



# **General Information:**

## **Properties**

## **Use as Sliding Material**

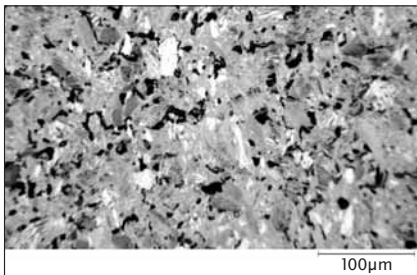
## **Design Recommendations**

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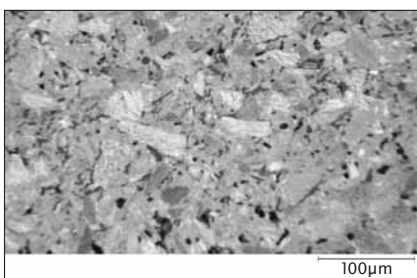
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# Properties

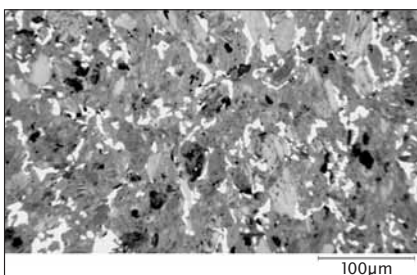
The following brochures give you some general information on our carbon and graphite materials. They are available for download on our website: "Manufacturing Process and Material Properties of Carbon and Graphite Materials" (03.05e),"Characteristic Data – Standard Materials" (30.14e). Some of the properties of carbon and graphite with particular regard to use for mechanical applications are shown below.



Section of a non-impregnated carbon graphite grade. Magnification x200



Section of a synthetic resin impregnated carbon graphite grade. Pores filled with synthetic resin. Magnification x200



Section of a metal impregnated carbon graphite grade. Pores filled with metal. Magnification x200

## a) Porosity

Due to the production method carbon graphite materials have to be regarded as ceramics.

During the baking process, the bonding agent is reduced thermally to carbon. The volatile constituents of the bonding agent cause a certain porosity of the materials which ranges, according to composition and structure of the basic mix of materials for mechanical applications, between approximately 8 and 25 % by volume. This results in permeability to fluids and particularly to gases. For some applications, the pores present in the materials are harmless. On the other hand, carbon materials with higher porosity are generally unsuitable for sealing components, for example seal rings in mechanical seals.

There are several possibilities to reduce or almost eliminate the open porosity of carbon and graphite materials.

**1.** Single impregnation followed by a thermal decomposition of the impregnating agent to carbon. However for sealing rings multiple cycles may be required.

**Disadvantages:** Expensive and time-consuming process.

**Advantages:** Increases strength and hardness without influencing the chemical resistance.

**2.** Single impregnation with synthetic resin and subsequent curing. However, for sealing rings multiple cycles may be required.

**Disadvantages:** Reduction in temperature resistance and minor restrictions on the chemical resistance.

**Advantages:** Distinct increase in mechanical strength, hardness and wear resistance.

**3.** Single impregnation with metals: Antimony, lead alloys and copper.

**Disadvantages:** Restrictions on the chemical resistance and, especially with lead alloys, reduction of the temperature stability.

**Advantages:** Greatest possible increase in strength and hardness together with an improvement to the wear resistance.

**4.** In addition, there are pore free, resin bonded carbon materials. Their chemical and thermal resistance is defined by the binder.

**Advantages:** Low-cost manufacturing of mass-produced parts by pressing to size of even complicated parts.

## b) Bulk Density

Because of present pores, usually the apparent or bulk density of carbon materials is given. The bulk density of non-impregnated materials typically is between 1.5 and 1.8 g/cm<sup>3</sup>, that of metal impregnated materials between 2.2 and 2.5 g/cm<sup>3</sup> and that of resin impregnated materials is approx. 1.8 g/cm<sup>3</sup>.

## c) Chemical Resistance

Because of their excellent chemical resistance, carbon graphite materials can be classified as corrosion-resistant materials.

