

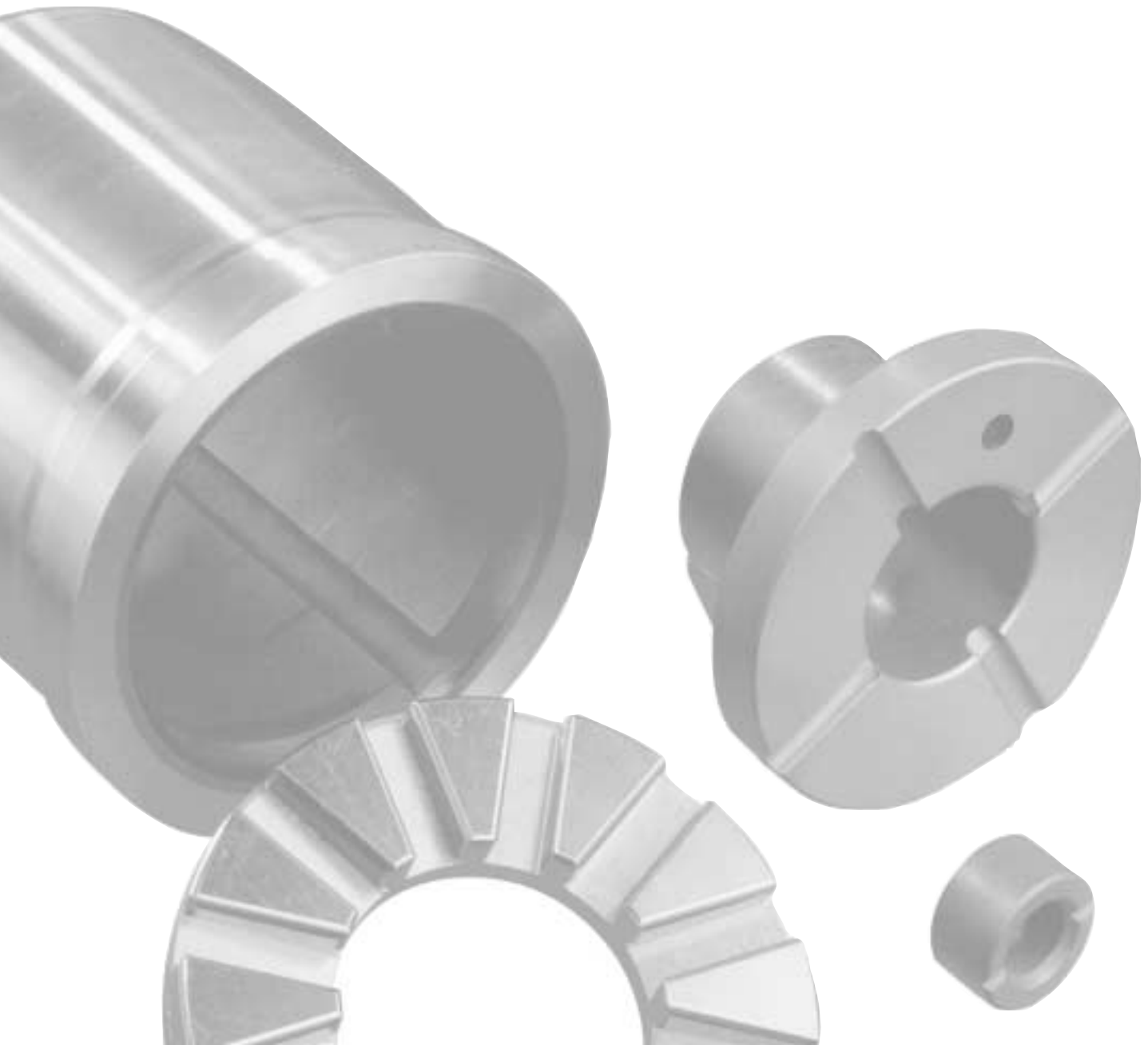


Bearing and Seal Technology

Bearings

Table of contents

Characteristic properties for use as a bearing material	Page 3
Bearing design	Page 3
Installation	Page 4
Bearing clearance	Pages 6-7
Counterpart materials and their surface quality	Pages 6-7
Loading capacity	Pages 8-10
Fields of application and material recommendations	Page 11



Characteristic properties for use

... as a bearing material

Carbon and graphite materials exhibit the following characteristic properties:

- excellent sliding and dry running properties, low coefficient of friction,
- good thermal conductivity,
- high chemical resistance,
- outstanding resistance to thermal shock,
- excellent dimensional stability,
- high fatigue resistance.

Due to these properties, carbon and graphite bearings are used in many applications, such as high and low temperature technology, chemical and petrochemical industries, food, pharmaceutical and cosmetic industries, automotive applications, and nuclear reactor technology.

Information on the production and physical properties of Schunk carbon and graphite materials is given in other publications.

Bearing design

The standard for radial and flanged carbon bearings is DIN 1850, page 4 ("Carbon bushes for sleeve bearings").

