



Bearings

Business Unit Tribology



Bearings

"Nothing less than perfection in tribology " - this is our standard.

The rings are particularly resistant to wear . Rings and seal rings of carbon, graphite and silicon carbide have developed for applications with high demands. Working extremely in industry and machinery industry chemical and petrochemical, and automotive , pharmaceutical and food industry .

The unit Tribology offers a wide range of products.

The Carbonex has vast experience in materials for sliding bearings pumps , and compressors



Business Unit Tribology

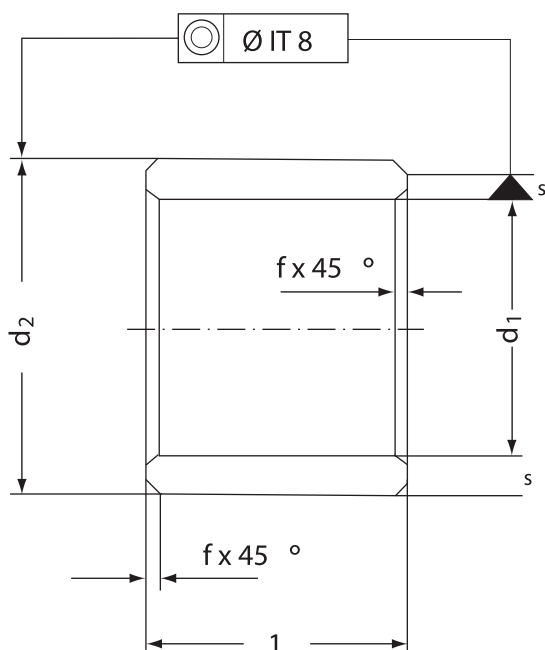


... as a Bearing Material

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.



General Guidelines

- $L = d_1$ to d_2
- $L_{\max} = 2 \times d_2$
- $s = 0.1$ to $0.2 \times d_1$
- $s_{\min} = 3\text{mm}$

In case of flanged bearings the flange thickness should follow the same recommendations like those for the wall thickness. Special instructions have to be observed regarding the flange design of shrunk-in flanged bearing (see figure on page 5). For dry running radial and axial bearings lubrication grooves are not necessary.

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.

Installation

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 comparatively low thermal expansion of the carbon materials.

Pressing-in

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. 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.

Recommended Tolerance Zones before Cold Pressing-in:

| | |
|----------------------------------|---------|
| Inside diameter d1: | F7 – E7 |
| Outside diameter d2: | s6 |
| Housing bore for carbon bearing: | H7 |

This results in a tolerance of H7 to H8 for the inside diameter d1. 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 on to the entire bearing face. A chamfer of 15 – 30° for the metal sleeve is recommended.

Shrinking-in

For bearing temperatures exceeding 120 to 150 °C, direct shrinking-in of the carbon bearings into the housing 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



Carbon bearing with metal sleeve

Installation

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 outer diameter of the metal sleeve can be met.

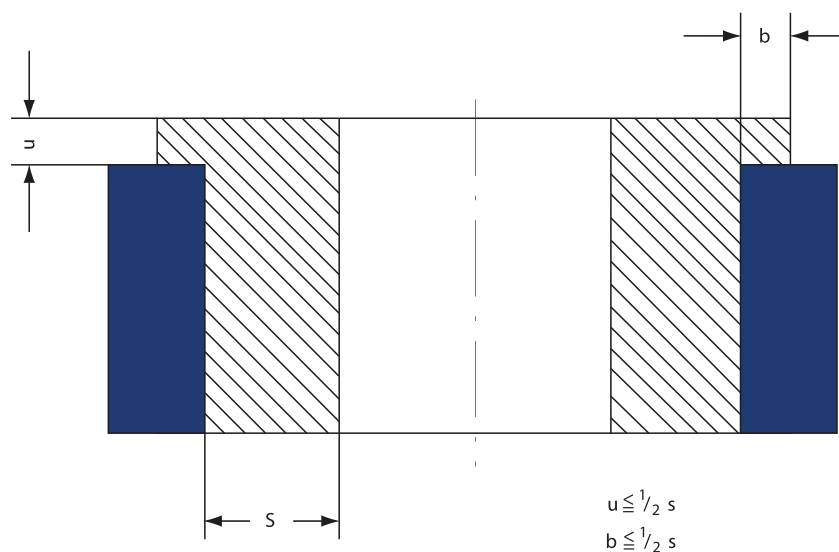
After shrinking-in, the carbon bearing in the metal sleeve is subjected to compressive strain. The carbon material is supported so well by the metal sleeve that, subsequently, it can be turned to very small wall thicknesses.