For details please refer to our brochure "Bearing and Seal Technology – Chemical Resistance" (39.12e) on our website.

## d) Temperature Resistance

At temperatures of approximately 350°C an oxidation of non-impregnated carbon graphite materials occurs. The oxidation of electrographite starts around 500°C.

The oxidation resistance of electrographite can be increased up to 600 – 650°C by special treatments.

In non-oxidizing atmospheres carbon and graphite can be used in temperatures up to those corresponding to the treatment temperature in the production process, i. e. approx. 1000°C or approx. 2500°C.

With the synthetic resin and metal impregnated grades the temperature resistance is limited by the decomposition point or melting point of the impregnating agents used.

The temperature limit of resin impregnated carbon graphite materials depend on the resin type and the curing process used and is typically between 200°C and 260°C. Resin bonded grades in continuous operation can only be used up to a maximum of 180°C.

## e) Mechanical Strength

As with all ceramic materials, a certain brittleness must be taken into account, when using carbon graphite as a construction material. This brittleness is higher than that of conventionally used metallic materials. Therefore, the mechanical strength of carbon graphite cannot be characterized by its tensile strength and elasticity. Usually the flexural and compressive strength as well as the Young's modulus are determined.

During construction, the lower tensile and flexural strength and the relatively high compressive strength of carbon graphite has to be considered. In contrast to metallic materials, the mechanical strength of carbon graphites does not decrease considerably with rising temperature, but is actually slightly increasing.

## f) Hardness

In order to enable a comparison with hardness values of other materials, our brochure "Characteristic Data – Standard Materials" (30.14e) gives both the Rockwell Hardness (HR) as well as the Brinell Hardness. For our regular quality assurance we do not refer to the Brinell hardness as it is only valid if the surface of the porous material is polished.

In our experience, dynamic hardness measurement methods are less suitable because of the structure of the material.

Since the Shore Hardness values strongly depend on the test equipment used, we determine the Rockwell Hardness HR5/40, HR5/100 and HR5/150 of our carbon graphite materials. For these tests, a 5 mm steel ball is pressed into the specimen to be tested with a 98N initial load and a 294N, 883N or 1373 N additional load. After removal of the additional load the resulting depth of penetration is a measure of the hardness HR 5/40, HR 5/100 or HR 5/150 respectively (non dimensional units). It is read off on the B scale of the Rockwell hardness tester.

### g) Thermal Conductivity

In the following table, the thermal conductivity of carbon graphite, electrographite and, for comparison, a number of other materials are summarized. As compared with carbon graphites (hard carbon), electrographites are distinguished by a considerably higher thermal conductivity.

### h) Coefficient of Thermal Expansion

A further characteristic which must always be taken into consideration when designing with carbon materials is the lower coefficient of thermal expansion, compared to that of metals (carbon graphite:  $2 - 6 \cdot 10^{-6}/K$ , which is only about a quarter of that of steel).

An exception are resin bonded carbon materials which have a coefficient of thermal expansion comparable to that of steel.

### i) Resistance to Temperature Cycling

The resistance to thermal shock is defined as the quotient of the product of strength and thermal conductivity and of the product of Young's modulus and coefficient of thermal expansion. The thermal shock resistance of carbon graphite (except resin bonded graphite) and that especially of electrographite is excellent.

### j) Sliding Properties

Because of its special crystal structure, graphite, whether natural graphite or electrographite, has lubricating properties. Since graphite is always used as a constituent in the production of hard carbons (carbon graphite grades) for bearings and sealing components, these grades, as well as the electrographite grades, contain a significant amount of dry lubricant.

Even without additional liquid lubricants, the coefficient of friction between carbon materials and the material of the counterface is therefore comparatively low, provided that the quality of the sliding surfaces is satisfactory.

