Schunk Carbon Technology

Carbon slide bearings
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We are Schunk Carbon Technology

Schunk Carbon Technology is a global leader in the development, manufacture and application of carbon and ceramic solutions. Like no-one else, Schunk Carbon Technology combines its innovative spirit and technological expertise with its exceptional customer service to provide a unique range of products and services.

With its highly-specialized technology portfolio consisting of mechanical carbon, electrical carbon, high-temperature applications and technical ceramics, Schunk Carbon Technology offers solutions perfectly coordinated with a variety of industrial fields of application. You can find us in millions of motor vehicles, in household devices, in railway and aviation technology, as well as in the chemical industry, in processes for heat treatment as well as solar and wind energy, all the way to medical technology and the semiconductor industry.

The Mechanical Carbon Industry business unit develops and produces materials for sealing rings, sliding bearings and pump components made of graphite and carbon, as well as SiC. The business unit’s products are used in sealing technology, as well as in machines, assemblies and systems in many industrial areas, such as the chemical and petrochemical industries, energy and supply engineering, the pharmaceutical and food industries, aviation and shipping and many more.

A Schunk Group division.
Schunk Carbon Technology is a division of the Schunk Group, a globally operating technology corporation with over 8,100 employees in 29 countries, which develops customized high-tech solutions in the fields of carbon and ceramics technology, environmental simulation, climate technology, sintered metal and ultrasonic welding.
Fields of Applications

Whether they’re used in classic pump construction in the chemical and petrochemical industries, in the food, pharmaceuticals, and cosmetics sectors, in the automotive industry, in power plant engineering, or in heat treatment – slide bearings made of carbon materials have a huge variety of different applications.

Their self-lubricating characteristics alone allow them to cover a wide range of uses, from dry-running bearings to hydrodynamically lubricated bearings under high load.

The following summary of applications for carbon slide bearings makes no claim to completeness. Instead, it is only a selection of applications; due to the unique properties of carbon graphite and graphite materials, industries are continuously discovering new uses for these slide bearings.

### Dry-running

<table>
<thead>
<tr>
<th>Applications</th>
<th>Recommended material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial ovens (food industry)</td>
<td>FE65</td>
</tr>
<tr>
<td>Veneer dryer</td>
<td>FH42, FH4422</td>
</tr>
<tr>
<td>Dryer for plaster and plasterboard</td>
<td>FHB2, FE45Y3, FE65</td>
</tr>
<tr>
<td>Annealing furnaces for glass</td>
<td>FE45Y3, FE65</td>
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<tr>
<td>Transportation networks for furnaces</td>
<td>FH42</td>
</tr>
<tr>
<td>Cooling racks in mills</td>
<td>FE45Y3</td>
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<tr>
<td>Guide vane adjustment for turbo compressors</td>
<td>FE45Y3</td>
</tr>
<tr>
<td>Valve flaps</td>
<td>FE45Y3</td>
</tr>
<tr>
<td>Vane pumps and air compressors</td>
<td>FH42Z2</td>
</tr>
<tr>
<td>Exhaust flaps</td>
<td>FE65</td>
</tr>
</tbody>
</table>

### Wet-running

<table>
<thead>
<tr>
<th>Applications</th>
<th>Recommended material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial water pumps</td>
<td>FH42Z2</td>
</tr>
<tr>
<td>Heating circulation pumps</td>
<td>FH42Z2, FH42A, FH82A, FC941</td>
</tr>
<tr>
<td>Submersible motor pumps, radial bearings</td>
<td>FH42Z2, FH42A, FH82A</td>
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<tr>
<td>Submersible motor pumps, axial bearings</td>
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<td>Gear pumps</td>
<td>FH42Y3, FH42A, SiC30</td>
</tr>
<tr>
<td>Chemical pumps</td>
<td>FH42Z2, FH42Y3, FE45Y3, SiC30</td>
</tr>
<tr>
<td>Pumps for heat transfer oils</td>
<td>FH42A</td>
</tr>
<tr>
<td>Pumps for liquid gases</td>
<td>FH42A, FH82A FH71ZH2, FH71A, SiC30</td>
</tr>
<tr>
<td>Power station pumps (main coolant pumps)</td>
<td>FH42(9)Y3</td>
</tr>
<tr>
<td>Pumps and systems (food industry)</td>
<td>FH42Z2, FH42Y3</td>
</tr>
<tr>
<td>Dyeing machines</td>
<td>FH42, FE45Y3</td>
</tr>
<tr>
<td>Bleaching machines</td>
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<tr>
<td>Industrial washing facilities</td>
<td>FH42, FH442Z</td>
</tr>
<tr>
<td>Galvanizing plants</td>
<td>FH42, FE45Y3</td>
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<tr>
<td>Positive displacement meter</td>
<td>FH42Y3, FH42A</td>
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<tr>
<td>Fuel pumps</td>
<td>FF521, FH42A</td>
</tr>
<tr>
<td>Coolant pumps (automotive)</td>
<td>FF521</td>
</tr>
</tbody>
</table>

