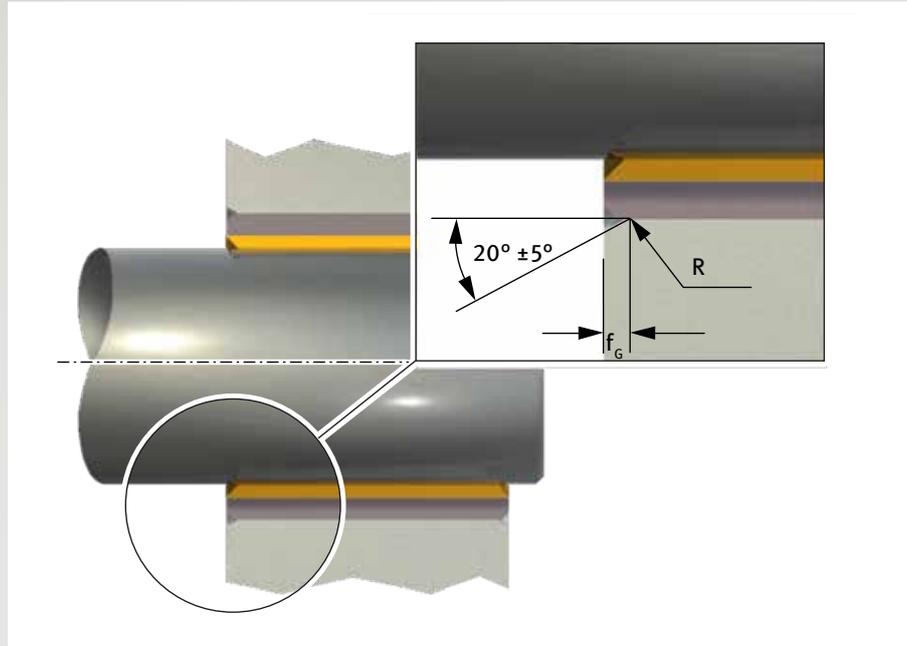


Fig. 39: Chamfer in housing for PAP bush

### 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 $f_G$
$d_G \leq 10$	$1.2 \pm 0.2$
$10 < d_G$	$1.7 \pm 0.2$

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

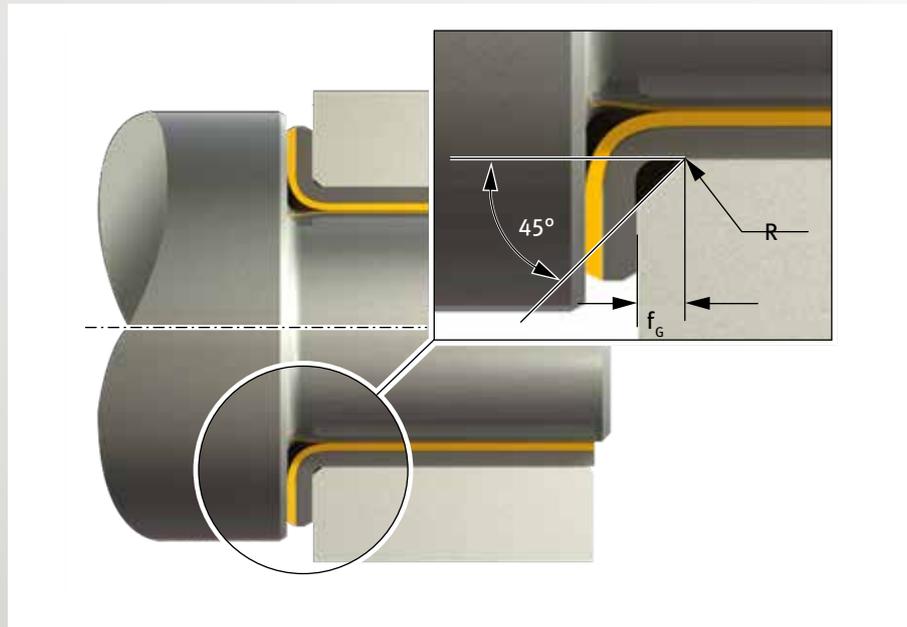


Fig. 40: Chamfer in housing for PAF bush

**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.

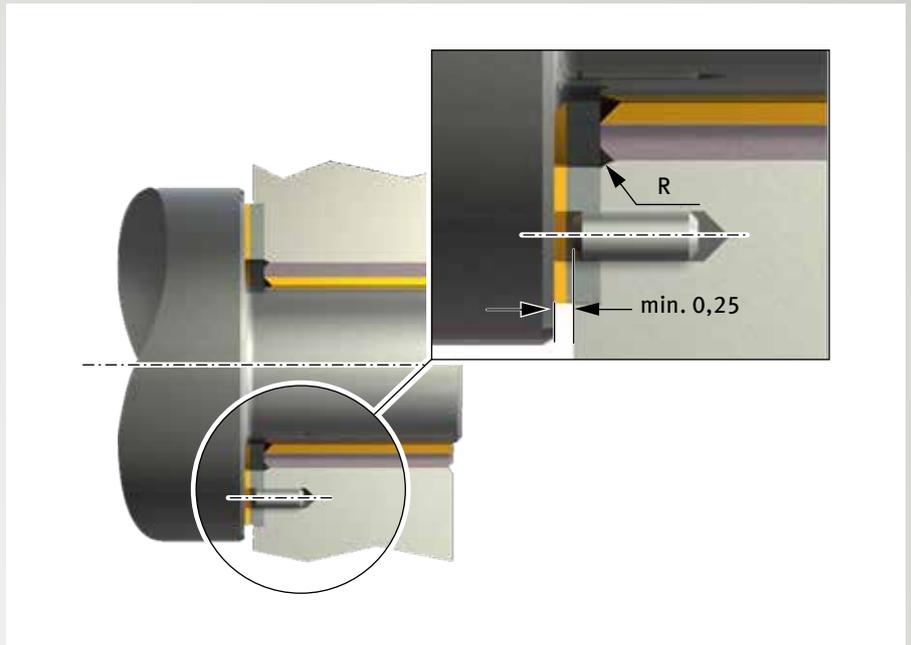


Fig. 41: Securing a PAW thrust washer in a recess in the housing

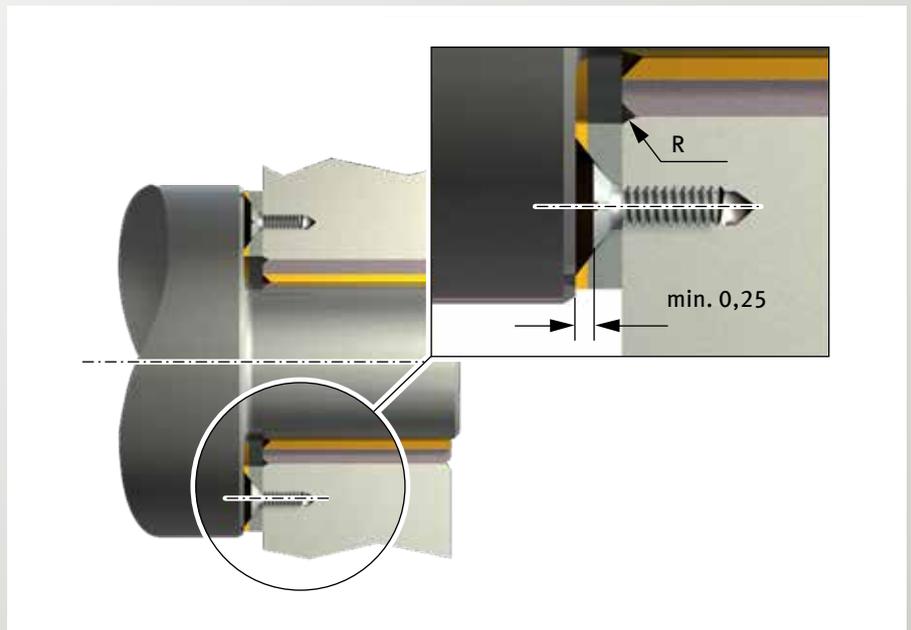


Fig. 42: Securing a PAW thrust washer without a recess in the housing

## 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  $R_z 0.8$  to  $R_z 1.5$ :
  - 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.

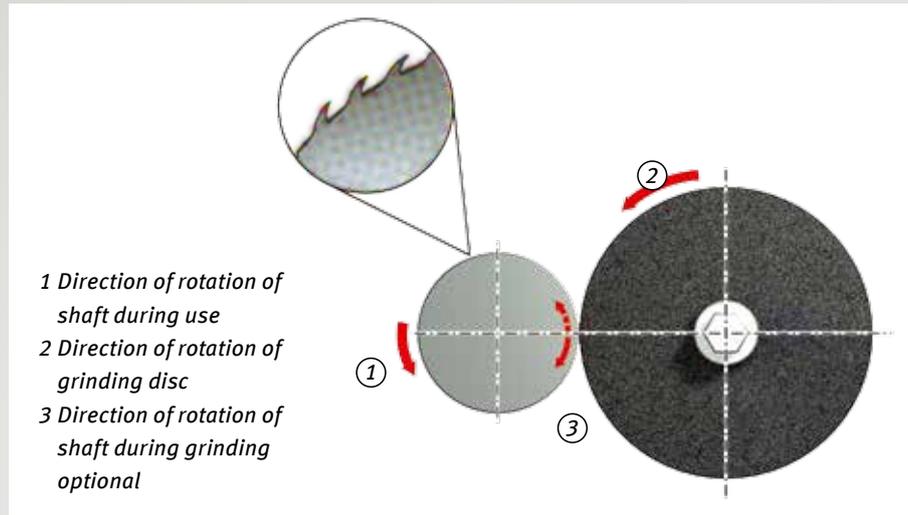


Fig. 43: Grinding a cast shaft

- 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  $R_z 0.8$  to  $R_z 1.5$ , can cause greater wear (precision turning produces spiral scores)

- Sphero cast (GGG) has an open surface structure, and can therefore be ground to  $R_z 2$  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.