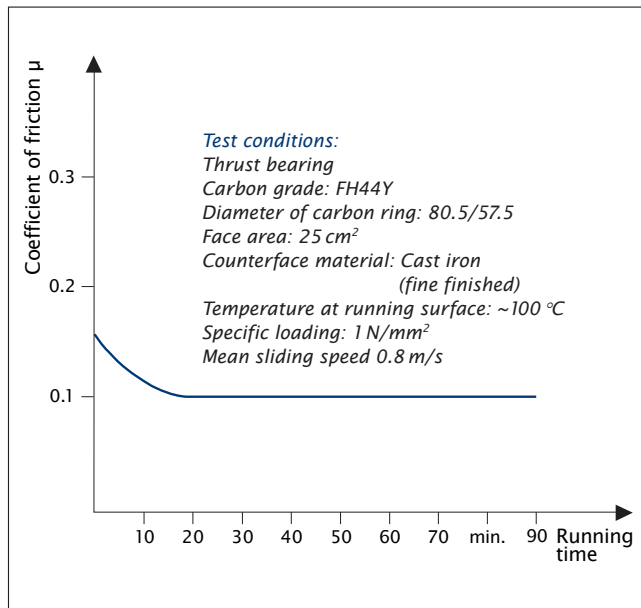
Because of the wide variation in operating conditions, no generally applicable data on the coefficient of friction can be given.

The coefficient of friction of grey cast iron as a counterface material at dry running conditions is approximately  $\mu = 0.1$  to  $0.3$ .

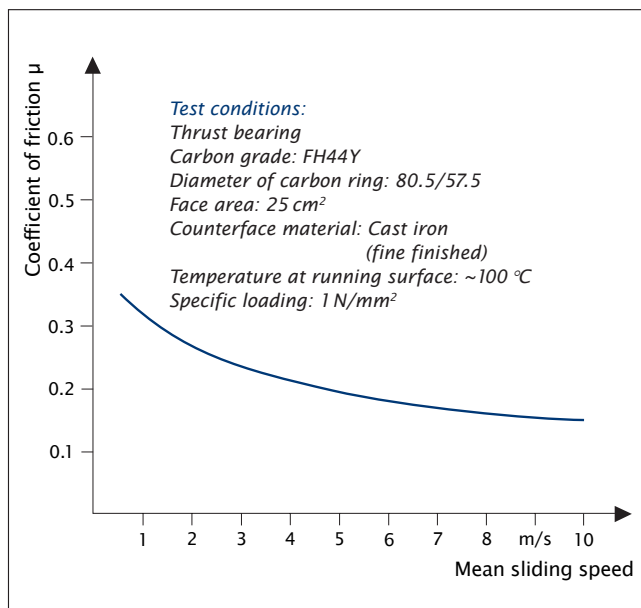
Material	Thermal Conductivity +20 °C W/mK
Electrographite	40 - 130
Carbon graphite	8 - 17
18/8 Chrome-Nickel Steel	15
Grey Cast Iron	45 - 60
Copper	395
Bronze SnBz 12	38
Cast Chrome Steel	19
Sintered Ceramic ( $Al_2O_3$ )	21
Silicon Carbide	80 - 130

In general, the coefficient of friction is considerably reduced by the presence of liquids or vapors. The nature of the liquids or vapors is of lesser importance, so that even in mixed friction conditions a coefficient of friction of  $\mu < 0.1$  can be expected.

The following four graphs give guideline values for the coefficients of friction between carbon graphite and grey cast iron or steel in dry-running conditions. The first graph, in which the coefficient of friction is plotted against the running-in time, shows that the coefficient of friction decreases with the progress of running-in and the associated progressive smoothing of the sliding surfaces, until a constant value is reached. Far more important certainly, is the fact that the coefficient of friction is a function of sliding speed and specific loading. Graphs 2 and 3 show this relationship for the non-impregnated carbon graphite grade -FH44Y-.