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.

Recommended Tolerance Zones before Hot Shrinking-in:

| | |
|----------------------------------|---------------|
| Inside diameter d1: | D8 |
| Outside diameter d2: | 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 d1 after shrinking-in. Finish reaming is recommended subsequent to shrinking-in for staying exactly within the tolerances.



Bearing Clearance

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 operating temperature can occur at elevated operating temperatures.

We recommended the following data for the bearing clearance:

Dry Running

at operating temperature 0.3 – 0.5 % of the shaft diameter

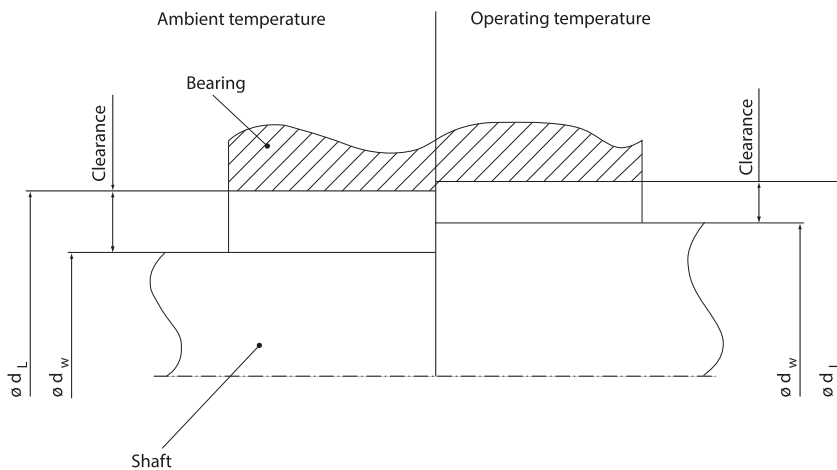
Wet running

at operating temperature 0.1– 0.3 % of the shaft diameter

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 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.



$$\text{Clearance (ambient temperature)} = \text{clearance (operating temperature)} + \Delta d_w - \Delta d_L$$
$$\Delta d_w - \Delta d_L = (\alpha_{\text{shaft}} - \alpha_{\text{bearing}}) \cdot d \cdot \Delta T$$

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 (Al₂O₃)
(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)

Bearing Clearance

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 finely ground shafts are recommended for carbon bearings. For highly demanding applications we recommend super finished shafts. 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 behavior of the carbon bearing, but also the counterpart material itself has a certain impact.

The use of not particularly hard, 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



radial bearings with spiral grooves

wear. Harder non nickel containing 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 graphite film on the counterpart material.

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



Axial bearing

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 ability. 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

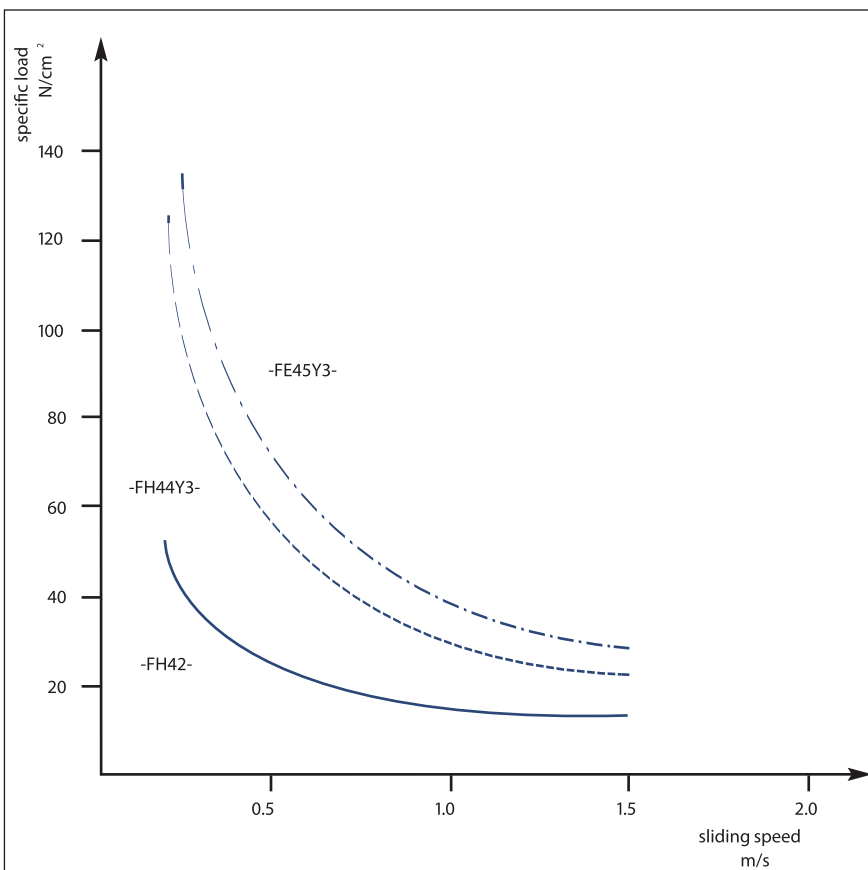
Wet running tests were carried out under tap water at ambient temperature. Radial bearings, $\varnothing 15/35 \times 15$ mm and $\varnothing 20/35 \times 20$ mm, and steel