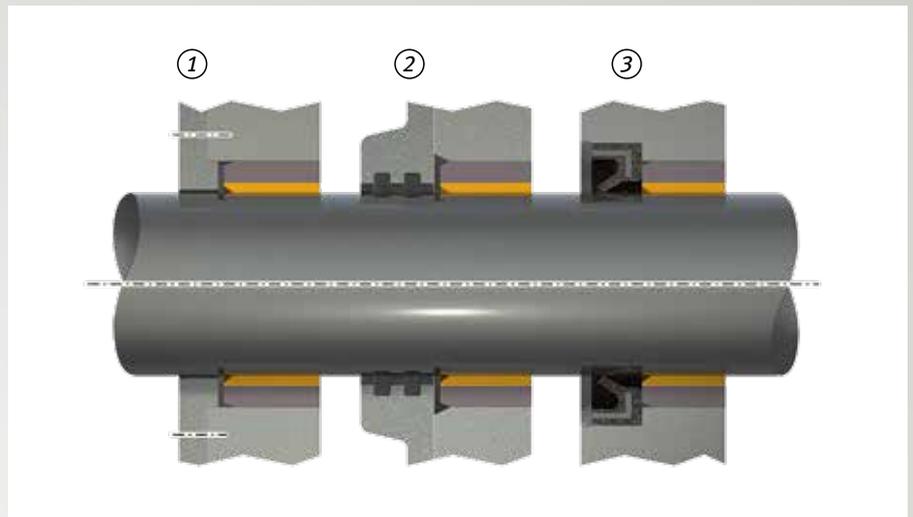


Fig. 44: Seals



**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.

## 7 | Design and layout of bearing assembly

### 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.

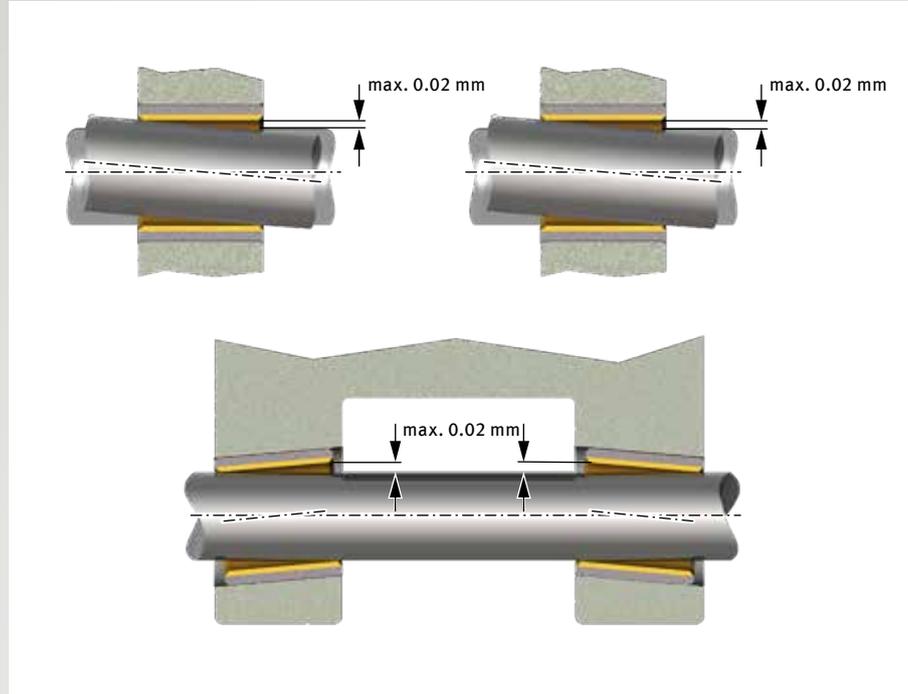


Fig. 45: Permitted misalignment

### 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.

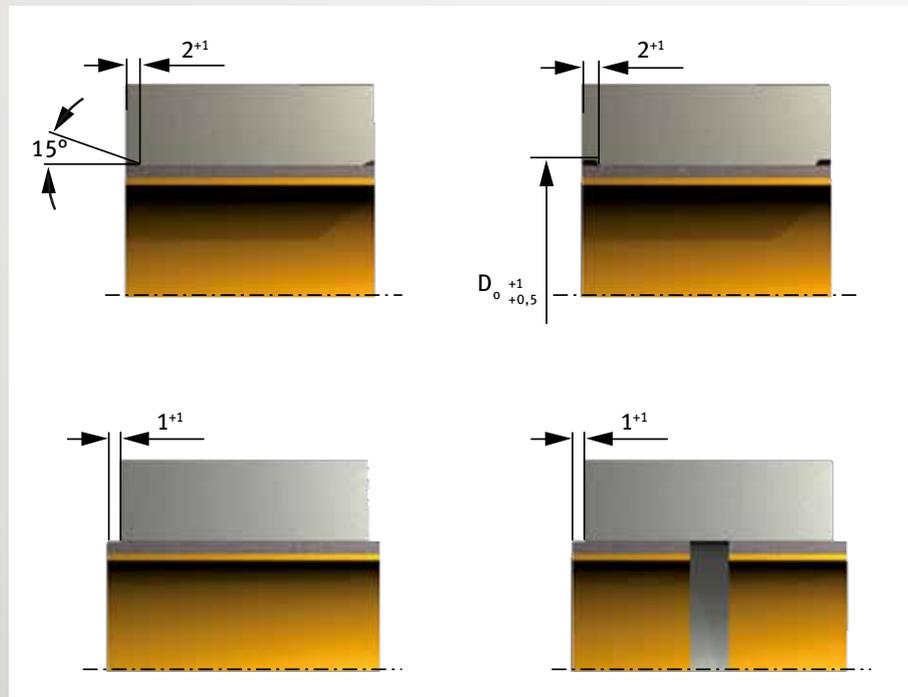


Fig. 46: Reducing excessive stress on edges

### 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 ]	$\Delta s_{\max} = d_{G\max} - 2 \cdot s_{3\min} - d_{W\min}$
[ 13 ]	$\Delta s_{\min} = d_{G\min} - 2 \cdot s_{3\max} - d_{W\max}$

$\Delta s_{\max}$	[mm]	Maximum bearing clearance
$\Delta s_{\min}$	[mm]	Minimum bearing clearance
$d_{G\max}$	[mm]	Maximum diameter of housing bore
$d_{G\min}$	[mm]	Minimum diameter of housing bore
$d_{W\max}$	[mm]	Maximum shaft diameter
$d_{W\min}$	[mm]	Minimum shaft diameter
$s_{3\max}$	[mm]	Maximum wall thickness
$s_{3\min}$	[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.

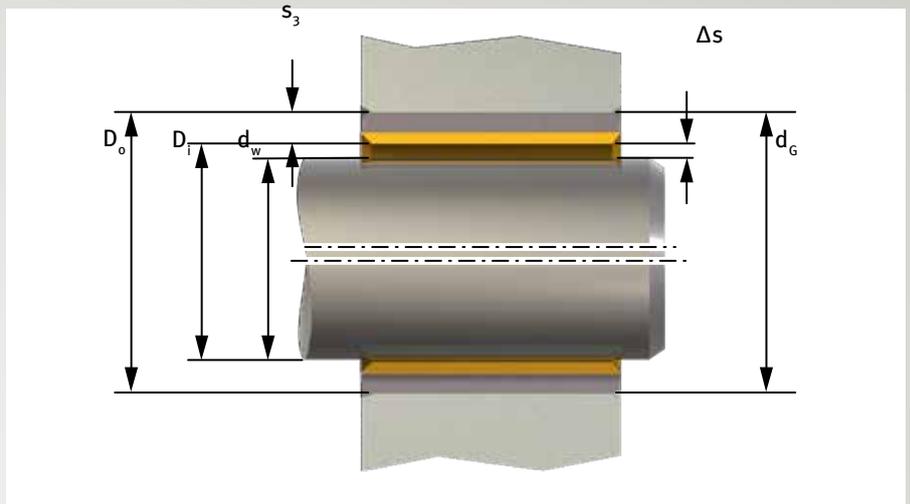


Fig. 47: Theoretical bearing clearance  $\Delta s$

**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  $\Delta s_{\max}$  and [13] for  $\Delta s_{\min}$ .

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

Tab. 28: Recommended fitting tolerances

\* On Request

## 7 | Design and layout of bearing assembly

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  $D_o$ .

Bush inside diameter $D_i$			Wall thickness $s_3$	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

Inside diameter $D_i$			Wall thickness $s_3$	Dimensions to DIN ISO 3 547-1, Table 3, row D, P20, P200	
				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

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

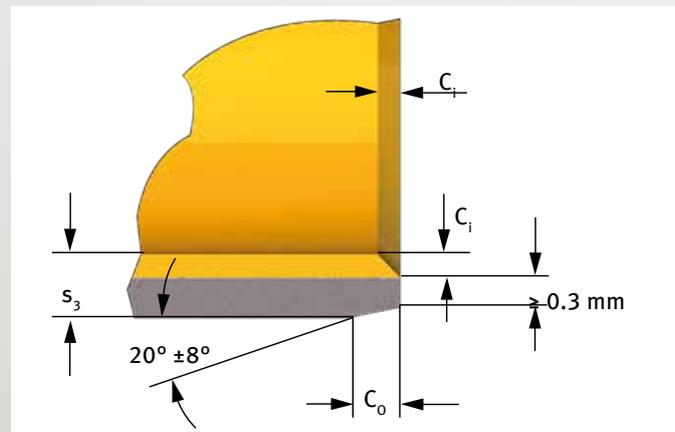


Fig. 48: Outside bevel  $C_o$  and inside bevel  $C_i$  with metric dimensions

\* Auf Anfrage

**Theoretical bearing clearance**

Bush diameter		Bearing clearance $\Delta s$			
		P10. P11. P14. P147*		P20. P200	
$D_i$ (mm)	$D_o$ (mm)	$\Delta s_{min}$ (mm)	$\Delta s_{max}$ (mm)	$\Delta s_{min}$ (mm)	$\Delta s_{max}$ (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 $\Delta s$			
		P10. P11. P14. P147*		P20. P200	
$D_i$ (mm)	$D_o$ (mm)	$\Delta s_{min}$ (mm)	$\Delta s_{max}$ (mm)	$\Delta s_{min}$ (mm)	$\Delta s_{max}$ (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

