Rings for dynamic seals
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We are 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 to 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.
Carbon materials in dynamic seals

Due to their particular properties, carbon materials are predestined for use in dynamic seals.

Carbon and graphite materials have opened up broad ranges of applications for sealing rings, including high- and low-temperature ranges, in the chemical and petrochemical industries, in the food, pharmacy and cosmetics sectors, in the construction of pumps, compressors and turbines, in airplane and motor vehicle construction, in the nautical sector, the paper industry, air-conditioning technology as well as the field of household appliances and power plant engineering.

Carbon materials are distinguished by their:

- excellent sliding and dry-running properties
- low friction coefficients
- resistance to wear
- chemical stability
- temperature resistance
- high heat conductivity
- excellent thermal shock behavior
- extraordinary dimensional stability
- gas-tight fabrication
- high fatigue strength
- uniform strength even at high temperatures
- an excellent ratio of strength/bulk density
- in contrast to metallic motion bearings, no danger of welding
- suitability in combination with nearly all typical counterface materials
Rings for axial face seals

Axial face seals represent an ideal system for sealing the shaft feed through. Constant new and continued developments to our materials expand their fields of use and take the highest demands into account.

Schunk’s palette of materials for sliding rings and counter rings ranges from carbon materials bound with synthetic resin to carbon graphite, electro-graphite, silicon carbide and SiC-C compounds. Schunk offers all the standard resin, metal and salt impregnations for sealing and property improvement as well as all-carbon materials.

Axial face seals, which are manufactured in a wide variety of construction design, are distinguished by axial-loaded sealing surfaces sliding against one another. There is a lubricating film between the sealing surfaces. Poorly-lubricating media, a tight lubrication gap due to strict impermeability requirements or even contact between solid materials often require materials with emergency and dry-running properties. Carbon materials are self-lubricating thanks to their particular ingredients.

Field of use

- sliding speed: max. 70 m/s
- or pressure gradient: max. 160 bar
- typical sliding pressure: 10 – 200 N/cm²
- generally <50 N/cm²
Material selection

Diverse conditions for application require adapted materials. You will be able to find the optimal solution in Schunk’s broad palette of materials. The following table provides a rough overview.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Application Conditions</th>
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<tbody>
<tr>
<td>Synthetic resin-bound carbon materials</td>
<td>Wet running, high number of pieces, low sliding speeds and pressures</td>
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<tr>
<td><em>Example: FF521</em></td>
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<tr>
<td>Carbon materials sealed with carbon</td>
<td>Highest chemical demands, wet running, medium sliding speeds and pressures</td>
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<td><em>Example: FH82Y5</em></td>
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<tr>
<td>Synthetic resin-impregnated carbon materials</td>
<td>Wet running, medium to high sliding speeds and pressures, high chemical demands</td>
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<tr>
<td><em>Example: FH42Z5, FH82Z5</em></td>
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<tr>
<td>Metal-impregnated carbon materials</td>
<td>Wet running, highest sliding speeds and pressures</td>
</tr>
<tr>
<td><em>Example: FH42A, FH82A</em></td>
<td></td>
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<tr>
<td>Carbon materials for absolutely dry conditions</td>
<td>Applications in absolutely dry environment or under very low temperatures</td>
</tr>
<tr>
<td><em>Example: FH71ZH5, FH71A</em></td>
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</tr>
</tbody>
</table>

For many years, Schunk Carbon Technology has been performing abrasion tests on standard materials and newly developed materials using mechanical seal test rigs.
Counter-face materials

Material selection is of decisive importance for the functionality of mechanical seals. Due to its capacity for developing a transfer film as a solid lubricant, carbon materials are used in combination with nearly all sealing ring materials. Only very soft materials are unsuited.

**well-suited**
- SiC/C-composite material SiC30
- Silicon carbide materials
- Tungsten carbide
- Chromium oxide (plasma-coated)
- Aluminum oxide (only for wet running)
- Hardened chromium steel
- Cast chromium steel
- Carbon graphite materials

**Usable under certain circumstances**
- Chromium-nickel steel
- Austenitic cast iron
- Stainless sintered steel (also polyester resin-impregnated)
- Gray cast iron
- Stellite
- Non-ferrous metals

**Unsuited**
- Aluminum
- Aluminum alloys (also anodized)

Surface roughness of the sliding surfaces

Carbon sliding surfaces: Ra 0.2 - 0.4 µm
Counter-surfaces: Dependent on the counter-face material used and the application.