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 from 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.



*p-v-diagram no. 1:
Loading capacity of dry running carbon bearings as a function of sliding speed*

Loading Capacity

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 $p \cdot v$ chart 2.

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

The $p \cdot v$ charts show that the product $p \cdot v$ is practically constant for each material.

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

- FH42 $p \cdot v = 11 \text{ N/cm}^2 \times \text{m/s}$
- FH44Y3 $p \cdot v = 30 \text{ N/cm}^2 \times \text{m/s}$
- FE45Y3 $p \cdot v = 40 \text{ N/cm}^2 \times \text{m/s}$
- FE65 $p \cdot v = 190 \text{ N/cm}^2 \times \text{m/s}$

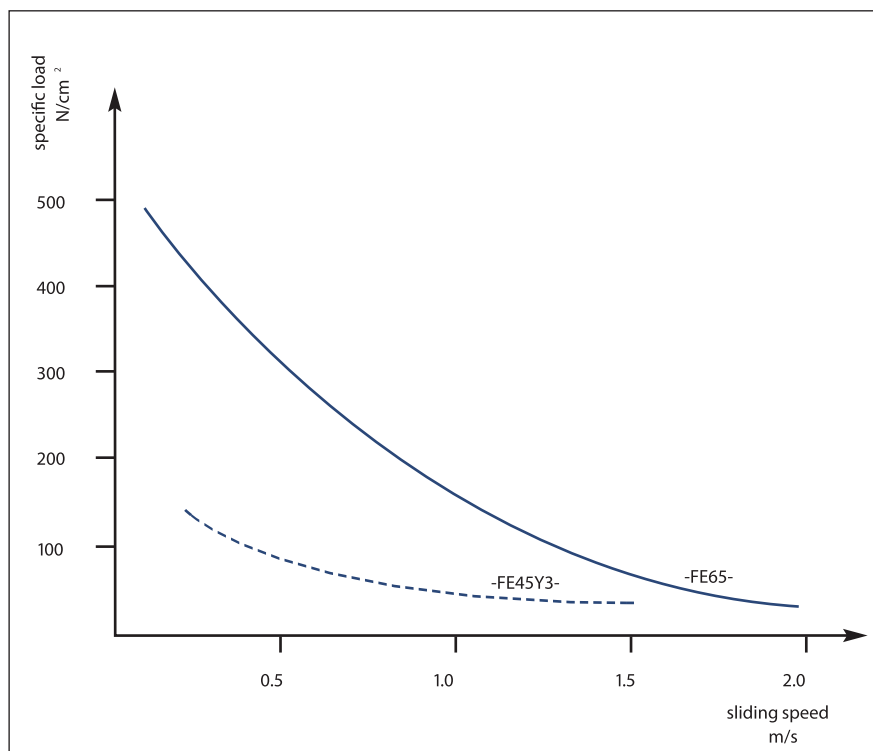
In the $p \cdot v$ charts the curves for maximum loads are given for sliding speeds of 0.2 to 1.5 and 2 m/s, respectively.

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 $p \cdot v$ is constant.

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

The $p \cdot v$ chart 3 shows the maximum loading curves for wet running radial carbon bearings out of material FH42Z2 (carbon graphite, impregnated with synthetic resin) and FH42A (carbon graphite, impregnated with antimony).



*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 have been necessary to obtain the values for one maximum loading curve. This is why these maximum loading curves are not available for all Carbonex 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 bearing porosity of the 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.