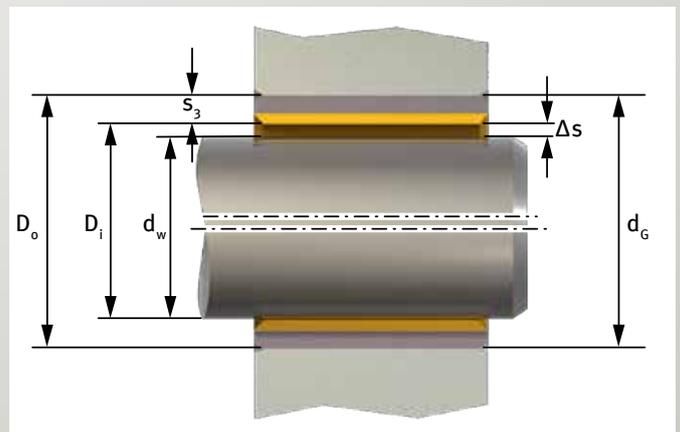


Fig. 49: Theoretical bearing clearance  $\Delta s$

\* On request

## 7 | Design and layout of bearing assembly

### 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 $0.015 \pm 0.003$ 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**

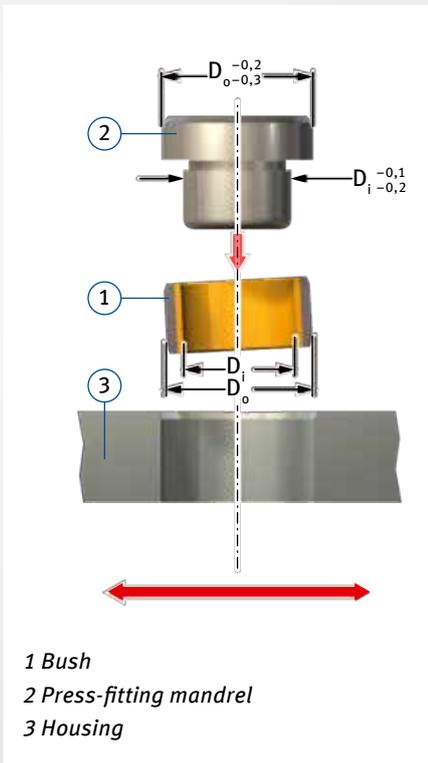


Fig. 50: Press-fitting with moving housing

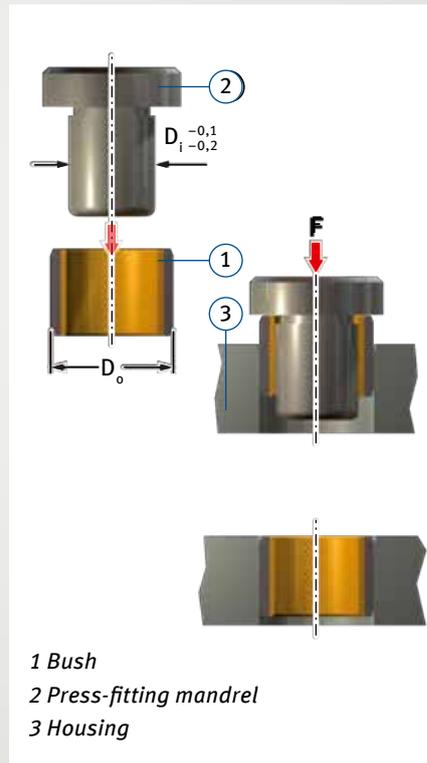


Fig. 51: Flush press-fitting  $D_o \leq 55$  mm

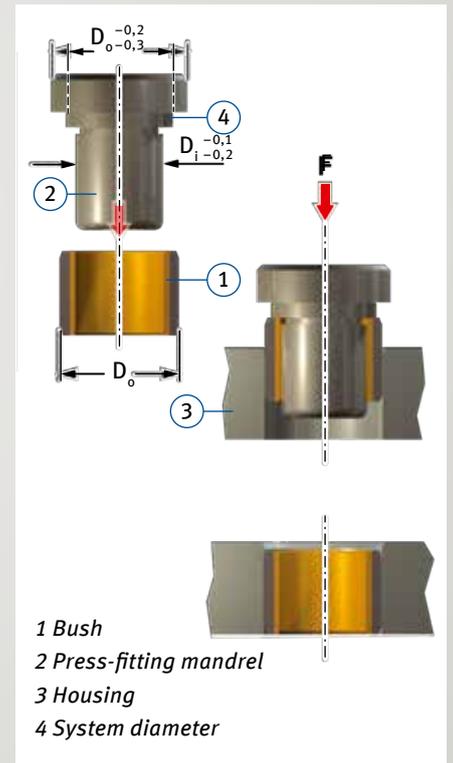


Fig. 52: Recessed press-fitting  $D_o \geq 55$  mm

## 8 | Plain bearing installation

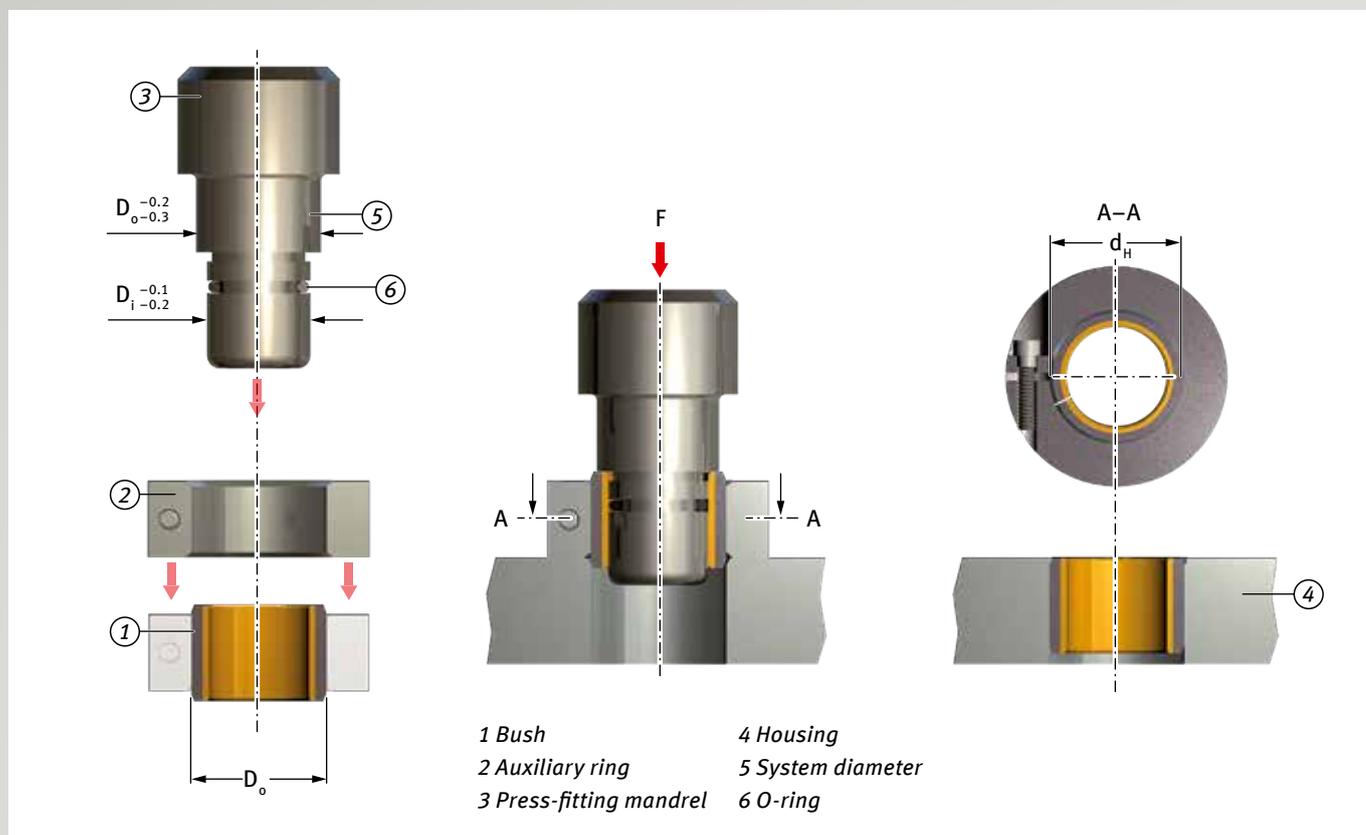


Fig. 53: Press-fitting bushes,  $D_o \geq 55$  mm, with auxiliary ring

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:**

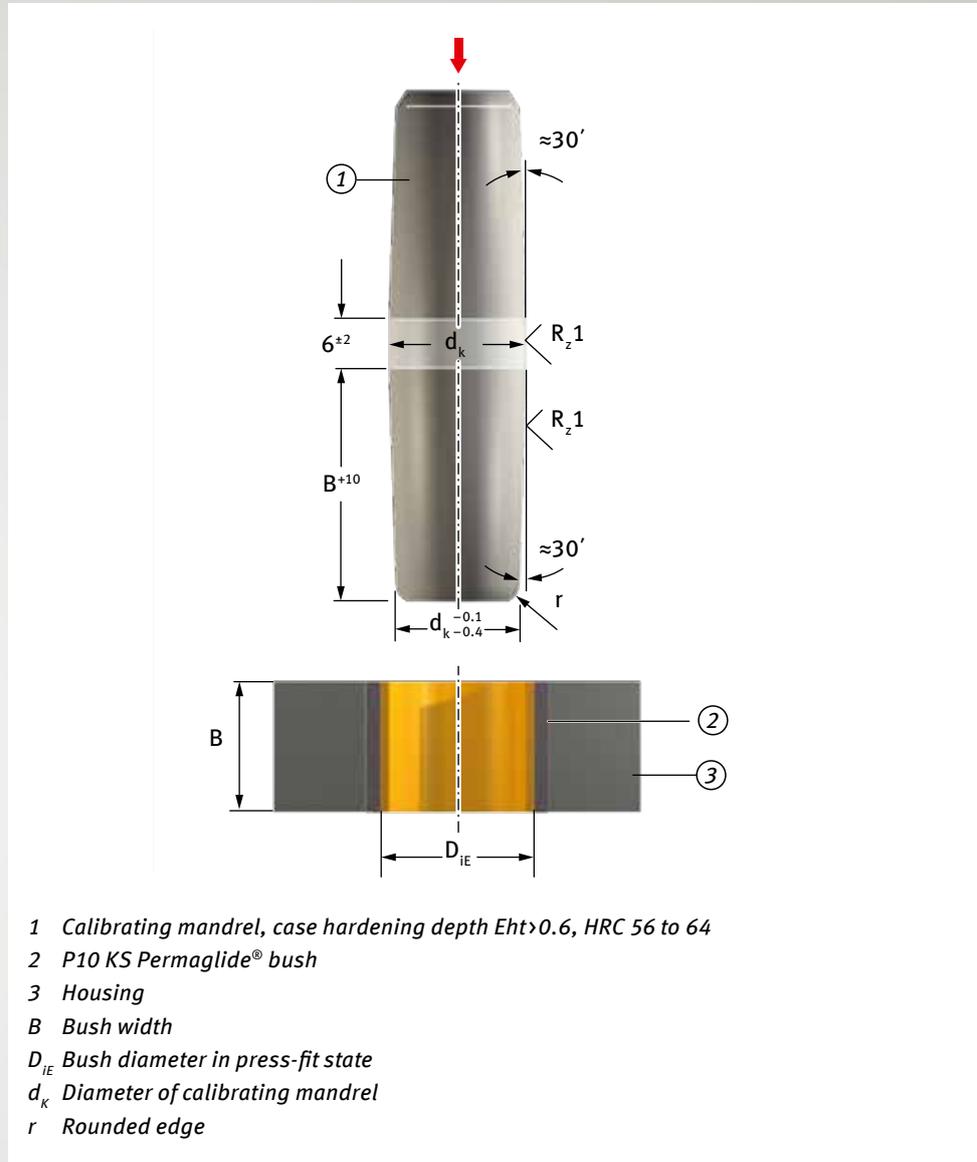
Calibration considerably shortens the service life of P1 KS Permaglide® bushes (see Tab. 36).

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  $E_{ht} > 0.6$ , 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 <sup>1)</sup> $d_k$	Service life <sup>2)</sup>
$D_{IE}$	–	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.

<sup>1)</sup> Approximate value, based on steel housing.

<sup>2)</sup> Approximate value for dry running.

## 8 | Plain bearing installation

### 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  $s_3$  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  $D_G : D_o \approx 1.5...2$ .

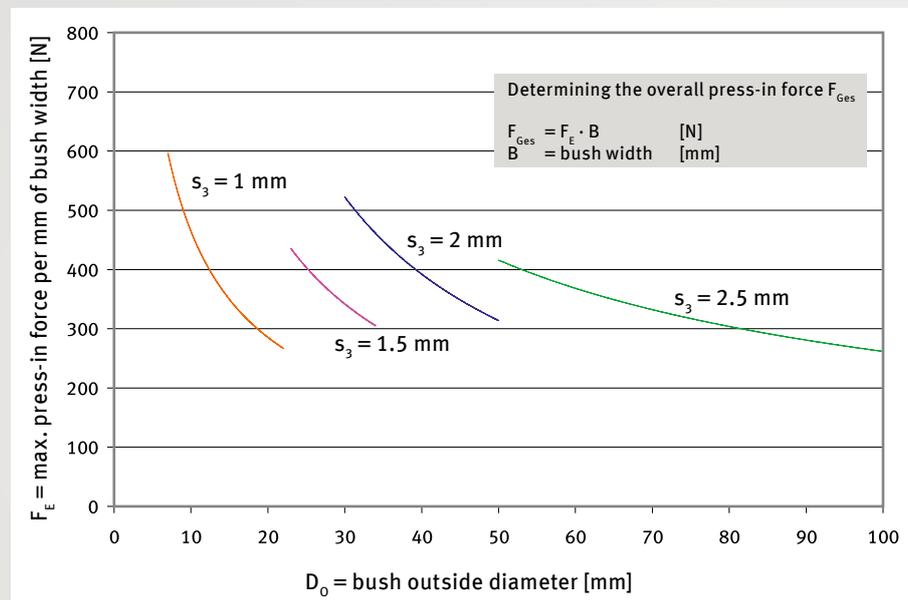