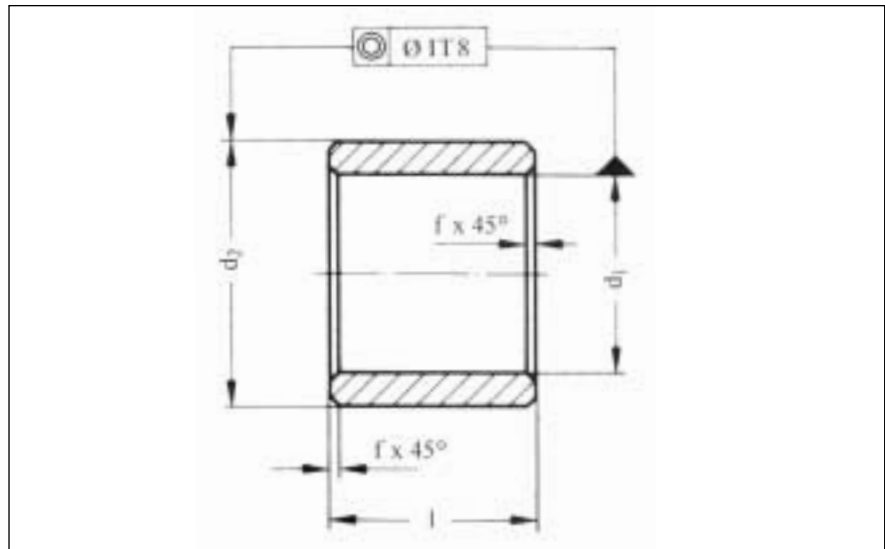
General guidelines

$$\begin{aligned}L &= d_1 \text{ to } d_2 \\L_{\max} &= 2 \cdot d_2 \\s &= 0.1 \text{ to } 0.2 \cdot d_1 \\s_{\min} &= 3 \text{ mm}\end{aligned}$$

Roughly the same specifications apply to the flange thickness of flanged bearings as apply to the wall thickness. In the case of shrunk-in flanged bearings, special specifications have to be observed for the collar design (see drawing, page 5). Dry running radial and axial bearings are not equipped with lubricating grooves.

This also applies predominantly to wet running radial bearings, though these can be provided with spiral or axial grooves in the bore. Facial grooves, however, are recommended for fluid lubricated axial carbon bearings (flanged bearings). Recommendations on the design of the facial grooves may be supplied on request.

It is possible to manufacture self-aligning spherical carbon bearings but this involves a correspondingly high effort in material and labour, since the bearings must be machined from cylindrical blanks. Partial pressing-to-size can be considered for larger quantities provided that no close spherical tolerances are required. For further information please refer to our brochure 30.20 ("Bearing and Seal Technology: General information; properties; use as sliding material; design recommendations").



Installation

Pressing-in

Recommended tolerance zones before cold pressing-in:

Inside diameter d_1 :	F7 - E7
Outside diameter d_2 :	s6
Housing bore for carbon bearing:	H7

This results in a tolerance of H7 to H8 for the inside diameter d_1 after pressing-in.

For cold pressing-in, a pressing-in mandrel should be used with a diameter of about 3 tolerance zones below the bore tolerance of the carbon bearing in its delivered state. Additionally, the mandrel's shoulder should press onto the entire bearing face.

Shrinking-in

Recommended tolerance zones before hot shrinking-in:

Inside diameter d_1 :	D8
Outside diameter d_2 :	x8 to z8
Housing bore for carbon bearing:	H7
Shrinking-in temperature:	300°C - 350°C

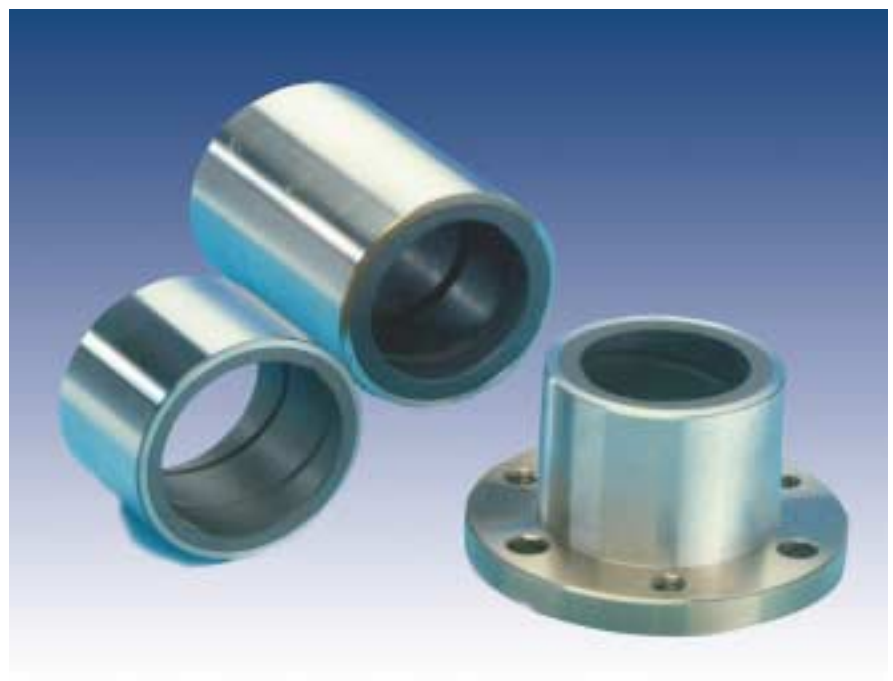
This results in a tolerance of H9 for the inside diameter d_1 after shrinking-in. Finish reaming is recommended subsequent to shrinking-in for staying exactly within the tolerances.