Carbon sliding surfaces run-in rapidly against the counter-surfaces and form a transfer film on these surfaces. Adapted roughness depths on the sliding surfaces guarantee rapid running-in and optimal formation of this friction-reducing and wear-reducing transfer film.

Flatness of the sliding surfaces

The flatness check is ideally performed using optical flat glass and monochromatic light on an interference testing device.

Exterior diameter of the sliding surfaces
- <80 mm
  - 2 helium light bands (ca. 0.6 µm)
- > 80 mm
  - +1 light band (ca. 0.3 µm) for a 30 mm larger diameter in each case
  (Higher demands regarding flatness on request.)

Requirements for the sliding surfaces

Also decisive for the tightness or leakage of a mechanical seal, in addition to abrasion on the sealing rings, is the machining quality of the sliding surfaces. For this reason, the sliding surfaces must be lapped or polished.

![Sliding surface, not perfectly flat](image1)

![Perfectly flat sliding surface](image2)
Non-destructive testing

In addition to the obligatory dimensional inspection, as requested by the customer, extra non-destructive tests can be conducted and also documented (gas tightness, X-ray and ultrasound tests, etc.).

Mounting

Carbon sliding rings are typically mounted using O-rings or in rubber or plastic sleeves, in which case an anti-rotation lock must be provided with each.

In metal housings or metal bellows, carbon sealing rings can also be glued. The adhesives used must be adjusted to the chemical and thermal requirements of the individual case.

Press fits or shrink fits are also possible. These require, first and foremost, compliance with strict tolerances regarding dimension and shape, such as the roundness and concentricity of the housing bore.

Press fit: H7/s6
Shrink fit: H7/x8–zb8
(depending on the housing material and operating temperature)

Potential alterations in shape must be taken into account; for this reason, the sliding surface should be processed for flatness after shrinkage.
Field of application and recommended materials

The following compilation of areas of application for rings made from carbon graphite materials makes no claim to completeness.

The Schunk materials named are to be understood as recommendations. They have been tested and proven for their respective application case; for higher requirements, we have additional materials ready for you. Our application engineer division will be happy to help you with relevant questions.

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<th>Application fields for mechanical seals</th>
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<td>Warm-water pumps FH82ZH5, FH82A</td>
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<td>Service water pumps FH42Z5, FH82Z5</td>
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<td>Feed water pumps FH82ZH5, FH82A, SiC30</td>
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<tr>
<td>Cooling compressors FH82A, FH82ZH5, SiC30</td>
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<tr>
<td>Fuel and heating oil pumps FH42A, FH82A</td>
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<td>Oil burner pumps FH421A, FF521</td>
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<tr>
<td>In airplane construction FE679Q, FH42AR, SiC30</td>
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<td>In ship construction</td>
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<td>Stern tube seals for surface and underwater vessels FH429A, FH829A, FH829Z5</td>
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<td>Bilge pumps FH42Z5, FH82Z5</td>
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<td>Bulkhead seal FE45S</td>
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<td>In pumps and systems within the food industry FH42Z5, FH82Z5, FH42Y5, FH82Y5</td>
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<td>Chemical pumps FH44Z5, FH42Z5, FH82Z5, FH82Y5, FE45Y2, FE45Z5, SiC30</td>
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<tr>
<td>Pumps in the petrochemical sector FH42A, FH82A, SiC30</td>
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<tr>
<td>Agitators</td>
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<tr>
<td>Wet running FH42Z5, FH82Z5, FH42A, FH82A, SiC30, FH71ZH5</td>
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<td>Dry running</td>
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<tr>
<td>Centrifuges FH44Z5, FH42Z5</td>
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<td>Compressors FH82A, FH82ZH5</td>
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<td>Thermal oil pumps FH42A, FH82A</td>
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<td>Pumps for power plant facilities FH82Z5, FH82ZH5, FH82A, FE709Y5, SiC30</td>
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<td>Reactor coolant pumps for nuclear power plants FH829Z5, FH829ZH5, SiC30</td>
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<tr>
<td>Pumps for liquid gases FH42A, FH82A, FE45A, FH71ZH5, FH71A</td>
<td></td>
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</tbody>
</table>
Feeder head sealing rings

Steam head seals, or more generally, feeder head seals, are a special form of mechanical seal.