Fig. 55: Press-in force  $F_E$

### 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

$$[14] \quad F_{Ges} = F_E \cdot B = 340 \text{ N/mm} \cdot 30 \text{ mm} = 10200 \text{ N}$$

$$F_E = 340 \text{ N/mm (from Fig. 55, } D_o = 44 \text{ mm, } s_3 = 2 \text{ mm)}$$

**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			
$p_{v_{max}}$	[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		
$p_{v_{max}}$	[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**

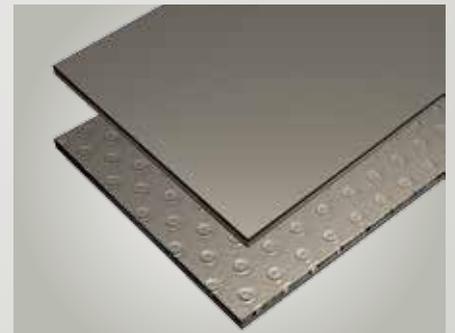


Fig. 59: Strips

**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

## 9 | Versions and dimension tables

### 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

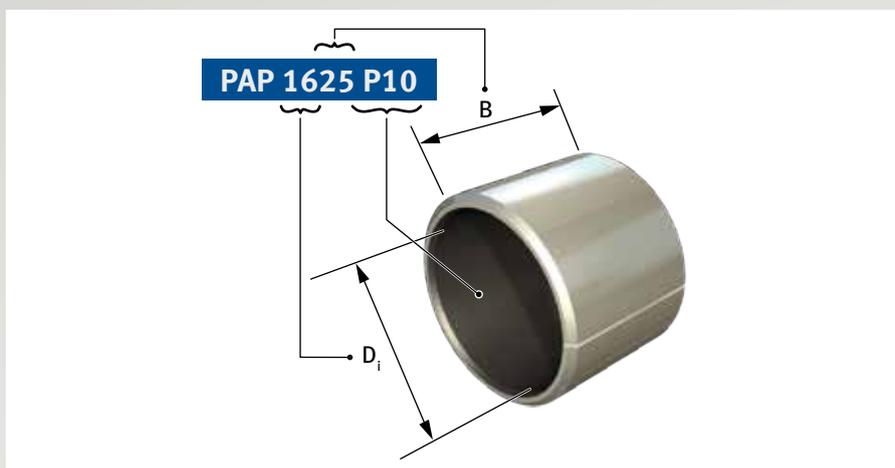


Fig. 60: Example order, P10 bush

#### 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

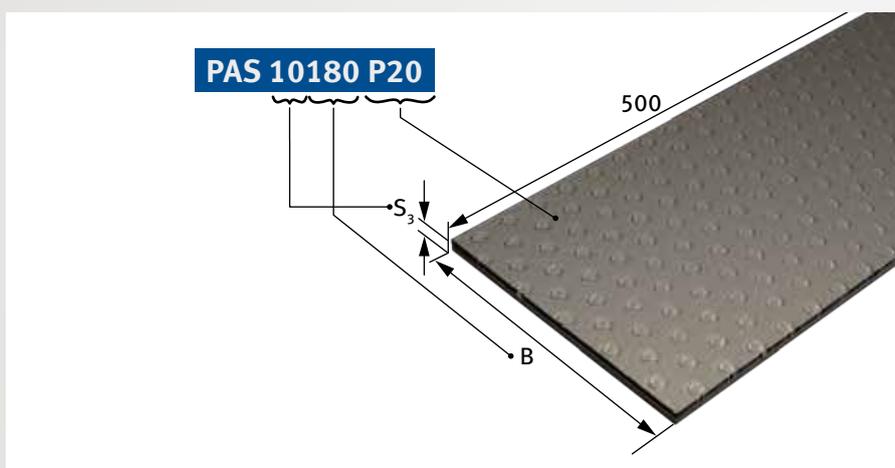


Fig. 61: Example order, P20 strip

#### 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

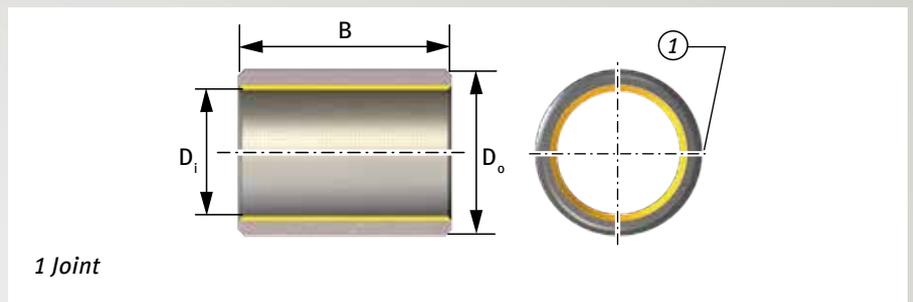
### 9.1.1 Series P10, P14, P147\* with steel back

Recommended fitting tolerance:

Shaft		House bore	
$d_w < 5$	h6	$d_g \leq 5.5$	H6
$5 \leq d_w < 80$	f7	$5.5 < d_g$	H7
$80 \leq d_w$	h8		

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

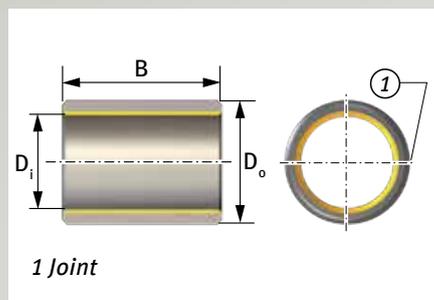
Bushes in special dimensions available on request.