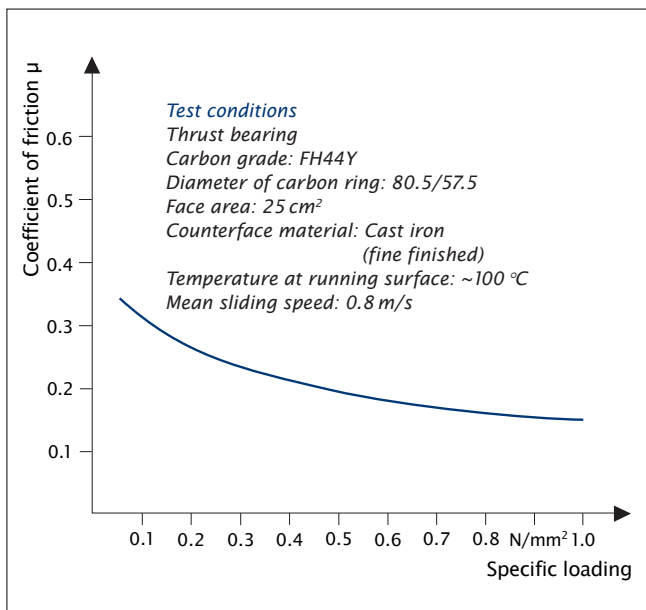


Graph 1  
 Variation of the coefficient of friction  $\mu$  during running-in



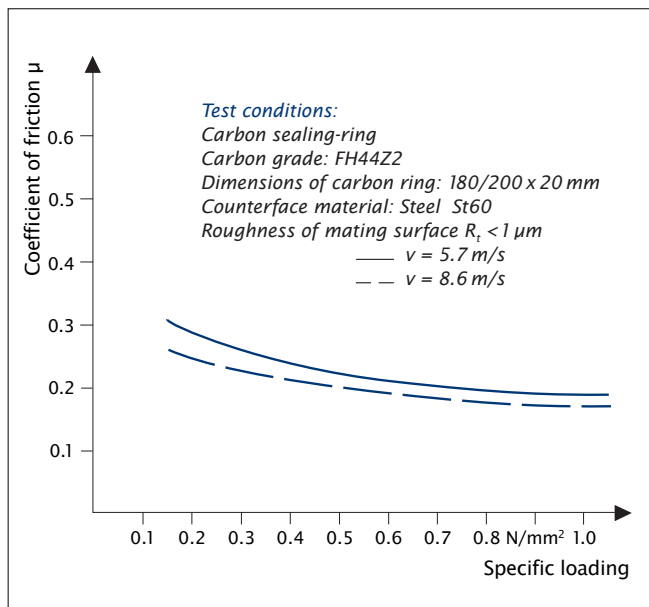
Graph 2  
 Coefficient of friction  $\mu$  as a function of the mean sliding speed

Graph 3  
Coefficient of friction  $\mu$  as a function of the specific loading



In graph 4\*, the relation of the coefficient of friction and the specific load at two constant running speeds is shown for the synthetic resin impregnated carbon graphite grade -FH44Z2-. It should be stressed that carbon materials in contrast to other substances with low coefficient of friction, also have an excellent wear resistance.

Graph 4  
Coefficient of friction  $\mu$  as a function of the specific loading of the material combination FH44Z2 - steel



\* from: Technische Hochschule Darmstadt: Thesis H. Hartmann: "On the temperature variation and the limits of use of dry-running graphite sealing rings".

# Use as Sliding Material

## a) Advice on Working Conditions

The use of carbon graphite materials is advantageous compared to other sliding materials. It is recommended under the following conditions:

1. With liquids with unfavourable lubricating capacities e. g. water, aqueous solutions, fuel, liquified gases etc., having no or minimal anti-friction effect with other material combinations.
2. At high or low temperatures exceeding the temperature limits of lubricating oils or greases.
3. With corrosive or radio-active gases or liquids which exclude the use of other sliding materials.
4. In such cases where sliding surfaces may get into contact with oil or grease solvent agents.
5. If a product must not be contaminated by oil or grease.
6. When oils or greases are incompatible with a process.
7. In applications where solvents, cleaning or sterilising agents are required.
8. In applications where the weight of the component takes priority.

Due to these special operating conditions and applications, Schunk carbon graphite materials have proved successful due to the outstanding properties mentioned above. Carbon and graphite are chemically resistant against oil, therefore sliding components made from these materials are successfully used in oil pumps and for sealing against oil (including as a barrier liquid).