The materials listed for each application have proven themselves in practice, and should be seen as recommendations. However, operating conditions may require the use of a different material in some individual instances. Our employees in application engineering will be happy to advise you on selecting a material.
CARBON SLIDE BEARINGS

Characteristic properties

Carbon and graphite materials offer the following key properties:

- Excellent dry-running and anti-friction properties, even in worse lubricants
- A low friction coefficient in pairing with a large number of counterface materials
- Outstanding chemical resistance
- Suitable for use with food and drinking water
- Resistant to high and low temperatures
- High heat conductivity
- Excellent thermal shock properties
- Great dimensional stability
- High fatigue resistance
- Mechanical strength is not temperature-dependent

Load capacity

A material’s p*v value can be used to provide an estimate of its service life. The load capacity of slide bearings is calculated using the sliding pressure p and sliding speed v. The sliding pressure p in N/cm² is calculated from reaction force F and the geometric dimensions of the bearing:

\[ p = \frac{F}{(d^2l)} \]

where F = bearing force (N); d = diameter (cm); l = length (cm).

The sliding speed v in m/s is calculated from the rotational speed of the shaft:

\[ v = d \times \frac{\pi \times n}{60} \]

where n = rotational speed (min⁻¹); d = diameter (m).
Dry-running slide bearings

In dry-running applications, wear increases with a higher \( p \) and/or higher \( v \). At almost equal wear rates the product of \( p \) and \( v \) is almost constant and can be used as material characteristic.

Since slide bearings are subject to a certain amount of wear in dry-running applications, a wear limit value of 0.7 \( \mu \text{m}/\text{h} \) has been determined for creating \( p*v \) value critical load curves.

Schunk has completed comprehensive test series on slide bearing test benches in order to apply these diagrams, with varying sliding speeds and pressures.

The following boundary conditions applied to the testing: dimensions of the radial bearing \( \varnothing 18/12 \times 10 \text{ mm} \); shaft material stainless steel 1.4104; shaft surface with a surface roughness of \( \text{Rt} \approx 0.7 \mu \text{m} \); dry running on air at room temperature.

\( p*v \) diagram 1 shows the load capacity of dry-running slide bearings made of non-impregnated material FH42 and all-carbon materials FH44Y3 and FE45Y3.

Carbon bearings made of fairly strong and hard carbon graphite FH42 have less load capacity in comparison with the other two materials in dry-running applications. Due to the higher percentage of graphite in carbon graphite FH44Y3, this material displays a significantly higher load capacity at the same wear rate. Electrographite FE45Y3 displays the highest load capacity among the three materials.

A variety of impregnation methods, such as synthetic resin impregnation, can increase load capacity even further. Antimony impregnation has only been shown to increase load capacity at low sliding speeds (< 0.5 m/s).

Specialized salt impregnation treatments, in contrast, provide significant improvements, as shown in \( p*v \) diagram 2. This \( p*v \) diagram compares the load capacity of electrographite FE45Y3 with salt-impregnated electro-graphite FE65.

The \( p*v \) diagrams show that the product \( p*v \) is practically constant within a wide pressure and velocity range for each material. The following values were determined for the individual materials:

\[
\begin{align*}
\text{FH42} & \quad p*v = 11 \text{ N/cm}^2*\text{m/s} \\
\text{FH44Y3} & \quad p*v = 30 \text{ N/cm}^2*\text{m/s} \\
\text{FE45Y3} & \quad p*v = 40 \text{ N/cm}^2*\text{m/s} \\
\text{FE65} & \quad p*v = 190 \text{ N/cm}^2*\text{m/s}
\end{align*}
\]

Maximum load curves are provided in \( p*v \) diagrams from 0.2 to 1.5 or 2 m/s. At sliding speeds of \( v < 0.2 \text{ m/s} \), the maximum load applicable for \( v = 0.2 \text{ m/s} \) should not be exceeded by a significant amount. Increased wear should be expected at sliding speeds over 1.5 or 2 m/s, in deviation from the assumption \( p*v = \text{constant} \).

The maximum load curves determined for dry-running radial bearings also apply to dry-running axial bearings.
Media-lubricated slide bearings

Product lubricated tribological systems can be described very well by Stribeck curves. The resulting friction resistance at constant load is spread out over the increasing sliding speed. The curve shape refers to different friction areas. In the static friction or boundary friction area at the beginning, solid state or dry friction occurs. A transitional area of mixed friction follows, and finally fluid friction occurs from the release point of minimum friction.

Solid state friction occurs in the dry and mixed friction areas, generating both an increase in friction and wear. By using carbon slide bearings, it is possible to significantly reduce friction and wear, even in the presence of small quantities of liquid or steams. Depending on load, medium, and geometry, hydrodynamic lubrication occurs in liquids above a certain sliding speed; no friction wear is created in such states.

Since the benefits of carbon materials are primarily evident in the boundary and mixed friction areas, the load capacity of different materials are represented in a small area of the Stribeck curve using a $p*v$ value diagram, and compared with one another. A wear limit of 0.1 $\mu$m/h was determined for this purpose. In general, of course, the load capacity of these materials is significantly higher.
Counterface materials

In general, a large number of counterface materials can be used. Even relatively soft metals can serve as contact materials, depending on load and carbon material.