Dimension table (dimensions in mm)					
Shaft diameter	Order designation ..... P10, P14, P147*	Weight g	Dimensions		
			Di	Do	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

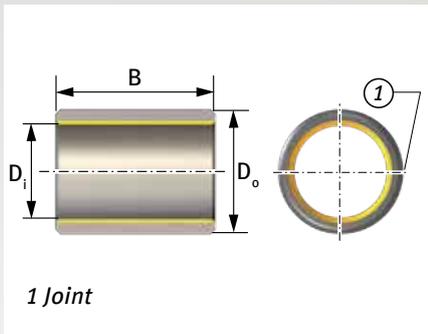
\* On request

## 9 | Versions and dimension tables



Dimension table - continued (dimensions in mm)					
Shaft diameter	Order designation ..... P10, P14, P147*	Weight g	Dimensions		
			D <sub>i</sub>	D <sub>o</sub>	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
28	PAP 2820 ....	29.1	28	32	20
	PAP 2830 ....	43.7	28	32	30

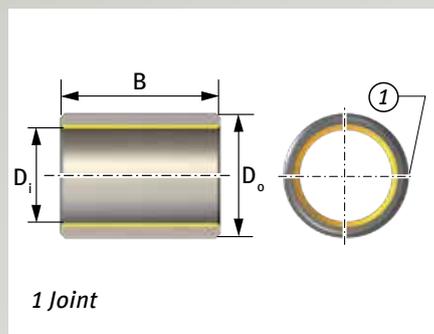
\* On request



Dimension table · continued (dimensions in mm)					
Shaft diameter	Order designation ..... P10, P14, P147*	Weight g	Dimensions		
			Di	Do	B ±0.25
30	PAP 3015 ....	23.3	30	34	15
	PAP 3020 ....	31.1	30	34	20
	PAP 3025 ....	38.8	30	34	25
	PAP 3030 ....	46.6	30	34	30
	PAP 3040 ....	62.1	30	34	40
32	PAP 3230 ....	49.5	32	36	30
	PAP 3240 ....	66	32	36	40
35	PAP 3520 ....	35.9	35	39	20
	PAP 3530 ....	53.9	35	39	30
	PAP 3540 ....	71.8	35	39	40
	PAP 3550 ....	89.8	35	39	50
40	PAP 4020 ....	40.8	40	44	20
	PAP 4030 ....	61.2	40	44	30
	PAP 4040 ....	81.5	40	44	40
	PAP 4050 ....	102	40	44	50
45	PAP 4530 ....	87	45	50	30
	PAP 4540 ....	116	45	50	40
	PAP 4550 ....	145	45	50	50
50	PAP 5020 ....	64	50	55	20
	PAP 5030 ....	96	50	55	30
	PAP 5040 ....	128	50	55	40
	PAP 5060 ....	192	50	55	60
55	PAP 5540 ....	140	55	60	40
	PAP 5560 ....	210	55	60	60
60	PAP 6030 ....	114	60	65	30
	PAP 6040 ....	152	60	65	40
	PAP 6060 ....	228	60	65	60
	PAP 6070 ....	266	60	65	70
65	PAP 6530 ....	123	65	70	30
	PAP 6540 ....	164	65	70	40
	PAP 6550 ....	205	65	70	50
	PAP 6560 ....	246	65	70	60
	PAP 6570 ....	288	65	70	70
70	PAP 7040 ....	176	70	75	40
	PAP 7050 ....	221	70	75	50
	PAP 7070 ....	309	70	75	70
75	PAP 7540 ....	189	75	80	40
	PAP 7550 ....	236	75	80	50
	PAP 7560 ....	283	75	80	60
	PAP 7580 ....	377	75	80	80

\* On request

## 9 | Versions and dimension tables



Dimension table - continued (dimensions in mm)					
Shaft diameter	Order designation ..... P10, P14, P147*	Weight g	Dimensions		
			Di	Do	B ±0.25
80	PAP 8040 ....	201	80	85	40
	PAP 8060 ....	301	80	85	60
	PAP 8080 ....	402	80	85	80
	PAP 80100 ....	502	80	85	100
85	PAP 8560 ....	319	85	90	60
	PAP 85100 ....	532	85	90	100
90	PAP 9050 ....	281	90	95	50
	PAP 9060 ....	338	90	95	60
	PAP 90100 ....	563	90	95	100
95	PAP 9560 ....	356	95	100	60
	PAP 95100 ....	593	95	100	100
100	PAP 10050 ....	312	100	105	50
	PAP 10060 ....	374	100	105	60
	PAP 100115 ....	717	100	105	115
105	PAP 10560 ....	392	105	110	60
	PAP 105115 ....	752	105	110	115
110	PAP 11060 ....	411	110	115	60
	PAP 110115 ....	787	110	115	115
115	PAP 11550 ....	357	115	120	50
	PAP 11560 ....	429	115	120	60
	PAP 11570 ....	500	115	120	70
120	PAP 12060 ....	447	120	125	60
	PAP 120100 ....	745	120	125	100
125	PAP 125100 ....	776	125	130	100
130	PAP 13060 ....	484	130	135	60
	PAP 130100 ....	806	130	135	100
135	PAP 13560 ....	502	135	140	60
	PAP 13580 ....	669	135	140	80
140	PAP 14060 ....	520	140	145	60
	PAP 140100 ....	867	140	145	100
150	PAP 15060 ....	557	150	155	60
	PAP 15080 ....	742	150	155	80
	PAP 150100 ....	928	150	155	100
160	PAP 16080 ....	791	160	165	80
	PAP 160100 ....	989	160	165	100
180	PAP 180100 ....	1110	180	185	100
200	PAP 200100 ....	1232	200	205	100
220	PAP 220100 ....	1354	220	225	100
250	PAP 250100 ....	1536	250	255	100
300	PAP 300100 ....	1840	300	305	100

\* On request

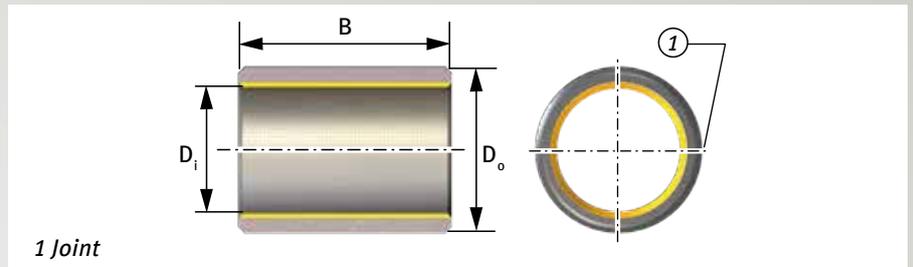
### 9.1.2 Series P11 with bronze back

Recommended fitting tolerance:

Shaft		Housing bore
$5 \leq d_w < 80$	f7	H7
$80 \leq d_w$	h8	

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

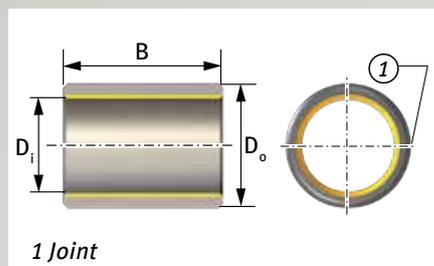
Bushes in special dimensions available on request.



Dimension table (dimensions in mm)					
Shaft diameter	Order designation P11	Weight g	Dimensions		
			D <sub>i</sub>	D <sub>o</sub>	B ±0.25
4	PAP 0406 ....	0.8	4	6	6
5	PAP 0505 ....	0.8	5	7	5
6	PAP 0606 ....	1.1	6	8	6
	PAP 0610 ....	1.8	6	8	10
8	PAP 0808 ....	1.9	8	10	8
	PAP 0810 ....	2.3	8	10	10
	PAP 0812 ....	2.8	8	10	12
10	PAP 1005 ....	1.4	10	12	5
	PAP 1010 ....	2.8	10	12	10
	PAP 1015 ....	4.2	10	12	15
	PAP 1020 ....	5.7	10	12	20
12	PAP 1210 ....	3.3	12	14	10
	PAP 1212 ....	4	12	14	12
	PAP 1215 ....	5.1	12	14	15
	PAP 1220 ....	6.7	12	14	20
	PAP 1225 ....	8.4	12	14	25
14	PAP 1415 ....	5.8	14	16	15
15	PAP 1515 ....	6.2	15	17	15
	PAP 1525 ....	10.3	15	17	25
16	PAP 1615 ....	6.6	16	18	15
	PAP 1625 ....	11	16	18	25
18	PAP 1815 ....	7.4	18	20	15
	PAP 1825 ....	12.3	18	20	25
20	PAP 2015 ....	12.8	20	23	15
	PAP 2020 ....	17	20	23	20
	PAP 2025 ....	21.3	20	23	25
	PAP 2030 ....	25.5	20	23	30
22	PAP 2215 ....	14	22	25	15
	PAP 2220 ....	18.6	22	25	20
	PAP 2225 ....	23.3	22	25	25
24	PAP2430 ....	30.3	24	27	30
25	PAP 2525 ....	26.2	25	28	25
	PAP 2530 ....	31.5	25	28	30
28	PAP 2830 ....	47.9	28	32	30

\* On request

## 9 | Versions and dimension tables

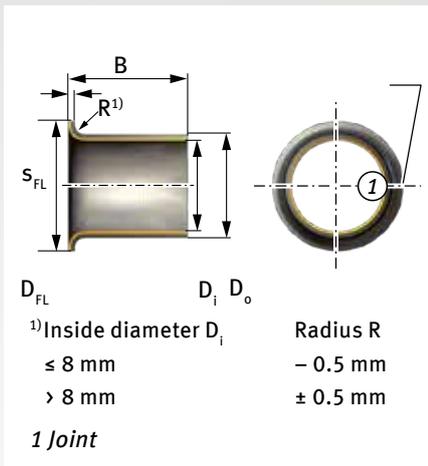


Dimension table - continued (dimensions in mm)					
Shaft diameter	Order designation P11	Weight g	Dimensions		
			$D_i$	$D_o$	$B \pm 0.25$
30	PAP 3020 ....	34.1	30	34	20
	PAP 3030 ....	51.1	30	34	30
	PAP 3040 ....	68.2	30	34	40
35	PAP 3520 ....	39.4	35	39	20
	PAP 3530 ....	59.1	35	39	30
40	PAP 4050 ....	112	40	44	50
45	PAP 4550 ....	159	45	50	50
50	PAP 5030 ....	105	50	55	30
	PAP 5040 ....	140	50	55	40
	PAP 5060 ....	211	50	55	60
55	PAP 5540 ....	154	55	60	40
60	PAP 6040 ....	167	60	65	40
	PAP 6050 ....	209	60	65	50
	PAP 6060 ....	251	60	65	60
	PAP 6070 ....	293	60	65	70
70	PAP 7050 ....	242	70	75	50
	PAP 7070 ....	339	70	75	70
80	PAP 8060 ....	331	80	85	60
	PAP 80100 ....	552	80	85	100
90	PAP 9060 ....	371	90	95	60
	PAP 90100 ....	619	90	95	100
95	PAP 9560 ....	391	95	100	60
100	PAP 10060 ....	411	100	105	60
	PAP 100115 ....	788	100	105	115

\* On request

## 9.2 KS Permaglide® collar bushes, maintenance-free

### 9.2.1 Series P10, P14, P147\* with steel back



Collar bushes in special dimensions available on request.