When installing carbon bearings, special attention has to be paid to the lower coefficient of thermal expansion of carbon and graphite materials compared to that of metals. Additionally, the lower strength and brittleness of carbon materials have to be considered. Therefore, carbon bearings should not be installed without support.

The normal press and shrink fits for metals result in good fits having a relatively low maximum temperature operating limit, when using carbon materials with metals, due to the relatively low thermal expansion of the carbon materials. Therefore, a cold press fit of carbon bearings in steel housings according to H7/s6 can only be used up to maximum bearing temperatures of approximately 120 - 150 °C.

The maximum allowable temperature is correspondingly lower for housings or sleeves made of materials possessing a higher coefficient of thermal expansion than steel.

A tolerance allowance on the diameter exceeding H7/s6 is not recommended for cold pressing-in of carbon bearings, except for plastic housings or sleeves, due to the likely occurrence of shearing.



Carbon bearings with metal sleeves

Schunk's grade FH531B is an exception: this material has been developed for small, pressed-to-size or partially pressed-to-size bearings. The lower shearing strength of this material allows a larger tolerance allowance of these pressed-to-size bearings. When pressing-in, any protruding material will be sheared off without damaging the bearing.

When cold pressing-in, particularly thin-walled bearings, great care must be taken that the bearings do not tilt, as this may cause fracture.

The carbon bearing bore is reduced by approximately 70 to 85 % of the pressing-in size difference, depending on the material, the wall thickness ratio and tolerance combination.

For bearing temperatures exceeding 120 to 150°C, direct shrinking-in of the carbon bearings into the housings or metal sleeves is the best way of fitting the bearings.

When shrinking-in, it should be possible to insert the cold carbon bearings easily into the housings or metal sleeves. These have to be heated to temperatures exceeding the maximum anticipated operating temperature by 100 to 150°C. The shrinking-in tolerance has to be determined according to the different coefficients of thermal expansion. In case the above-mentioned shrink fits H7/x8 (shrinking-in temperature: appr. 300°C) and H7/z8 (shrinking-in temperature: appr. 350°C) are not sufficient for the anticipated operating temperature, shrinking-in can be performed at correspondingly higher pre-heating temperatures of up to about 600°C to shrink fits H7/za8 or H7/zb8. In some cases an additional locking mechanism may be required.

When shrinking-in, the carbon bearing bore is reduced; housings and sleeves, particularly thin walled ones, may increase in size. Depending on the diameter and the wall thickness ratio, a bore reduction of

about 3 to 6 tolerance zones or of 80 to 100 % of the shrinking-in tolerance can be expected with the above-mentioned shrink fits H7/x8 and H7/z8.

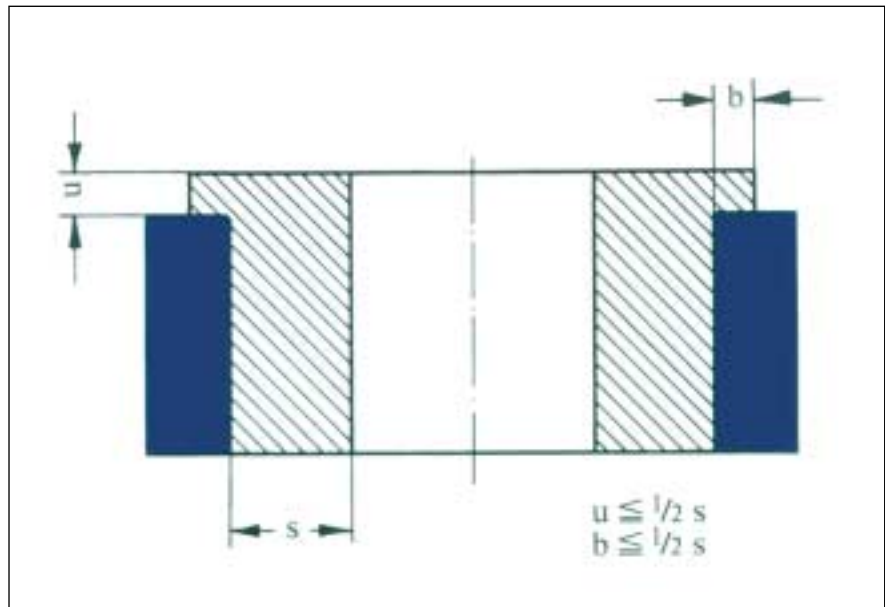
Detailed data on the reduction of carbon bearing bores as well as on size increase of the sleeves cannot be provided. Finish machining of the bearing bore is always necessary in order to meet close tolerances.