Both impregnated materials (FH42Z2 and FH42A) in the $p \cdot v$ chart 3 have the same base material (FH42). If a more solid and harder basic materials 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.

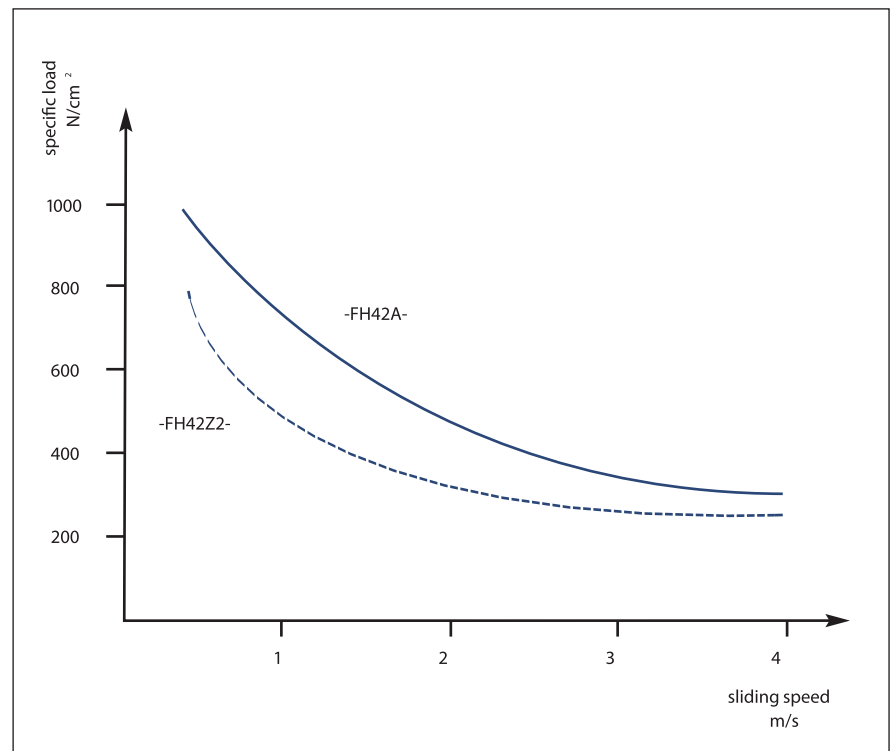
The $p \cdot v$ chart 3 also shows that carbon bearings can be significantly higher loaded in wet running than in dry running conditions. Additionally, wet running carbon bearings can be applied at much higher sliding

speeds. The maximum sliding speed of 4.1 m/s in the $p \cdot v$ chart does not signify an application limit but was determined by the available test conditions.

The maximum load curves in $p \cdot v$ 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 hydro-dynamic 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*

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.

The Carbonex materials listed below have been proved 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. We will be glad to help you!



Carbon bearings for veneer dryers/plaster board dryers



Split turbine pump with carbon bearings

Fields of Application

Material Recommendation

| Fields of Application | Material Recommendation |
|---|-------------------------------------|
| Dry running | |
| Venner dryers | FH42, FH44Z2 |
| Plaster and plaster board dryers | FE45Y3, FE65 |
| Glass furnace | FE45Y3, FE65 |
| Conveyor belts for furnace | FH42 |
| Cooling racks for rolling mills | FE45Y3 |
| Guide vane adjustment of turbo compressors | FE45Y3 |
| Valve flaps | FE45Y3 |
| Vane pumps and air compressors | FH42Z2 |
| 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 |
| Submergible pumps | |
| radial bearings | FH42Z2, FH42A |
| thrust bearings | FH42Z5, FH82Z5, FH82A |
| Booster pumps | FH42ZP2, FH42A |
| Industrial water pumps | FH42ZP2 |
| Chemical pumps | FH42Z2, FH42Y3, FE45Y3, SiC30 |
| Circulating heating pumps | FH42A, FH42Z2, FH82A, FC941 |
| Thermal oil pumps | FH42A |
| Pumps for liquid gases | FH42A, FH42Z2, FH82A, FH71A, FH71ZH |
| Industrial fuel oil pumps | FH42A |
| Fuel feed pumps and injection pumps for automobiles | FH531A, FF521, FH541 |
| Pumps and units for use in food pharmaceuticals and cosmetic industries | FH42ZP2, FH42Z2, FH42Y3 |



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