Dimension table (dimensions in mm)							
Shaft diameter	Order designation ... .. P10, P14, P147*	Weight g	Dimensions				
			$D_i$	$D_o$	$D_{FL}$ $\pm 0.5$	B $\pm 0.25$	$S_{FL}$ $-0.2$
6	PAF 06040 ....	0.9	6	8	12	4	1
	PAF 06070 ....	1.4	6	8	12	7	1
	PAF 06080 ....	1.6	6	8	12	8	1
8	PAF 08055 ....	1.7	8	10	15	5.5	1
	PAF 08075 ....	2.1	8	10	15	7.5	1
	PAF 08095 ....	2.5	8	10	15	9.5	1
10	PAF 10070 ....	2.5	10	12	18	7	1
	PAF 10090 ....	3	10	12	18	9	1
	PAF 10120 ....	3.8	10	12	18	12	1
	PAF 10170 ....	5	10	12	18	17	1
12	PAF 12070 ....	3	12	14	20	7	1
	PAF 12090 ....	3.6	12	14	20	9	1
	PAF 12120 ....	4.5	12	14	20	12	1
	PAF 12170 ....	5.9	12	14	20	17	1
14	PAF 14120 ....	5.1	14	16	22	12	1
	PAF 14170 ....	6.9	14	16	22	17	1
15	PAF 15090 ....	4.4	15	17	23	9	1
	PAF 15120 ....	5.5	15	17	23	12	1
	PAF 15170 ....	7.3	15	17	23	17	1
16	PAF 16120 ....	5.8	16	18	24	12	1
	PAF 16170 ....	7.8	16	18	24	17	1
18	PAF 18120 ....	6.5	18	20	26	12	1
	PAF 18170 ....	8.7	18	20	26	17	1
	PAF 18220 ....	10.9	18	20	26	22	1
20	PAF 20115 ....	11.4	20	23	30	11.5	1.5
	PAF 20165 ....	15.1	20	23	30	16.5	1.5
	PAF 20215 ....	18.9	20	23	30	21.5	1.5
25	PAF 25115 ....	14	25	28	35	11.5	1.5
	PAF 25165 ....	18.6	25	28	35	16.5	1.5
	PAF 25215 ....	23.5	25	28	35	21.5	1.5
30	PAF 30160 ....	30.5	30	34	42	16	2
	PAF 30260 ....	45.5	30	34	42	26	2
35	PAF 35160 ....	35	35	39	47	16	2
	PAF 35260 ....	53	35	39	47	26	2
40	PAF 40260 ....	61	40	44	53	26	2

\* On request

## 9 | Versions and dimension tables

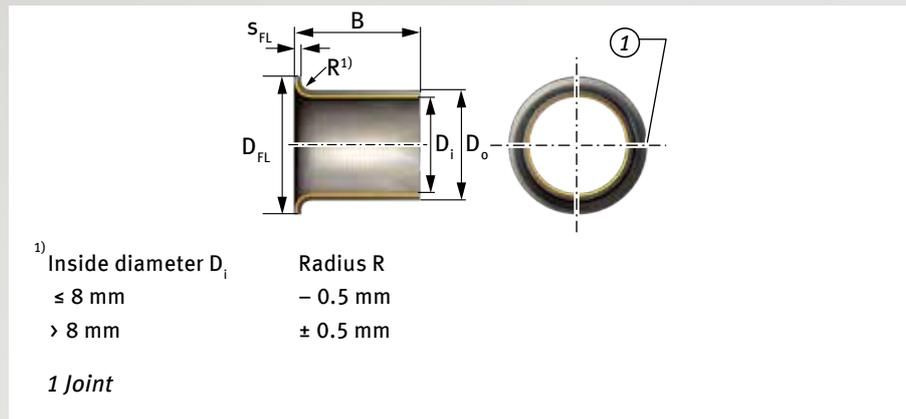
### 9.2.2 Series P11 with bronze back

Recommended fitting tolerance:

Shaft	House bore
f7	H7

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

Collar bushes in special dimensions available on request.



Dimension table (dimensions in mm)

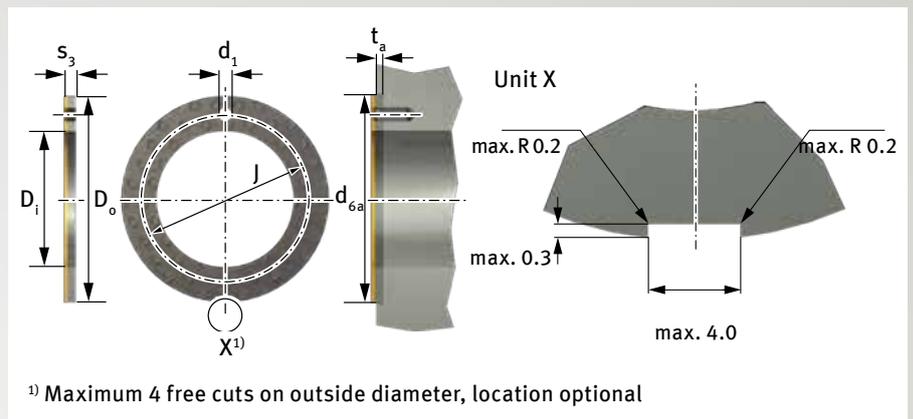
Shaft diameter	Order designation P11	Weight g	Dimensions				
			$D_i$	$D_o$	$D_{FL} \pm 0.5$	$B \pm 0.25$	$S_{FL} - 0.2$
6	PAF 06080 ....	1.8	6	8	12	8	1
8	PAF 08055 ....	1.8	8	10	15	5.5	1
	PAF 08095 ....	2.7	8	10	15	9.5	1
10	PAF 10070 ....	2.7	10	12	18	7	1
	PAF 10120 ....	4.1	10	12	18	12	1
	PAF 10170 ....	5.5	10	12	18	17	1
12	PAF 12070 ....	3.2	12	14	20	7	1
	PAF 12090 ....	3.9	12	14	20	9	1
	PAF 12120 ....	4.9	12	14	20	12	1
15	PAF 15120 ....	6	15	17	23	12	1
	PAF 15170 ....	8	15	17	23	17	1
16	PAF 16120 ....	6.3	16	18	24	12	1
18	PAF 18100 ....	6.1	18	20	26	10	1
	PAF 18220 ....	11.8	18	20	26	22	1
20	PAF 20115 ....	12.4	20	23	30	11.5	1.5
	PAF 20165 ....	16.6	20	23	30	16.5	1.5
25	PAF 25215 ....	25.5	25	28	35	21.5	1.5
30	PAF 30160 ....	33.5	30	34	42	16	2
	PAF 30260 ....	50	30	34	42	26	2
35	PAF 35260 ....	58	35	39	47	26	2
40	PAF 40260 ....	67	40	44	53	26	2

\* 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.



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

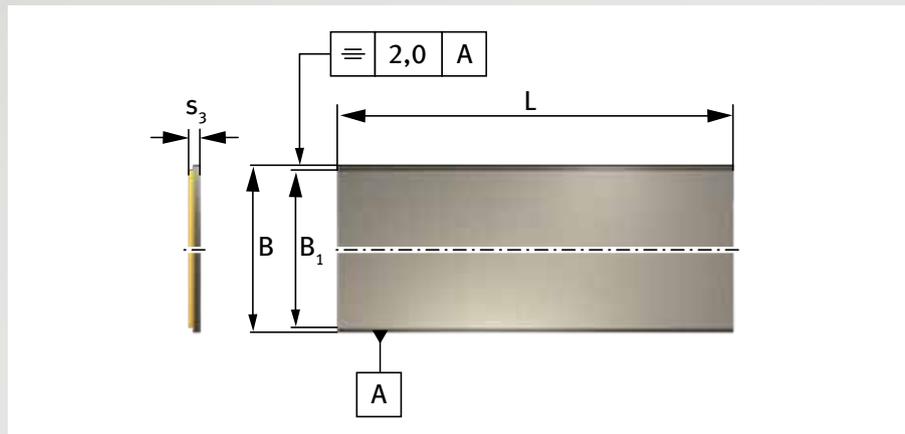
\* On request

## 9 | Versions and dimension tables

### 9.4 KS Permaglide® strips, maintenance-free

#### 9.4.1 Series P10, P14, P147\* with steel back – Series P11 with bronze back

Strips in special dimensions available on request.