If close tolerances are required, metal sleeved carbon bearings, which can be pressed into the housing like metal bearings, are to be preferred. On request, carbon bearings can be shrunk-in into metal sleeves by Schunk Kohlenstofftechnik GmbH and delivered as a set ready for

installation. Tolerances up to IT7 for the bearing bore and IT6 for the outside diameter of the metal sleeve can be met.

After shrinking-in, the carbon bearing in the metal sleeve is subjected to compressive strain. The carbon material is supported so well by the metal sleeve that, subsequently, it can be turned to very small wall thicknesses.

When shrinking-in flanged bearings, it has to be ensured that the values of flange thickness and flange width do not exceed more than half of the value of the bearing wall thickness. Otherwise, chipping-off of the flange may occur during shrinking-in or when the bearing is under load.



Bearing clearance

Dry running

at operating temperature 0.3 % - 0.5 %
of the shaft diameter

Wet running

at operating temperature 0.1 % - 0.3 %
of the shaft diameter

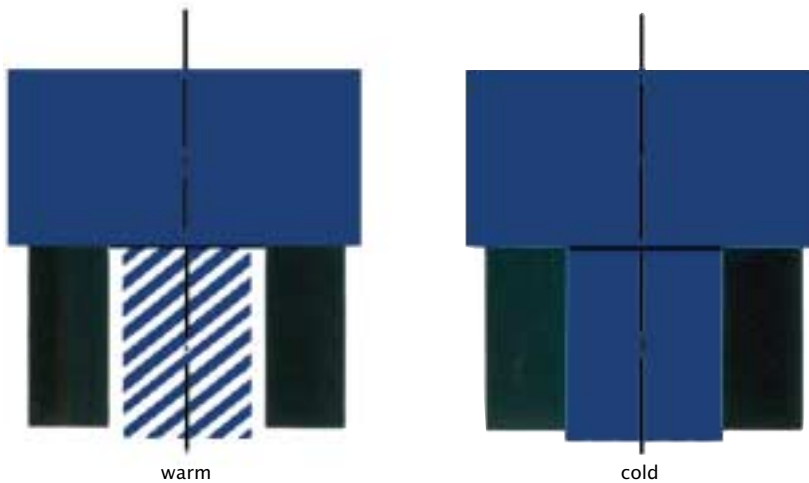
When determining the bearing clearance, the carbon material's low coefficient of thermal expansion, compared to that of most shaft materials, has to be taken into account. Substantial differences between the cold clearance and the clearance at elevated operating temperatures.

If a very tight cold clearance is selected, the shafts may even seize up in use.

The cold clearance is obtained by adding the difference in expansion at operating temperature of the carbon bearing and the shaft to the above-mentioned value of the bearing clearance.

In the case of pre-stressed shrunk-in carbon bearings which expand on heating at the same rate as the coefficient of thermal expansion of the housing or sleeve material, the difference in expansion is not to be considered for the determination of cold clearance.

As the clearance of carbon bearings always has to be larger than that of oil lubricated metal sleeves, a bore tolerance closer than IT8/IT7 generally is not necessary.



Counterpart materials and their surface quality

Suitable counterpart materials

- Chrome steel
- Cast chrome steel
- Nitrified steel
- Cast iron
- Hard-chrome plated materials
- Unalloyed steel
- Silicon carbide
- Hard metal
- Sintered ceramics (Al_2O_3)
(only for wet running)
- Chromium oxide
(plasma plated)

Partially suited counterpart materials

- Nickel chromium steel
- Austenitic cast iron
- Nonferrous metal

Unsuitable counterpart materials

- Aluminium
- Aluminium alloys
(even if anodised)

The best running performance is achieved with a surface roughness of the counterpart material of $R_t \leq 1 \mu\text{m}$. A higher surface roughness of $R_t \approx 2 \mu\text{m}$ will only result in higher initial wear during the running-in period.

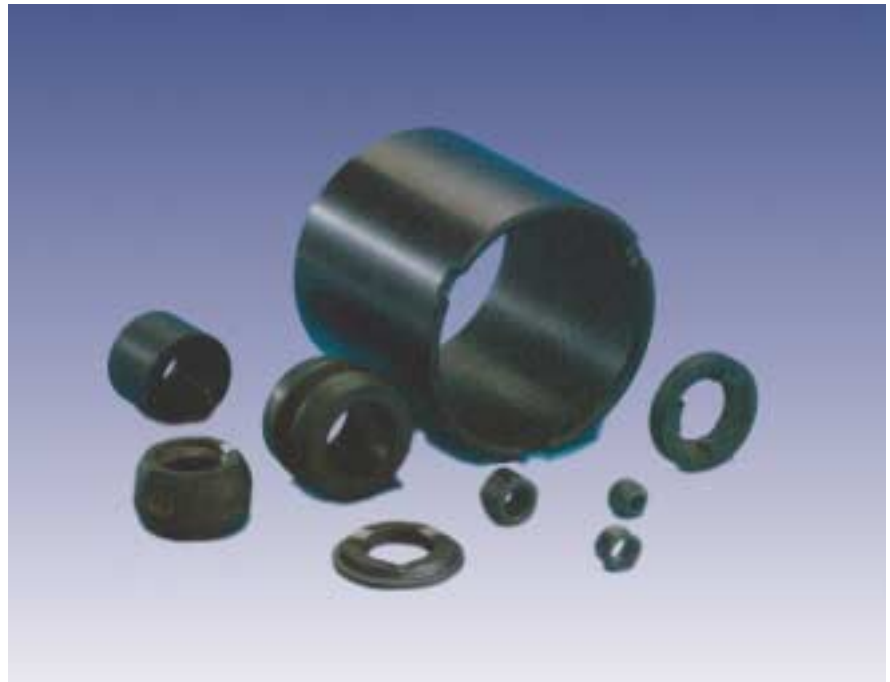
Finely ground shafts, superfinished for more onerous requirements, are recommended for carbon bearings. Drawn shafts are only allowable for applications at low sliding speeds and loads. Surface hardened and drawn shafts are not suitable for carbon bearings.