Chrome steels (13 – 17 % Cr) have proven effective, even under high loads. Part of the reason harder counterface materials are better suited is that it is more easy for a transfer film of graphite (patina) to build up on the counterface of harder materials. A hardness of HRC ≥ 40 is recommended, especially under high loads.

The best running results are achieved at a counterface surface roughness of Rt ≤ 1 µm. Higher surface roughnesses of up to Rt ≈ 2 µm only result in increased wear during the start-up phase. Precision ground shafts are recommended, while smoothed shafts should be avoided.

Using non-hardenable, stainless steels containing nickel as counterface materials is not recommended, since there are other materials available which are better suited for the application. Otherwise, particularly in dry-running applications, insufficient liquid lubrication or severely contaminated liquids undesirable scoring can occur.

Highly suitable counterface materials
- Chromium steel
- Cast chromium steel
- Nitrided steel
- Gray cast iron
- Hard chrome plated materials
- Unalloyed steel
- Silicone carbide
- Carbide
- Sintered ceramics (Al₂O₃)

Counterface materials with limited use
- Stainless steel
- Austenitic cast iron
- Non-ferrous metal

Unsuitable counterface materials
- Aluminum
- Aluminum alloys
Construction

Bearing design

In general, Schunk slide bearings are manufactured in accordance with the specific needs and design requests of our customers. In addition, DIN 1850 page 4 (“artificial carbon bushes”) may be taken into account for radial and flanged bearings.

Besides a construction suitable for ceramics, there are some general geometric guidelines to take into consideration. The following proportions can serve as reference values for simple cylindrical radial bearings:

Lubricated bearings can also be designed with spiral or longitudinal grooves to ensure lubricant is delivered to the bearing gap and to pump medium through the bearing gap. For axial bearings, it is necessary to determine in each case whether lubrication grooves should be constructed in the mating face. In general, however, almost any groove geometry is possible here as well.

The following dimensions should be observed for flanged bearings:

For press-in or shrink-fit bearings (see chapter „assembling“) in particular, there should be no deviations from these guidelines for any flanged and/or protrusion.
Assembling

In comparison with metals and plastics, lower thermal expansion coefficients for carbon and graphite materials must be taken into account when installing the slide bearings. Carbon ceramics also should not be placed under tension, and not used without structural support if possible. To respond to both special properties of the materials, slide bearings can be pressed or shrink-fit into metal housings. The guideline on proportions must be observed, especially during pressing-in or shrink-fitting flanged bearings. Otherwise, the non-inserted flanged will cause peak stress areas in the material which will quickly cause it to fail. The carbon material will be under compressive stress after joining, which is the optimum type of stress and which will protect the bearing appropriately.

Press-fitting

A press fit of H7/s6 is recommended for cold press-fitted carbon slide bearings. Depending on the housing material, this is usable up to a temperature of 120 °C. A chamfer or edge break of 15 – 30° on the housing simplifies the joining process. If there are large overlaps, carbon slide bearings should not be cold press-fitted, since joining could cause the material to shear off.

Shrink-fitting

Shrink-fitting directly into the housing or metal frame has proven to be the best way to fasten carbon bearings under high mechanical loads or at operating temperatures above 120 °C. Shrink-fit adjustments are designed based on the applicable thermal expansion coefficient and the operating temperature. In general, ISO 286-2 up to overlap H7/zb8 applies here. When we complete shrink fitting at Schunk, we warm the metallic housings in the oven until the cold bearing bushes can be inserted into the mounting hole without additional effort. Depending on the wall thickness ratios and Young’s modulus, the bearing bore hole for the bushing becomes narrower due to the excess size of the shrink-fit, and the exterior diameter of the housing becomes larger. If narrow tolerances must be observed for the final part, appropriate reworking will be required after shrink-fitting. Bearing bushes can also be machined with very thin walls, which would not be possible without the support of the housing.

Bearing clearance

The different thermal expansion coefficients must also be taken into account when determining bearing clearance. If the selected clearance is too narrow, the shaft may get stuck at operating temperature. Therefore, a differentiation is made between cold clearance at room temperature and warm clearance at operating temperature.

No differentiation must be made between cold and warm clearance for shrink-fitted carbon slide bearings, which are under sufficient prestress. The bearing bush will expand roughly in accordance with the thermal expansion coefficients of the metal housing. We recommend for dry-running applications at operating temperature a clearance of 0.3 to 0.5% and for lubricated bearings 0.1 to 0.3% of the shaft diameter.

Cold clearance at room temperature = \( \text{Warm clearance at operating temperature} - \Delta d_L \)

The following approximate equation applies:
\[
\Delta d_w - \Delta d_L = (\alpha_{\text{shaft}} - \alpha_{\text{bearing}}) \times d \times \Delta T
\]

Where:
- \( \alpha_{\text{shaft}} \) = thermal expansion coefficient of the shaft
- \( \alpha_{\text{bearing}} \) = thermal expansion coefficient of the slide bearing
- \( \Delta T = \) temperature difference (operating temperature - room temperature) in K
- \( d = \) rated diameter of bearing clearance