However, allowing small amounts of grease or oil to come into contact with the sliding surfaces must be avoided because, especially at higher temperatures, a paste can develop which is made up of oil or grease and rubbed-off carbon particles or solid impurities originating from the surroundings can be expected. This paste which toughens on cooling down may lead to mechanical or starting problems.

## b) Material Selection

For special questions and above all for new applications our application engineers will be glad to assist you.

Based on the details regarding your special application and operating conditions we may offer you our services for advice and provide you with problem solving solutions.



*Sliding rings*

# Design Recommendations

## Introduction

Since all sliding elements are manufactured by Schunk according to customers' drawings and/or specifications, the construction engineer is not limited to standard patterns with regard to design, dimensions and material.

On the other hand, the special properties of carbon graphite materials must be considered when designing bearings and sealing components.

It is therefore useful to contact us at a very early stage of planning a new component in order to avoid designs which, for carbon graphite materials, are disadvantageous or unproducible.



*Bearings*

## General Design Recommendations

In the design of carbon graphite or graphite engineering components, attention must be paid to its ceramic nature and associated special properties of this group of materials in comparison with metals.

Because of the lower mechanical strength of carbon materials, compared to that of metals, the wall thickness should, wherever possible, be no less than 3 mm. With circular bodies, the wall thickness should be set at 10 to 20% of the internal diameter, depending on the size of the parts.

As far as possible, the length of the parts should be so selected, that it does not exceed twice the outside diameter. If necessary a division into two or three pieces must be allowed. Long, narrow bores should be avoided, because of the difficulties in maintaining tolerances.

Because of the danger of breakage and also for reasons of cost, it is

advisable to avoid large changes in cross-sections. As an alternative, the part can be sub-divided into a number of parts, each with a uniform wall thickness.

If carbon graphite or graphite components have to be secured against rotation, screws and cotter pins cannot be used because of notch effects and the danger of breakage. The protection against rotation must be achieved with a plain pin, which exerts no pressure on the carbon material and acts on an unloaded part of the carbon body.

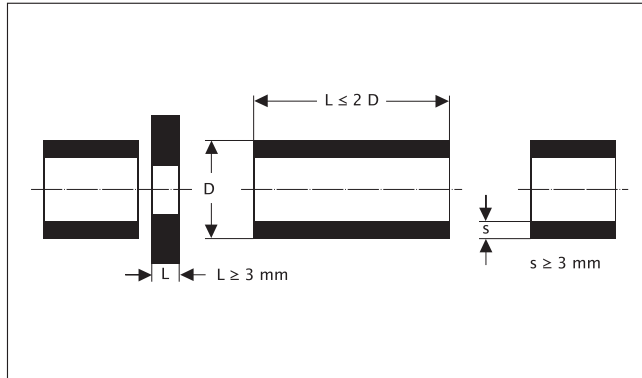
Sharp edges should be broken and sharp transitions avoided.

Carbon parts need to be supported, when pressed or shrunk into metal bushes or directly into housings, as far as possible over their whole length. If they are installed self supporting, correspondingly large wall thicknesses should be provided.

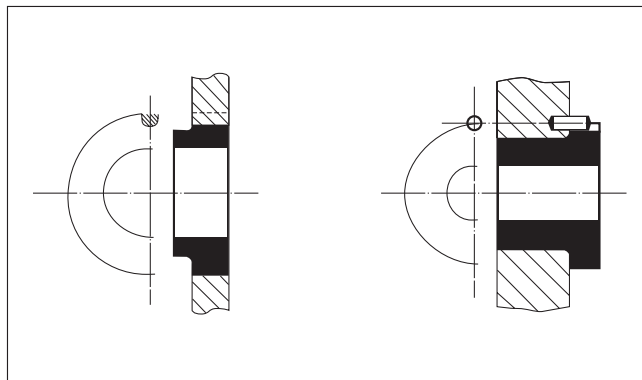
With machined one-piece carbon parts, an internal tolerance of IT7 and an external tolerance of IT6 can be achieved. With multi-part bodies, tolerances selected over several rough tolerance ranges are generally quite adequate.