Not only the surface finish of the counterpart surface is highly important for the running behaviour of the carbon bearing, but also the counterpart material itself has a certain impact.

The use of low-hardness, nickel containing stainless steel as counterpart material is not recommended, especially if other more suitable materials can be used. Dry running, where there is insufficient fluid lubrication, or highly contaminated liquids may lead to undesired scoring, resulting in an increase in wear. Harder nickel-free stainless steel types are preferred, at least for use at low or medium load. Hardened chrome steel (13 - 17 % Cr) has proved to be best, also at higher loads.

The preference for hard counterpart materials is mainly based on the fact that the harder the counterpart material, the easier the formation of the graphite film on the counterpart material.

[Clark, W. T. and Lancaster, J. K. (1963). Wear 6. 467.]



Various carbon bearing designs

Experience shows that the best running results are achieved by using counterpart materials with a hardness of $HRC \geq 40$.



Loading capacity

As carbon and graphite bearings are mainly used with dry and mixed friction and, therefore, are subject to wear, it is possible to take the wear rate as a measure of loading capacity. So it is possible to provide the design engineer with information on the carbon bearing life.

As bearing wear is higher with dry rather than mixed friction, $p \cdot v$ graphs using a wear rate of $0.7 \mu\text{m/h}$ for dry running carbon bearings and of $0.1 \mu\text{m/h}$ for wet running carbon bearings were established. Extensive tests on bearing test rigs were performed at Schunk, in which different sliding speeds and specific loads were applied for each test. The data obtained was the basis for the $p \cdot v$ charts which show the maximum allowable specific bearing load as a function of sliding speed,

Radial bearings, $\varnothing 12/18 \times 10$ mm and stainless steel shafts, material number 1.4104, with a surface roughness $R_t \approx 0.7 \mu\text{m}$, were used for dry running tests. The tests were performed in air at ambient temperature.

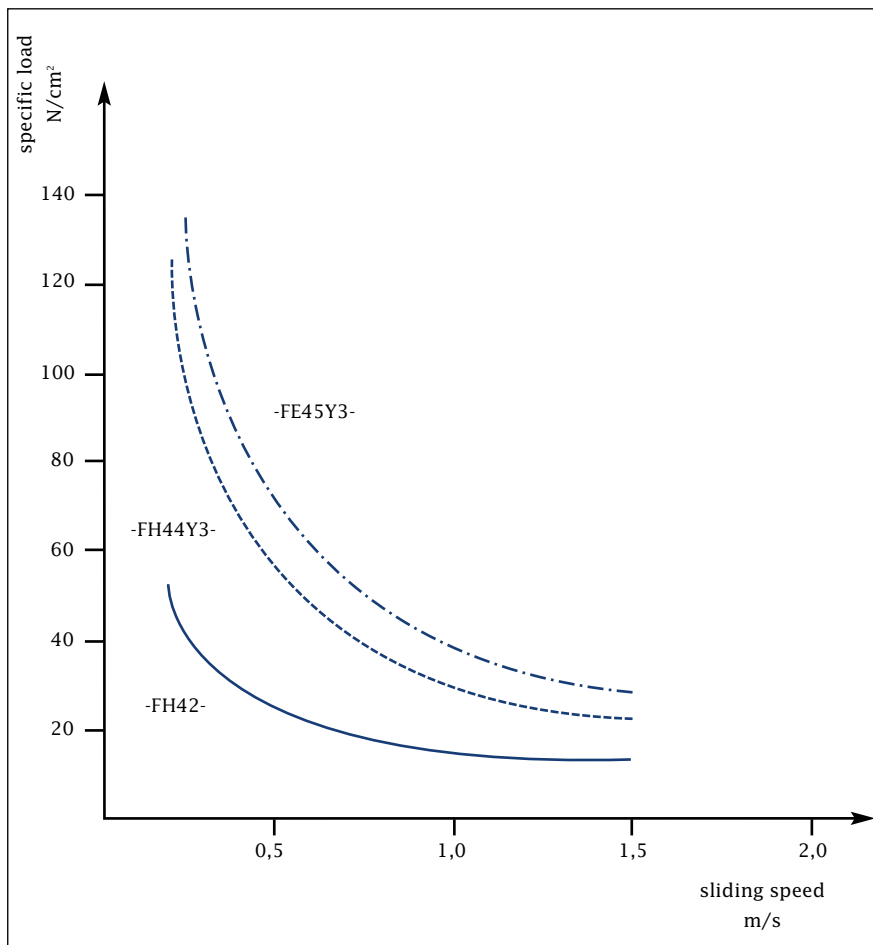
Wet running tests were carried out under tap water at ambient temperature. Radial bearings, $\varnothing 15/35 \times 15$ mm and $\varnothing 20/35 \times 20$ mm, and steel shafts, material number 1.4122, with a surface roughness $R_t \approx (0.7 \mu\text{m})$, were used for these tests.