Dimension table (dimensions in mm)

Order designation ... .. P10, P14, P147*	Weight g	Dimensions			
		$s_3$ -0.04	B +1.5	$B_1$	L +3
PAS 05180 ....	330	05	180	168	500
PAS 07250 ....	703	0,75	250	238	500
PAS 10250 ....	948	1	250	238	500
PAS 15250 ....	1439	1.5	250	238	500
PAS 20250 ....	1930	2	250	238	500
PAS 25250 ....	2420	2.5	250	238	500
PAS 30250 ....	2970	3.06	250	238	500

Dimension table (dimensions in mm)

Order designation ... .. P11	Weight g	Dimensions			
		$s_3$ -0.04	B +1.5	$B_1$	L +3
PAS 10160 ....	658	1	160	148	500
PAS 15180 ....	1132	1.5	180	168	500
PAS 20180 ....	1523	2	180	168	500
PAS 25180 ....	1915	2.5	180	168	500

$B$  = overall width

$B_1$  = useful width

\* On request

## 9.5 KS Permaglide® bushes, low-maintenance

### 9.5.1 Series P20, P200

**Recommended fitting tolerance:**

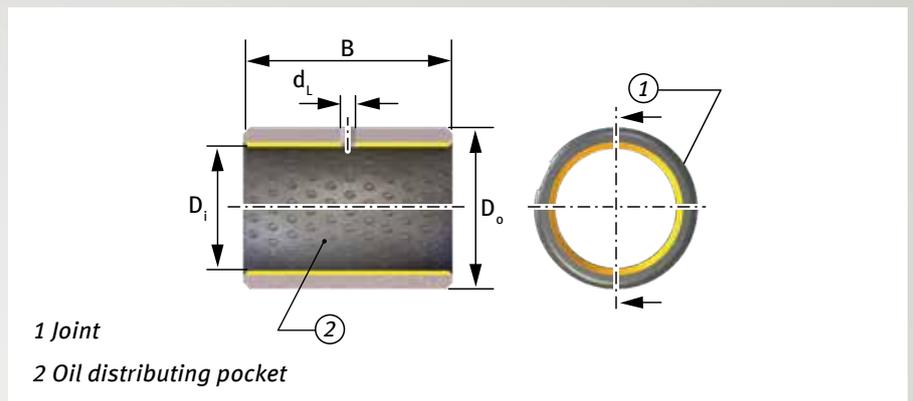
Shaft	Housing bore
h8	H7

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

Shaping the lubricating bore by roll bending is permitted.

Bushes P22, P23, P202 and P203 available on request.

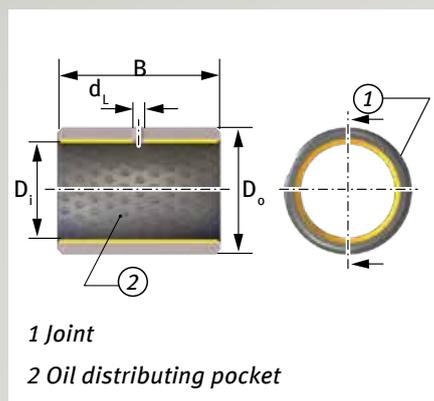
Bushes in special dimensions available on request.



Dimension table (dimensions in mm)						
Shaft diameter	Order designation ... .. P20, P200	Weight g	Dimensions			
			D <sub>i</sub>	D <sub>o</sub>	B ±0.25	d <sub>L</sub>
8	PAP 0808 ....	1.6	8	10	8	– <sup>1)</sup>
	PAP 0810 ....	2	8	10	10	– <sup>1)</sup>
	PAP 0812 ....	2.4	8	10	12	– <sup>1)</sup>
10	PAP 1008 ....	2	10	12	8	– <sup>1)</sup>
	PAP 1010 ....	2.4	10	12	10	3
	PAP 1015 ....	3.7	10	12	15	3
12	PAP 1210 ....	2.9	12	14	10	3
	PAP 1212 ....	3.5	12	14	12	3
	PAP 1215 ....	4.4	12	14	15	3
	PAP 1220 ....	5.9	12	14	20	3
14	PAP 1420 ....	6.8	14	16	20	3
15	PAP 1510 ....	3.6	15	17	10	3
	PAP 1515 ....	5.4	15	17	15	3
	PAP 1525 ....	9	15	17	25	3
16	PAP 1612 ....	4.6	16	18	12	3
	PAP 1615 ....	5.7	16	18	15	3
	PAP 1620 ....	7.7	16	18	20	3
18	PAP 1815 ....	6.4	18	20	15	3
	PAP 1820 ....	8.6	18	20	20	3
20	PAP 2015 ....	11.2	20	23	15	3
	PAP 2020 ....	15	20	23	20	3
	PAP 2025 ....	18.8	20	23	25	3
	PAP 2030 ....	23.1	20	23	30	3

<sup>1)</sup> No lubricating hole

## 9 | Versions and dimension tables



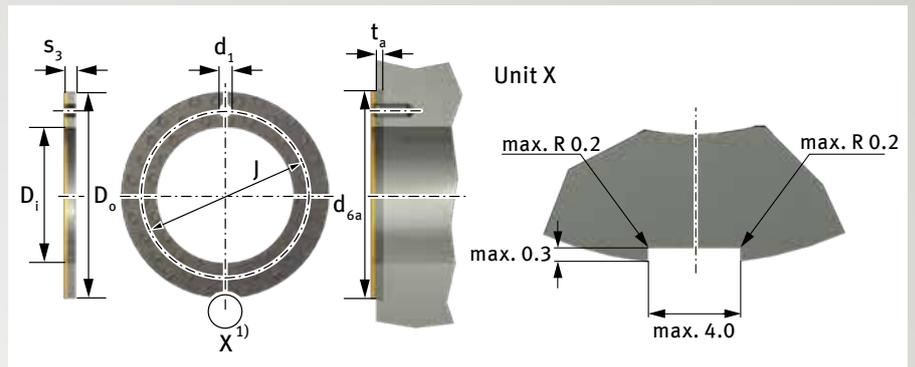
Dimension table · continued (dimensions in mm)						
Shaft diameter	Order designation ... .. P20, P200	Weight g	Dimensions			
			D <sub>i</sub>	D <sub>o</sub>	B ±0.25	d <sub>L</sub>
22	PAP 2220 ....	16.4	22	25	20	3
25	PAP 2515 ....	13.9	25	28	15	4
	PAP 2520 ....	18.5	25	28	20	4
	PAP 2525 ....	23.1	25	28	25	4
	PAP 2530 ....	27.8	25	28	30	4
28	PAP 2830 ....	42.6	28	32	30	4
30	PAP 3020 ....	30.3	30	34	20	4
	PAP 3025 ....	37.8	30	34	25	4
	PAP 3030 ....	45.4	30	34	30	4
	PAP 3040 ....	60.6	30	34	40	4
32	PAP 3230 ....	48.2	32	36	30	4
35	PAP 3520 ....	35	35	39	20	4
	PAP 3530 ....	52.5	35	39	30	4
	PAP 3550 ....	87.5	35	39	50	4
40	PAP 4020 ....	39.7	40	44	20	4
	PAP 4030 ....	59.6	40	44	30	4
	PAP 4040 ....	79.5	40	44	40	4
	PAP 4050 ....	99.3	40	44	50	4
45	PAP 4540 ....	113	45	50	40	5
	PAP 4550 ....	142	45	50	50	5
50	PAP 5025 ....	78	50	55	25	5
	PAP 5040 ....	125	50	55	40	5
	PAP 5060 ....	188	50	55	60	5
55	PAP 5540 ....	137	55	60	40	5
60	PAP 6030 ....	112	60	65	30	6
	PAP 6040 ....	142	60	65	40	6
	PAP 6060 ....	224	60	65	60	6
70	PAP 7040 ....	173	70	75	40	6
	PAP 7050 ....	216	70	75	50	6
	PAP 7070 ....	303	70	75	70	6
75	PAP 7540 ....	185	75	80	40	6
	PAP 7580 ....	370	75	80	80	6
80	PAP 8040 ....	197	80	85	40	6
	PAP 8055 ....	271	80	85	55	6
	PAP 8060 ....	295	80	85	60	6
	PAP 8080 ....	394	80	85	80	6
90	PAP 9060 ....	331	90	95	60	6
100	PAP 10050 ....	305	100	105	50	8
	PAP 10060 ....	366	100	105	60	8

## 9.6 KS Permaglide® thrust washers, low-maintenance

### 9.6.1 Series P20, P200

Thrust washers of P22, P23, P202 and P203 available on request.

Thrust washers in special dimensions available on request.



Dimension table (dimensions in mm)								
Order designation ... P20, P200	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 12 ....	3.8	12	24	1.5	18	1.5	1	24
PAW 14 ....	4.2	14	26	1.5	20	2	1	26
PAW 18 ....	6.1	18	32	1.5	25	2	1	32
PAW 20 ....	7.8	20	36	1.5	28	3	1	36
PAW 22 ....	8.4	22	38	1.5	30	3	1	38
PAW 26 ....	11	26	44	1.5	35	3	1	44
PAW 28 ....	13.3	28	48	1.5	38	4	1	48
PAW 32 ....	16.5	32	54	1.5	43	4	1	54
PAW 38 ....	21	38	62	1.5	50	4	1	62
PAW 42 ....	22.5	42	66	1.5	54	4	1	66
PAW 48 ....	37.5	48	74	2	61	4	1.5	74
PAW 52 ....	40	52	78	2	65	4	1.5	78

<sup>1)</sup> Maximum 4 free cuts on outside diameter, location optional

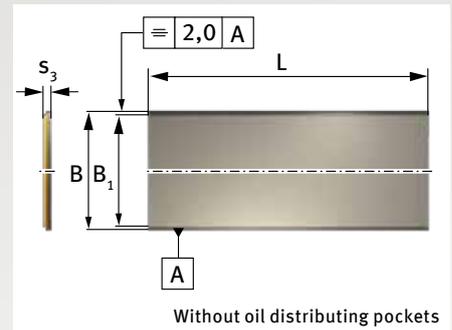
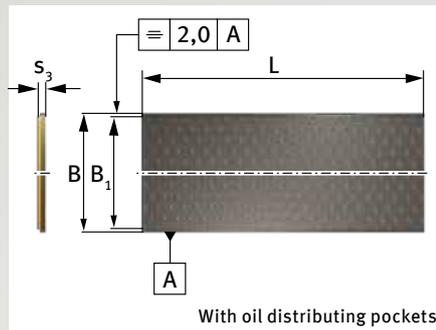
## 9.7 KS Permaglide® strips, low-maintenance

### 9.7.1 Series P20, P200

- P20 With oil distributing pocket, ready to install
- P22 Without oil distributing pocket, with machining allowance
- P23 Without oil distributing pocket, ready to install
- P200 With oil distributing pocket, ready to install
- P202 Without oil distributing pocket, with machining allowance
- P203 Without oil distributing pocket, ready to install

Strips P22, P23, P200, P202 and P203 available on request.

