Installation housing

Shaft

Besides the rotary shaft seal, the shaft is a key machine element in the rotation sealing system and must therefore fulfill a number of technical requirements in order to ensure good sealing action.

The correct shaft composition design in the contact surface area of the sealing edge of the rotary shaft seal is very important to the lifespan and the sealing function of the rotation sealing system.

Tolerances

The ISO tolerance field h_{11} according to DIN ISO 286 is to be applied to the shaft diameter d_1 in the contact surface area of the sealing edge of the rotary shaft seal in order to attain the necessary prestressing. Tolerance class IT 8 is valid for the roundness of the shaft.

Surface finish of the shaft

The shaft must be treated circularly in the contact surface area.

The surface roughness, measured longitudinally, should lie within the following ranges:

R_a = 0.2 to 0.8 µm
R_z = 1.0 to 4.0 µm
R_{max} ≤ 6.3 µm

Shaft surfaces that are too smooth (Ra < 0.2 µm) combined with excessive peripheral speeds lead to malfunctions. The supply of lubricant to the sealing edge is impeded, the hydrodynamic lubricating film under the sealing edge is broken and thermal damage to the sealing edge results. Shaft surfaces that are too rough quickly lead to premature wear of the sealing edge. In both cases, serious leakage is the result.

Should axial movements also occur at the rotating shaft, the following roughness depths should be observed to ensure a good sealing action:
R_a ≤ 0.2 µm
R_z ≤ 0.8 µm

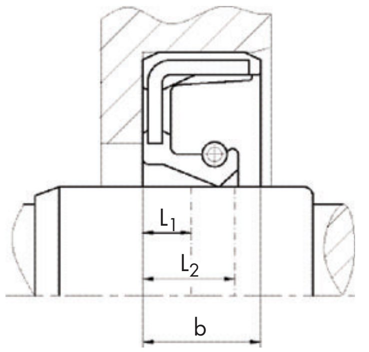
Surface hardness of the shaft

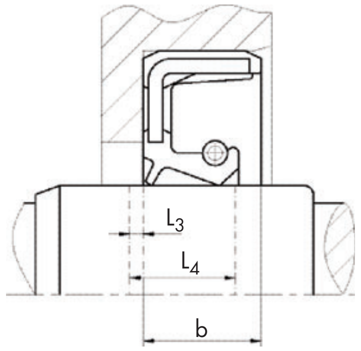
The lifespan of the sealing point is also dependent on the surface hardness of the contact surface on the shaft. The surface hardness should be at least 45 HRC.

Should there be influx of contaminated media or dirt from the outside, and with peripheral speeds of ≥ 4 m/s, the surface hardness must be at least 55 HRC – 60 HRC.

In the event of surface hardening, a hardness penetration depth of at least 0.3 mm is required.

Chrome-plated, cadmium-plated, nitrided and phosphated shaft surfaces require special treatment processes. Case by case decisions must be made regarding their suitability. Following nitration the grey layer is to be smoothed. With chrome-plated shaft surfaces the formation of lubricating film is to be determined by subsequent plunge grinding.





Contact surface area

The previously named values for surface finish and surface hardness are to be observed within the contact surface area specified in the table below. The contact surface area is specified in terms of the sealing width b.

b	L_1 min.	L_2 min.	L_3 min.	L_4 min.
7	3.5	6.1	1.5	7.6
8	3.5	6.8	1.5	8.3
10	4.5	8.5	2	10.5
12	5	10	2	12
15	6	12	3	15
20	9	16.5	3	19.5

Treatment of the shaft surface

The shaft is treated spiral-free and circularly in the contact surface area of the sealing edge to ensure that no feeding or pumping effect occurs at the sealing point and thereby causes leakage. The correct treatment of the contact surface is very important for the sealing function.

The following treatment methods are used:

Plunge grinding

The most frequently used method is plunge grinding (grinding without axial feed of the grinding wheel) as this produces a completely spiral-free sliding surface. To obtain a high degree of efficiency the sparking out time must be 30 seconds. The grinding wheel is whetted with a multi-grain dresser to ensure that no spiral occurs. During grinding, an integral transmission ratio between the rotational speed of the shaft (e.g. 50 1/min) and the rotational speed of the grinding wheel (e.g. 1500 1/min) is to be avoided.