The $p \cdot v$ chart 1 shows the loading capacity of dry running bearings of our non-impregnated materials FH42 (carbon graphite), FH44Y3 (carbon graphite) and FE45Y3 (electrographite).

According to the chart, carbon bearings made out of the very solid and hard carbon material FH42 show the lowest load bearing capacity under dry running conditions. Carbon bearings out of the carbon material FH44Y3 exhibit a significantly higher load bearing capacity due to the higher graphite content of this material.

The electrographite FE45Y3 has the highest load bearing capacity of the three tested non-impregnated carbon bearing materials. Resin impregnations lead to a substantial increase in loading capacity of dry running carbon bearings.

The loading capacity may be considerably improved by lead impregnations. These impregnations are usually not applied for dry running operations due to their relatively low maximum operating temperature.



Carbon bearing test rigs (dry running)

$p \cdot v$ diagram no. 1:
loading capacity of dry running carbon bearings as a function of sliding speed;

An increase in loading capacity by impregnation with antimony is only achieved for low sliding speeds of less than 0.5 m/s. The most significant improvement can be observed by special salt impregnations, as shown in the p · v chart 2.

This p · v chart gives the loading capacity of the non-impregnated electrographite FE45Y3 compared to that of the salt impregnated electrographite FE65.

The p · v charts show that the product p · v is practically constant for each material.

The following values have been determined for the different Schunk materials:

$$\text{FH42 } p \cdot v = 11 \text{ N/cm}^2 \cdot \text{m/s}$$

$$\text{FH44Y3 } p \cdot v = 30 \text{ N/cm}^2 \cdot \text{m/s}$$

$$\text{FH45Y3 } p \cdot v = 40 \text{ N/cm}^2 \cdot \text{m/s}$$

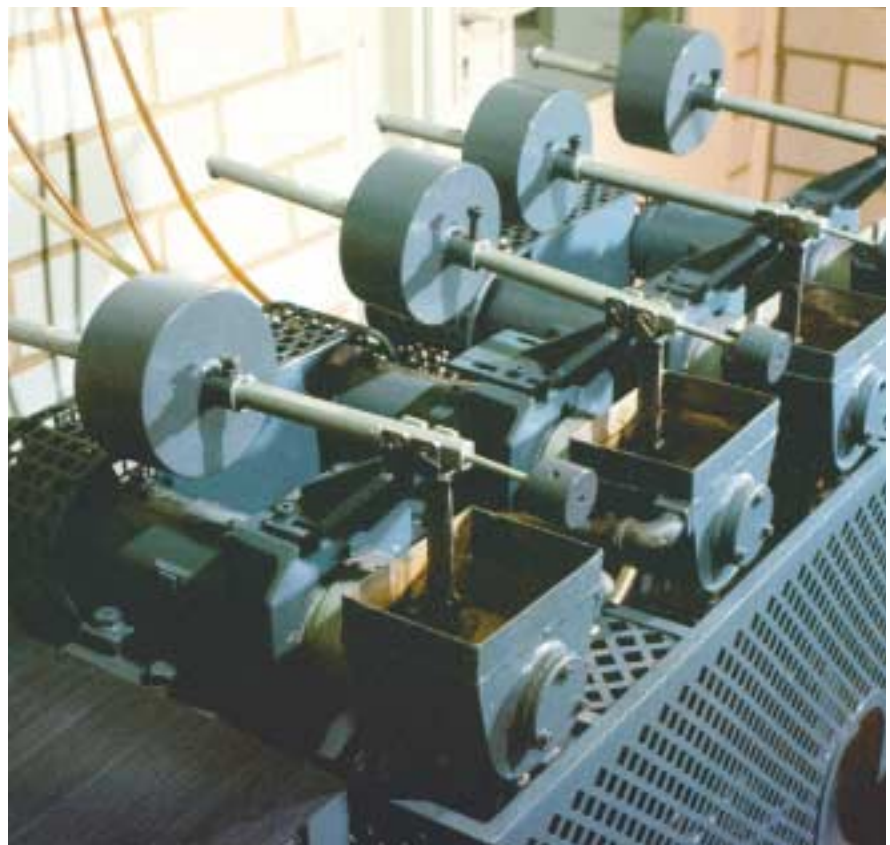
$$\text{FE 65 } p \cdot v = 190 \text{ N/cm}^2 \cdot \text{m/s}$$

In the p · v charts the curves for maximum loads are given for sliding speeds of 0.2 to 1.5 and 2 m/s, respectively.