When feeding steam, hot or cold water and thermal oils into rotating rollers and drums, vibrating, oscillating and tumbling movements can occur in addition to rotational movement. The construction of the feeder head must therefore allow certain angular movements. This is primarily achieved by using rings with a convex or concave sliding surface.

In steam head seals, for instance in the paper and cellulose industry, the seals need to run uninterrupted over long periods of time without maintenance, even though only mixed friction due to steam lubrication or even dry running is possible for sealing rings made from carbon graphite materials. At the typically low sliding speeds of <0.1 m/s, the load can amount to more than 150 N/cm².

Contact pressure through spring elements: 1 - 3 N/cm²

Material recommendation
- Steam: FH27S, FH42, FH42A, FH44Y2, FH27Z2, FH44Z2
- Cold water: FH44Z5, FH42Z5
- Warm water: FH42A, FH44ZH5, FH42ZH5
- Thermal oils: FH42A, FH82A
Sealing rings for ball valves

Sealing rings for ball valves made from carbon graphite materials are used in high-temperature applications and in fire-safe areas, that is, in refineries, oil tankers, in the chemical industry etc.

In these fields, sealing rings serve to seal off hot steams and gases which no longer permit the application of usual materials such as PTFE compounds.

Roughness depth of counter-surface: $R_t \leq 1.5 \mu m$

Materials that have been successfully tested: FE45A, FH42A

In addition to seal rings, bearings made from carbon materials are also used in ball valves in the shaft area. (For information on bearings see our separate brochure 35.38)
Sealing rings for radial seals

Sealing rings made from carbon graphite materials have been successfully implemented for many years in radial seals, both with rotary and axial movement, because of their exceptional properties.

Radial seals predominantly use – apart from a few exceptions – multi-part, that is, segmented sealing rings. Their multiple parts allow for simple assembly of the carbon graphite materials, which are not elastically malleable like other sealing materials for radial seals. Both rotating and translation movements can be sealed.

**Contact seals**

Only multi-part or single-part slit sealing rings can be used for seals that run in constant contact. In this way, a certain degree of adjustability is guaranteed in construction and abrasion that unavoidably occurs does not negatively impact tightness. This type of ring is implemented in single-part design as piston rings or multi-part design as throttle rings in high-temperature applications, bulkhead seals and water turbines.

**Gap seals**

These are preferable to contact seals if critical operating conditions, such as high sliding speed and/or high pressures, are anticipated on contact with intense heating of the sealing surfaces and increased wear.

In addition to multi-piece sealing rings, single-piece elements such as so-called metal-clad carbon rings are also used as gap seals. Typical implementation fields for gap seals include steam turbines, high-speed blower, piston rod seals for oil-free piston compressors and screw compressors.

The number of sealing rings planned in gap and contact seals is determined based on the given operating conditions, the type of seal and the amount of permissible leakage. When using several multi-piece rings in sequence, their junction points are arranged to be offset with the help of anti-rotation locks.

Based on experience, the number of rings can be roughly calculated using the formula $n = 2 + k \times \Delta p$.

- $k = 1 \text{ MPa}^{-1}$ for contact seals
- $k = 2 \text{ MPa}^{-1}$ for gap seals
($\Delta p$ in MPa)

**Counter-face materials for radial seals:**

All typical shafts and piston rod materials that are usable

Under certain circumstances: Austenitic varieties of steel

Unsuitable: aluminum, aluminum alloys and non-ferrous metals

Exception: hard chromium or nickel plating on the surface

**Roughness depth of the counter-surface:** $R_t \leq 2 \mu m$
Multi-piece sealing rings

Division into 3, 4, 6, 8, 12 or more segments is generally based on the size of the given sealing ring.

Multi-piece sealing rings are braced with cylindrical extension springs. Springs using stainless steel 1.4310 have been successfully tested for this use.

A flexible or floating arrangement of multi-piece rings in chambers is beneficial for balancing out radial deflections of the shaft.