The above mentioned tightest possible tolerances for one piece, machined carbon parts are often necessary e.g. with radial carbon bearings. At times, however, considerably coarser tolerances are sufficient for machine parts in carbon graphite materials or a close tolerance is only necessary for one dimension.

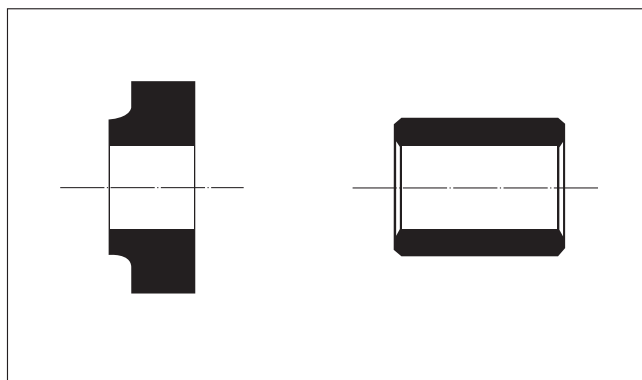
For carbon parts, which are required in large numbers, pressing to a finished or substantially finished state can be done.



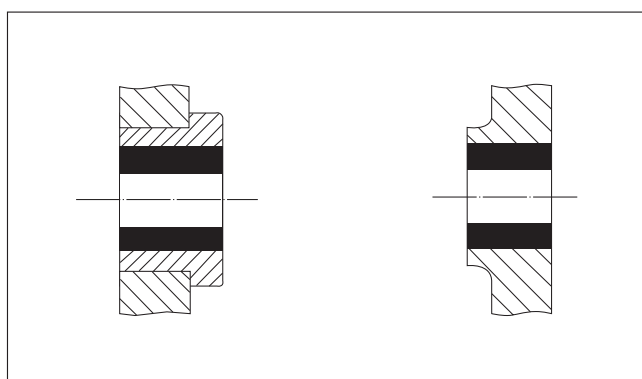
*Sub-divided into several plain parts*



*Protection against rotation with plain pin in the unloaded part of a carbon body*



*Transitions radiused, edges broken*



*Carbon parts shrunk or pressed into metal bush or directly into housing*

## Pressed-To-Size and Partially Pressed-To-Size Components out of Pitch Coke Bonded Carbon Graphite Materials (FH Grades)

Taking into account the stoppable tolerances, carbon parts can also be produced pressed-to-size or partially pressed-to-size, so that only partial further machining has to be carried out, for example:

- with thin-walled sections which cannot be pressed
- with undercut steps in the axial direction

With cylindrical carbon bearings outer and/or inner diameters often have to be machined.

The pressed-to-size molding technique, the compression of the prepared carbon mixtures to form the desired molded parts directly, has long been in use at Schunk, for instance for carbon brushes and contacts for electrical machines when large quantities are required.

In order to keep the shrinkage which occurs during the heating process within the smallest possible tolerances, the pressed-to-size step operation is followed by a special heating process. During shrinkage, the original shape of the molded carbon part is maintained.

Throughout the manufacturing process QA measures such as SPC are applied.

In the last 40 years, this technique has been continuously improved, in order to be able to produce parts of more complicated design, for example carbon sealing rings and bearings, in a ready-pressed form.

### Examples:

- Sealing rings for automobile water cooling pumps, water pumps, swimming pool pumps, dish-washer lye pumps
- Thrust bearing segments
- Bearings for magnetic driven pumps, injection pumps
- Bearings for circulating heating pumps
- Control valves

Large production quantities of at least 5,000 pieces are a prerequisite for the application of this production method. The determination of the minimum quantities for which the pressed-to-size technique can still be practicable in each individual case must always be based on a cost comparison between machining and ready-pressing, taking into account the sometimes high costs for special dies. For the application of this mass production method, various factors involved in the design of the parts must be taken into account and these will be dealt with in rather more detail in the following sections.