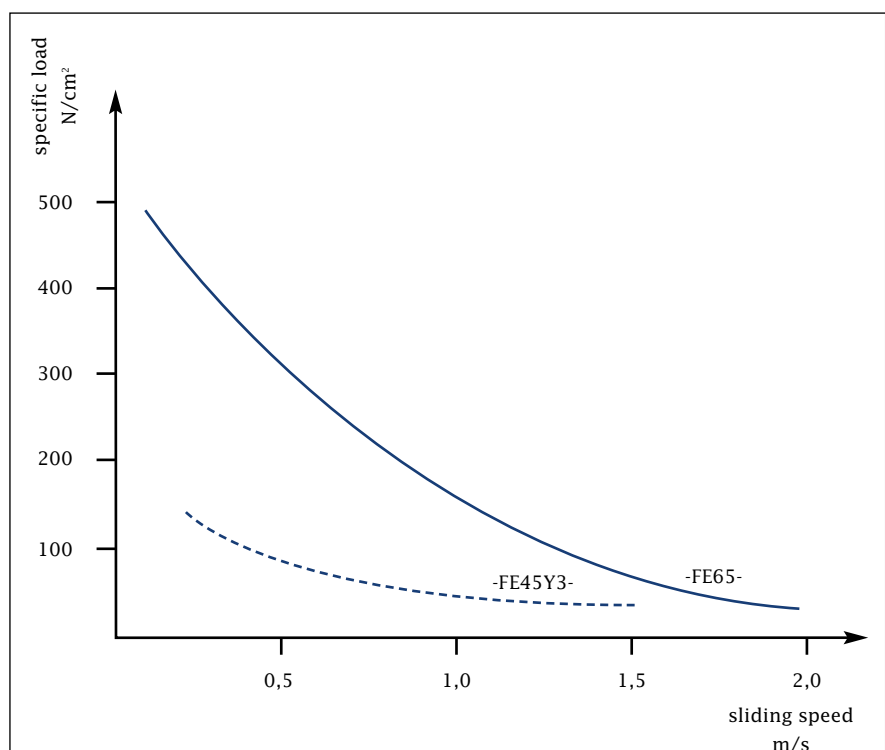
At sliding speeds of $v < 0.2 \text{ m/s}$ the maximum load given for $v = 0.2 \text{ m/s}$ should not be substantially exceeded. Sliding speeds above 1.5 and 2 m/s respectively, result in higher wear, assuming p · v is constant.

The maximum loading curves determined for dry running radial bearings also apply to dry running axial bearings.

The p · v chart 3 shows the maximum loading curves for wet running radial carbon bearings out of material FH42Z2 (carbon graphite, impregnated with synthetic resin) and FH42B (carbon graphite, hard lead impregnated).



Carbon bearing test rigs (wet running)



p · v diagram no. 2:
loading capacity of dry running carbon bearings as a function of sliding speed; comparison FE45Y3/FE65

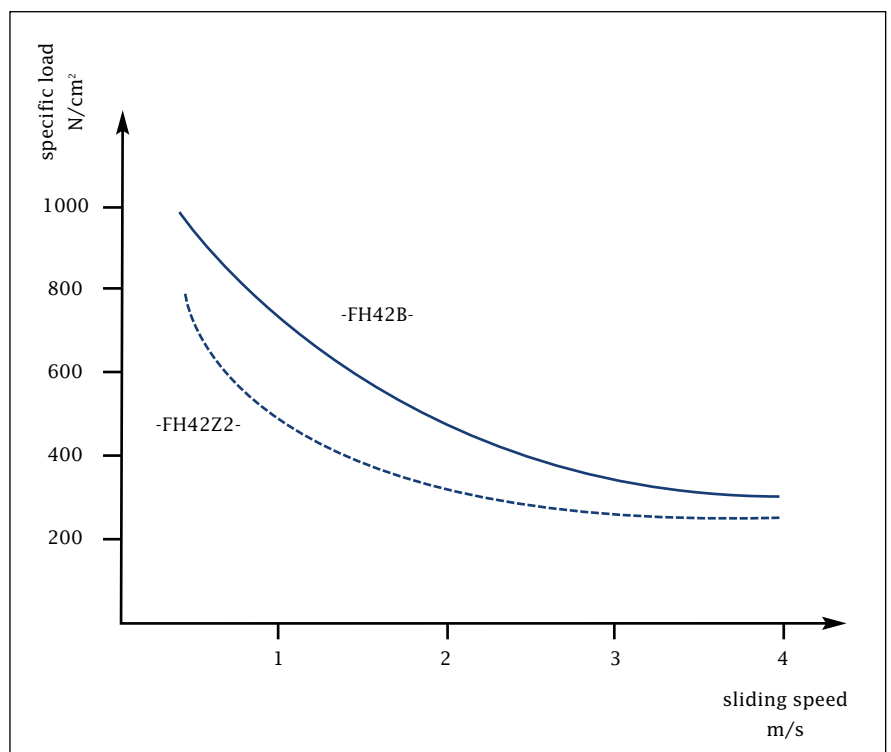
Loading capacity

More than 70 running tests of at least 500 h test period each were necessary to obtain the data for one maximum loading curve. Therefore, these maximum loading curves are not available for all Schunk materials. However, supplementary tests have proved that the loading capacity of non-impregnated carbon graphite materials is significantly lower than that of materials impregnated with synthetic resins. The porosity of the bearing material has a decisive effect on the material loading ability as also has the material composition, strength and hardness. Particularly at higher porosities it can be observed that the influence of hydrodynamic lubrication decreases, especially with fluids exhibiting only a slight hydrodynamic lubrication effect, as a sufficient pressure in the clearance between bearing and shaft cannot be generated. Compared to a lead impregnation, an impregnation of the same material with antimony results in an increase in wet running loading capacity of approximately 10 %.