Hard turning

When hard turning, special process parameters such as feed, cutting speed, depth of cut and cutting material must be observed in order to produce a usable sliding surface. The reason for choosing this treatment method is its high cost-efficiency. Other advantages are:

– complete treatment in one mounting
– short set-up times
– fewer production steps
– no wheel swarf to dispose of
– precisely defined surface structure of the shaft

Turned shafts have a considerable feed effect in one direction, i.e. due to the orientation of the treatment scores (spiral) the oil is fed in one direction, as with a micro-thread. The feed direction is dependent on the rotational direction of the shaft. When selecting the rotary shaft seal it is essential that the shaft can also feed against the sealing direction if the rotational direction changes. For this reason, either hard turning should be used for shafts with only one rotational direction (shaft feed direction towards the oil chamber) or a rotary shaft seal should be selected that is capable of feeding the feed stream created by the hard-turned shaft back into the oil chamber.

The friction torque of rotary shaft seals is comparable to that of ground shafts.

Dichtomatik conducts various test runs with different rotary shaft seal types at a renowned scientific institute. In order to guarantee the maximum possible functional reliability we strongly advise that the selection of seals should be verified by test runs. For further information, e.g. process parameters or test runs, please contact Dichtomatik's development department.

Flow turning

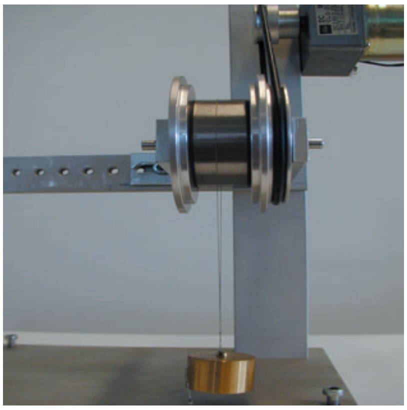
Deep-drawn sheet metal

Other methods include lapping, honing, grinding with emery, reaming and abrasive blasting. These methods can produce sliding surfaces of only limited correctness for a rotary shaft seal. Sliding surfaces prepared like this should definitely be checked with sufficient test runs.

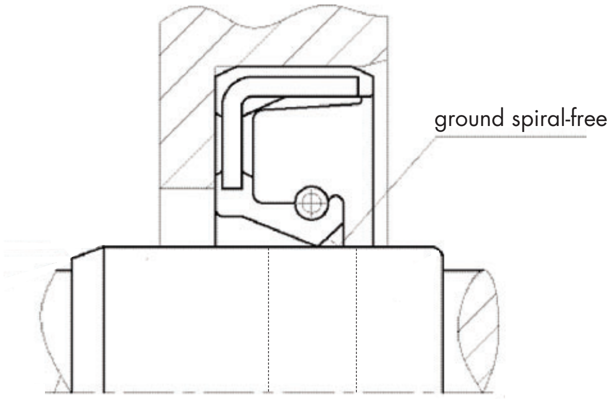
Spiral-freeness of the shaft surface

It is essential that the contact surface area of the shaft has been made spiral-free to ensure that no feed or pump effect occurs at the point of sealing, thereby disturbing the functional mechanism of the rotary shaft seal and causing leakage. Spiral-free means that the treatment marks show no orientation such as a rising micro-thread.

Shafts and shaft sleeves can be tested for spiral-freeness using the thread method. To obtain a reliable result, various parameters, e.g. angle of thread contact, rotational speed and weight must be observed. The test thread slides on the wetted, spiral-free contact surface without any change in the axial track. If there is a spiral the test thread moves axially to the left or right, depending on the rotational direction.



Shaft surface spiral measuring devise “Thread method”



Shaft material

Common tempering steels are suitable as shaft material if the values for the surface hardness are observed.

The formation of corrosion in the contact surface area of the rotary shaft seal is to be avoided. Shafts made of heat-treatable, high-alloy, rust-resistant steel are therefore to be used to seal water or aqueous media. For low peripheral speeds and secondary applications, nonferrous metals can also be used.

Cast iron materials are sometimes suitable as shaft material if they are cavity-free and have a pore size of < 0.05 mm.

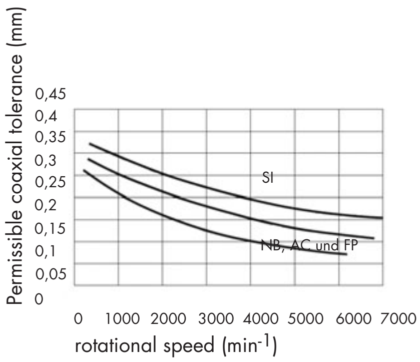
In special cases, ceramic layers can be used as shaft material if the surface is sealed and a pore size of < 0.05 mm is ensured. In addition, the required surface finish must be observed and a good bond to the basic shaft material ensured.