As already mentioned at the start, segmented rings can work both in contact and with a gap. Multi-piece sealing rings which run in contact must be self-adjusting in order to balance for abrasion against the interior diameter. For rings with overlapping or mortised overlay joints, this is accomplished through sufficient clearance at the junction points between the segments. Self-adjustment can also be achieved using varying segments with a tangential cut and the contact surfaces resulting therefrom. This type of ring is also capable of sealing under translational movement, as is the case for instance for pistons rods. The sliding pressure of radial seals constantly running in contact is produced by cylindrical extension springs on the exterior diameters and should be between 1 and 1.5 N/cm².

Gap sealing rings have very high requirements regarding the tolerances of the inner diameter. This is generally also true for multi-piece rings. However, they can also be designed with low clearance at the junction points, making them work in contact at first. Due to the low run-in wear occurring, the clearance at the junction points approaches zero, generating a practically contact-free gap seal with minimal gap loss and thus optimal sealing effect.

Multi-piece gap sealing rings without clearance at the junction points can also be manufactured with broken joints. To this end, Schunk uses its own patented manufacturing process.
RINGS FOR DYNAMIC SEALS

Dimensioning of multi-piece sealing rings made from carbon graphite materials

- **D** = 1.2 to 1.5 x **d**
- **b**\(_{\text{min}}\) = 8 mm for a blunt and overlapping joint
- **b**\(_{\text{min}}\) = 10 mm for a mortised overlay joint
- **h** \(\approx\) 0.15 x **d**
- **h**\(_{\text{min}}\) = 6 mm for a blunt and overlapping joint
- **h**\(_{\text{min}}\) = 8 mm for a mortised overlay joint
- **r** = (External diameter of spring / 2) + 0.3 to 0.5 mm
- **s** depends on type of seal, size of the shaft diameter and number of ring segments

Sample designs for joints of multi-piece sealing rings

- With overlapping, mortised joint for shaft seals
- With blunt joint for shaft and piston seals
- With overlapping, mortised joint and external bevel for shaft seals
- With overlapping joint for piston seals
- With overlapping, mortised joint for piston seals
**Metal-clad sealing rings**

In order to ensure a constantly narrow sealing gap between the ring and steel shaft of a non-contact seal across the entire operating temperature range, carbon graphite rings must be shrunk into steel casings. The reason for this is the difference between the expansion coefficients of carbon graphite materials and steel. The metal-clad sealing rings are under compressive stress and expand along with the casing material if the temperature increases. To ensure that the carbon ring is firmly secured, the shrink fit is designed according to the maximum operating temperature. The required shrinkage temperature is also dependent on the casing material used.

Typical shrink fit: H7/z8-zb8

When shrinking into steel casings, the following must be observed:
- subsequent finishing of the ring bore
- depending on the required tolerances, subsequent external diameter processing for thin-walled steel casings (machining allowance ~ 0.3 mm).

**Labyrinth rings**

Single and multi-piece gap sealing rings with grooves in the ring hole are called labyrinth rings. The grooves improve the sealing effect.
Single-part slit rings

Particularly in the case of translational movements, such as the motion of pistons in a cylinder, contacting single-piece slit rings can be used for sealing. The rings are finalized in separated, offset positions. Of course, during design and assembly, the limited elasticity of the carbon materials must be taken into account.

Support rings

If plastic rings, for example those made from PTFE or PTFE compounds, can only be used under certain circumstances due to their lack of structural stability under high temperatures, the use of support rings made from carbon graphite materials is standard. Carbon support rings are integrated with low clearance to the shaft or piston rod between the plastic sealing rings. This prevents the plastic sealing rings from slipping over the gap between the piston rod or shaft and the chamber ring under heat and pressure stress. Rings made from carbon materials are dimensionally stable and their self-lubricating properties prevent damage to the shaft or piston rod sealing surface during short-time contact.

Material selection

<table>
<thead>
<tr>
<th>Material description</th>
<th>Carbon seal rings materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial seals primarily use carbon seal rings made from non-impregnated carbon graphite and electro-graphite materials.</td>
<td>FH27S, FH42, FH429, FE45Y2, FE45Y2, FH44Y2, FE679</td>
</tr>
<tr>
<td>For more critical operating conditions, synthetic resin-impregnated materials have been successfully tested.</td>
<td>FH27Z2, FE45Z2, FH44Z2</td>
</tr>
<tr>
<td>For high pressure gradients and potential erosion wear, the choice of metal-impregnated materials is recommended.</td>
<td>FE45A, FH42A, FH44A, FE679A</td>
</tr>
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