Both impregnated materials (FH42Z2 and FH42B) in the p · v chart 3 have the same basic material (FH42). If a more solid and harder basic material is selected (e. g. material FH82), higher loading capacities will be achieved with identical impregnations. However, the use of these materials, such as FH82Z2 or FH82A requires harder counterpart materials.

carbon bearings can be significantly higher loaded in wet running than in dry running conditions. Additionally, wet running carbon bearings can be applied at much higher sliding speeds. The maximum sliding speed of 4.1 m/s in the p · v chart does not signify an application limit but was determined by the available test conditions.

The maximum load curves in p · v chart 3 were determined for wet running radial bearings. Therefore, their validity for axial bearings is limited with respect to the design of such bearings and the amount of achievable hydrodynamic lubrication. Axial bearings, except segmented axial bearings, should always be provided with lubricating grooves.



p · v diagram no. 3:
loading capacity of wet running carbon bearings as a function of sliding speed



Pump test rig

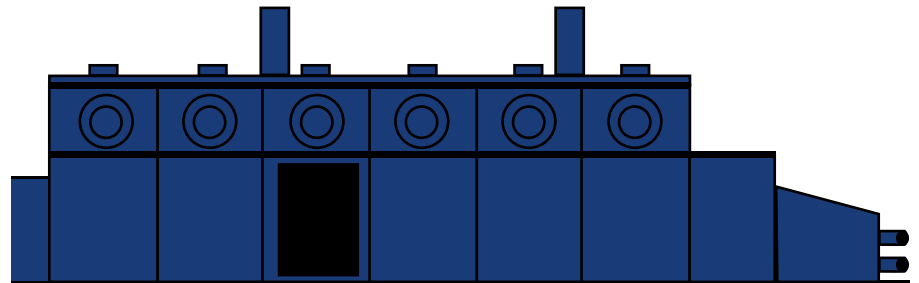


Fields of application

Fields of application and material recommendations

The following summary of fields of application for carbon bearings is not complete. It comprises the currently most important applications. We are firmly convinced, however, that the outstanding properties of carbon and graphite materials will open further fields of application for carbon bearings.

We are constantly engaged, in close cooperation with our customers, in the improvement of our current materials and development of new grades in order to meet new requirements.



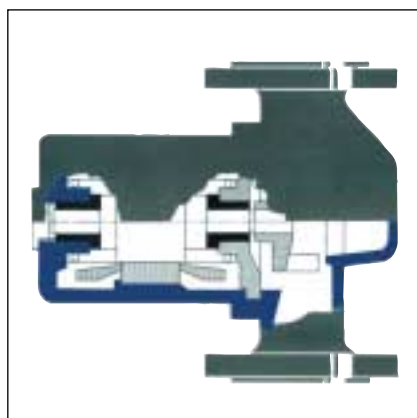
Carbon bearings for veneer dryers

The Schunk materials listed below have been proven to be suitable for the applications given and are to be taken as recommendations.

Special applications may require the selection of different carbon and graphite materials. Please do not hesitate to contact our Department of Application Engineering as well as Research and Development. Our staff will be glad to help you!



Carbon bearings for veneer dryers



Split tube pump with carbon bearings

Fields of application

Material recommendations

Dry running

Veneer dryers	FH42; FH44Z2
Plaster and plaster board dryers	FE45Y3; FE65
Glass furnaces	FE45Y3; FE65
Conveyor belts for furnaces	FH42
Cooling racks for roller mills	FE45Y3
Guide vane adjustment of turbo compressors	FE45Y3
Valve flaps	FE45Y3
Vane pumps and air compressors	FH42Z2; FF511

Wet running

Dyeing machines	FH42; FE45Y3
Bleaching machines	FE45Y3
Industrial washing plants	FH42; FH42Z2
Galvanic plants	FH42; FE45Y3
Flow meters	FH42Y3; FH42A
Gear pumps	FH42Y3; FH42A
Submersible pumps	
radial bearings	FH42Z2; FH42B
thrust bearings	FH42Z5; FH82Z5; FH82A
Booster pumps	FH42B; FH42ZP2
Industrial water pumps	FH42ZP2
Chemical pumps	FH42Z2; FH42Y3; FE45Y3
Circulating heating pumps	FH42B; FH42Z2
Thermal oil pumps	FH42A
Pumps for liquid gases	FH42A; FH42Z2
Industrial fuel oil pumps	FH42A
Fuel feed pumps and injection pumps for automobiles	FH531B; FF511; FF931; FH421B
Pumps and units for use in food, pharmaceutical and cosmetic industries	FH42ZP2; FH42Z2; FH42Y3

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