Strips in special dimensions available on request.



**Dimension table (dimensions in mm)**

Order designation ... .. P20	Weight g	Dimensions			
		$s_3$ -0.04	B +1.5	$B_1$	L +3
PAS 10180 ....	640	0.99	180	168	500
PAS 15180 ....	986	1.48	180	168	500
PAS 20180 ....	1332	1.97	180	168	500
PAS 25180 ....	1678	2.46	180	168	500

$B$  = overall width

$B_1$  = useful width

**Dimension table (dimensions in mm)**

Order designation ... .. P22, P23, P200, P202, P203	Weight g	Dimensions			
		$s_3^{1)}$ -0.04	B +1.5	$B_1$	L +3
PAS 10180.....	988	1.11	180	168	500
PAS 15180 ....	1375	1.61	180	168	500
PAS 20180 ....	1833	2.11	180	168	500
PAS 25180 ....	2279	2.63	180	168	500

Supplied on request.

<sup>1)</sup> Machining allowance: 0.15 mm.

## 10.1 Testing wrapped bushes

Unlike a cylindrical pipe section, wrapped bushes are produced from a level section of material through forming. They therefore feature a joint that may be open when free. The wrapped bush only has a closed joint and the required dimensional and contouring accuracy after it has been pressed into the bearing housing. Before installation, the outside diameter  $D_o$  and inside diameter  $D_i$  of wrapped bushes can only be measured using special test methods and test equipment.

### Bush outside diameter $D_o$

Test A, DIN ISO 3547 Part 2

Here, the wrapped bush is placed in a two-piece test holder with defined test diameter  $d_{ch}$ , with the joint facing upwards. The test holder is subjected to a test force  $F_{ch}$ . The distance  $z$  between the dies changes under the test force. The bush diameter  $D_o$  is then calculated from this measured value  $\Delta z$ .

Test D, DIN ISO 3547 Part 2

Wrapped bushes with an outside diameter  $D_o > 180$  mm are tested using a precision tape measure. Here, the tape measure is placed around the centre of the bush, and sufficient tension applied to close the joint. The measured circumference  $\Delta z$  indicates the difference between the adjusting mandrel and the bush. From this value, the bush outside diameter  $D_o$  is calculated.

### Bush inside diameter $D_i$

Test C with gauge, DIN ISO 3547 Part 2

The wrapped bush is pressed into a gauge ring with a test diameter defined according to DIN ISO 3547 Part 1, Tab. 5. The bush inside diameter  $D_i$  is checked using a go/no go plug gauge or a 3-point touch probe.

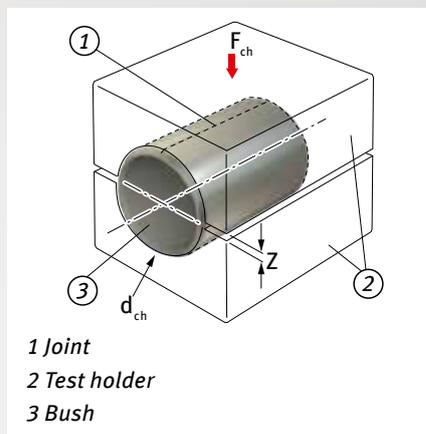


Fig. 63: Test of bush outside diameter  $D_o$

### Wall thickness test of wrapped bush (following agreement)

The wall thickness test is set out in DIN ISO 12036.

The bush wall thickness  $s_3$  is tested on one, two or three measuring lines, depending on the bush width  $B$ . Following agreement, the test can be performed in accordance with the aforementioned standard:

### Caution:

The wall thickness  $s_3$  and bush inside diameter must not be given simultaneously as a test dimension.

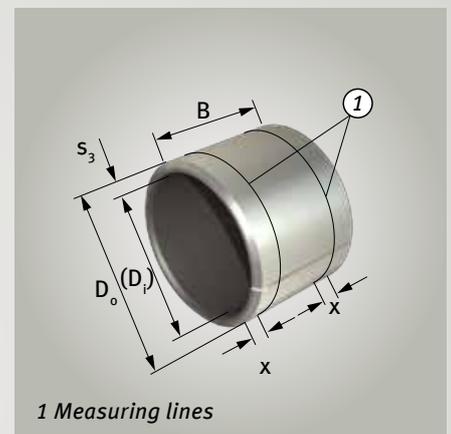


Fig. 64: Measuring lines for the wall thickness test (example)

### Important note:

The section on the testing of wrapped bushes describes the most important processes in a generalised fashion. It is to be used purely for the purpose of information. The exact procedure is set out in the respective current standards. These standards alone must be used to determine the dimensional and functional quality of wrapped bushes.

## 10.2 Machining the sliding layer

The sliding layer of KS Permaglide® P22 and P202 has a machining allowance of around 0.15 mm. This can be machined by turning, drilling or reaming to:

- Achieve smaller clearance tolerances
- Compensate for misalignment.

Tried and tested methods are turning and drilling with:

- Dry cutting
- Cutting speeds from 100 to 150 m/min
- Feed from 0.05 mm/rev
- Cutting depth max. 0.1 mm
- Carbide tools (Fig. 65)

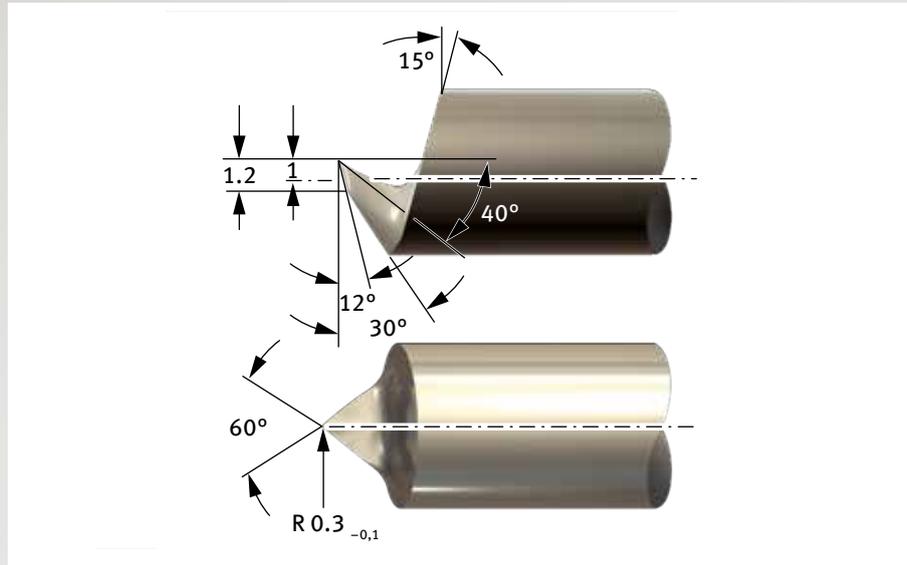


Fig. 65: Cutting tool for KS Permaglide® P22 and P202

Machining temperatures above 140°C constitute a health hazard.

P22 chips contain lead. Lead is hazardous to health.



**Caution:**

Removing more material reduces service life.



**Caution:**

Inexpert machining will have a negative impact on service life and load carrying capacity.



**Caution:**

Parts must be cleaned after machining.

## Delivery condition, Storage

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### Delivery condition

- Packed in a bag in a cardboard box, or
- Packed in a cardboard box.

### Storage

KS Permaglide® plain bearings should be stored:

- In a dry, clean place
- At a constant temperature, as far as possible
- At a relative humidity of max. 65 %.



### Caution:

Keep packaging closed, where possible. Only remove KS Permaglide® plain bearings from their original packaging immediately before installation.

## Environmental issues, health & safety

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In your own interests, please observe legislation and other regulations concerning

- Protection of the environment
- Occupational health & safety and similar issues.

## References

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### References

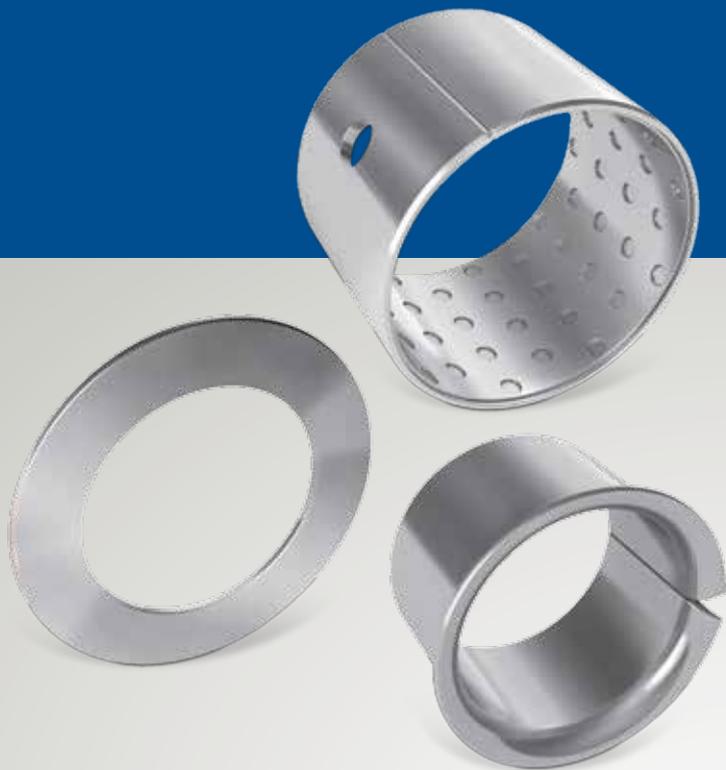
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### Further reading:

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**Original**  
**KS PERMAGLIDE®**  
**Plain Bearings**

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