### Dimensioning

The minimum wall thickness of a die molded carbon part should be  $\geq 1.5$  mm. The maximum height should not exceed 30 mm, taking account of the ratio of the smallest wall thickness to the molding thickness of 1:2.5. This applies correspondingly for the height of steps in profiled parts. If the maximum diameter exceeds 50 mm, an individual decision must be taken in each case on the possibility of production by the pressed-to-size

technique. The smallest carbon bearing so far produced economically in large quantities has dimensions of  $1.8/0.5\text{mm } \varnothing \times 1.0\text{mm}$ .

### Tolerances

The dimensional tolerances which can be maintained with die molded parts after the heating process depend on the design and size of the part. In relation to the diameters, 1.2% can be indicated as reference values for parts being manufactured under process control. For dimensions in molding direction, for example for the ring thickness, a tolerance of  $\pm 0.10$  mm up to  $\pm 0.25$  mm will generally be needed. Definite tolerances should be fixed after experimental manufacturing with statistical evaluation.

### Design

As well as tolerances and the smallest and largest possible dimensions, the shape must also be adapted to the relevant molding technology. In relation to this, the costs for manufacturing the molding tool should also be considered.

The most important points which have to be observed during the shaping process of pressed-to-size carbon parts are listed below.

The molding tools, with a vertical press axis, must be designed so that uniform compression is obtained over the whole cross-section and that satisfactory ejection is also ensured.

To improve this, tapers up to  $1^\circ$  should be allowed, as far as possible, both for the largest outside

diameter and the smallest inside diameter. Broken edges and chamfers should be applied at an angle of  $\leq 45^\circ$ . In general broken edges should be provided on all edges of the pressed pieces unless it has openings.

With pressed-to-size parts, steps, staggered in relation to one another, on the outer circumference and in the bore should be avoided as far as possible, i. e. external steps require straight-through bores and vice versa.

If, as well as an external step, an internal step is absolutely necessary, the internal step should not significantly exceed a depth of 1 mm. It should be reiterated that experiments to determine whether production is possible are worth-while in special cases.

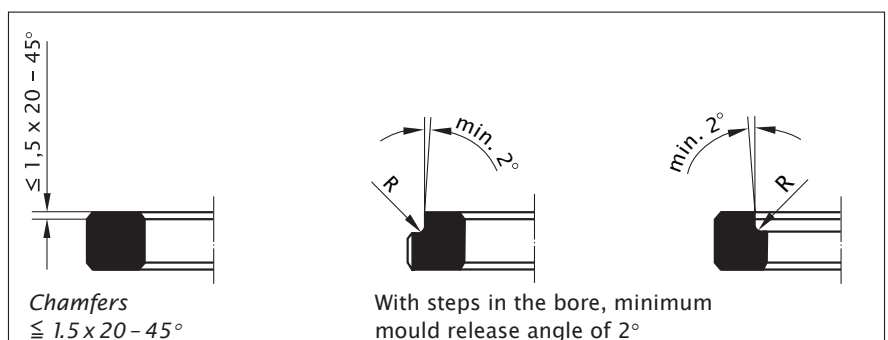
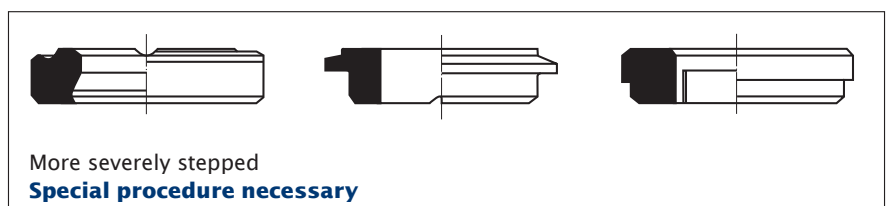
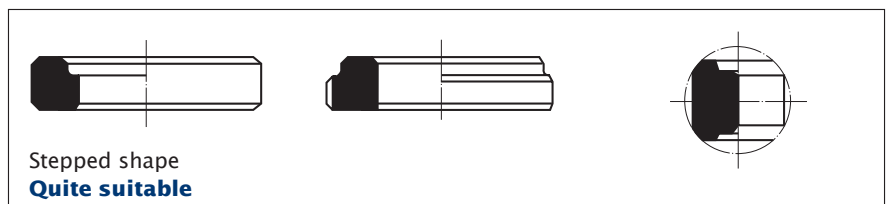
If vertical grooves are necessary, these should be arranged continuously (i. e. straight-through) and all transitions should be radii.

Radii are useful with transition  $\geq 2$  mm. Steps in the radial direction are to be  $> 1$  mm.

The design sketches shown are intended for guidance and illustrate the statements made in the text.

All the information given so far with regard to the pressed-to-size technique applies to our pressed-to-size carbon graphite grades, such as

- -FH421-
- -FH421A-
- -FH421Z-
- -FH821A-
- -FH821Z-



## Pressed-To-Size and Partially Pressed-To-Size Components out of Synthetic Resin Bonded Carbon Materials (FF Grades)

These materials consist of carbon and/or graphite filled phenolic resin. With the different grades such as -FF521- and -FF541- the compositions and the contents of the fillers are varied in order to comply with the various requirements.

Fields of application are bearings, sealing rings and pump components for use in the automobile industry, in mechanical engineering and plant construction and control technique.

### Examples:

- Bearings for magnetic driven pumps
- Sealing rings for domestic water pumps, oil-burner feed pumps, pumps for washing machines and automobile cooling water pumps
- Complete pumps for central locking and orthopaedic seat adjusting systems for automobiles
- Control valves for pneumatic control units
- Pump wheels for fuel feed pumps in automobiles

The physical properties of our phenolic resin bonded grades are given in our brochure "Characteristic Data - Standard Materials" (30.14e) which can be downloaded from our website.

We would like to draw special attention to the temperature resistance of up to 180°C for the standard grades and the coefficient of thermal expansion being similar to that of steel. With a special thermal treatment the temperature resistance can be increased up to 250°C. By injection molding of these materials it is therefore possible to bring formed parts directly onto steel shafts, thus ensuring an optimal connection with a component. Schunk Kohlenstofftechnik has much

experience in fully automated production of such parts including the corresponding loading and removal stations.

These resin bonded materials can be processed by injection molding and extruding. In particular, injection molding of these materials allows flexible designing of components and significantly more complicated shapes compared to parts made from pitch coke bonded carbon graphite materials (FF grades).

On the other hand, the high costs of the necessary hot-pressing dies have to be considered. Therefore a minimum production lot of 25,000 pieces is required for parts made from resin bonded materials.

## Dimensioning

The minimum wall thickness with these materials is primarily defined by the tool manufacture and should not be below 0.5 mm. The maximum wall thickness should not exceed 10 mm due to the fact that curing of these duroplastic materials in the hot die would no longer allow cost-effective production.

## Tolerances

After the molding process in heated dies the resin bonded components are only cured or tempered in drying cabinets. This heat treatment results in minor dimensional deviations so that for dimensions produced by the tool a tolerance of IT9/IT10 can be indicated as a reference value. For dimensions related to the parting plane of the tool, a tolerance of minimum 0.10 mm can be maintained.

Definite tolerances should be fixed after experimental manufacturing with statistical evaluation.

In order to comply with tolerances which are decisive for the function of a part, process control procedures are used for quality assurance.

## Design

For the production of resin bonded components with axial presses in heated dies most of the recommendations for the pressing to-size of pitch bonded carbon graphite materials (FH grades) can be observed.

This does not apply to injection molding, where the molding compound is injected in an almost liquid phase into a closed hot die. As a result the densification will be homogenous over the entire cross-section of a component. Therefore off-set steps on the outer diameter and the bore can be realized. Furthermore, even if a component has both outer and inner steps this

will not pose a problem. With a special tool even undercuts can be realized. Special attention has to be paid to the choice of an appropriate location of the gate mark, since it will influence the properties of the finished part.



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