Hard chrome-plated shafts are suitable only to a limited degree due to poor formation of the lubricating film and eccentric wear. The formation of the lubricating film can be improved only by subsequent plunge grinding.

Plastic shafts are also suitable only to a limited degree. As plastics have a very low thermal conduction coefficient, the heat dissipation via the shaft is impaired and there is a high rise in temperature at the sealing edge. At and above certain rotational speeds the plastic can soften or melt.

For all shaft surface materials the same applies: the required values for surface finish and hardness must be observed.

If the shaft cannot be made with the required contact surface properties for economic, design or technical manufacturing reasons, corresponding shaft sleeves can be used. Dichtomatik supplies shaft sleeves in all dimensions and various materials and the development department realises them in terms of design.



Permissible coaxial tolerance of the shaft

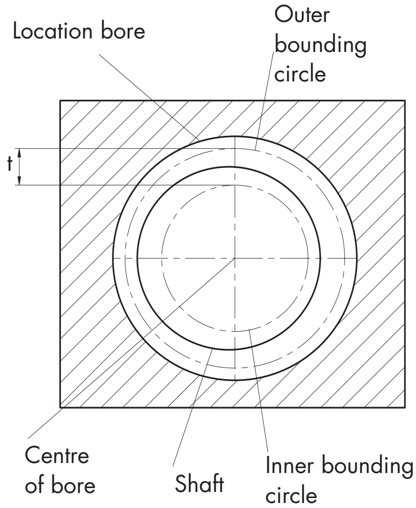


Illustration of out-of-roundness tolerance

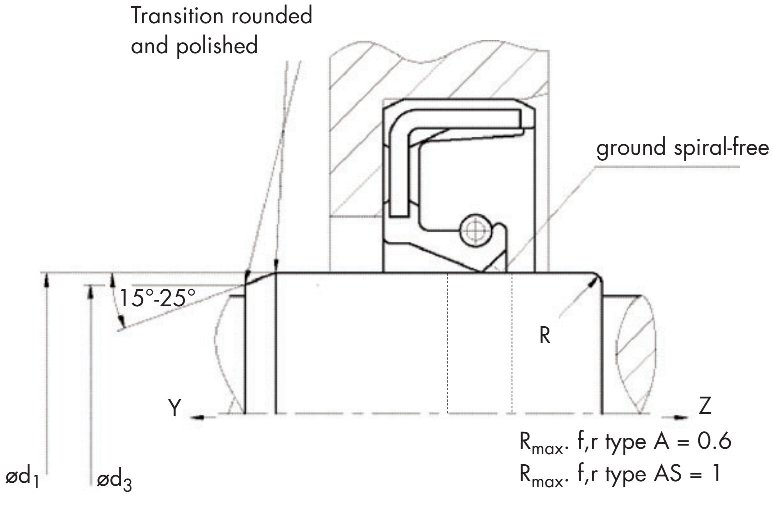
Out-of-roundness
The out-of-roundness or dynamic eccentricity of the shaft should be kept within small tolerances. Otherwise, at high rotational speeds, there is a danger of the sealing lip, due to its inertia, no longer being able to follow the shaft.
If this creates too large a gap between sealing edge and shaft on one side, the medium to be sealed escapes and leakage occurs. It is therefore advisable to position the rotary shaft seal in the immediate vicinity of the bearing and to keep bearing play as small as possible.
The permissible values for out-of-roundness in terms of rotational speed are shown in the diagram on the left.

Limited values apply to our pressurisable type WAY/WASY because the sealing lip here is considerably more rigid.

Installation		chamfer
d_1		**d_3**
<10		d_1 -1.5
10 <	20	d_1 -2
20 <	30	d_1 -2.5
30 <	40	d_1 -3
40 <	50	d_1 -3.5
50 <	70	d_1 -4
70 <	95	d_1 -4.5
95 <	130	d_1 -5.5
130 <	240	d_1 -7
240 <	500	d_1 -11

Chamfer on the shaft
Two following designs of the shaft shoulder are suggested:
Installation direction Z of the shaft
Rounding of the shaft shoulder with r = 0.6 to 1mm.

Installation direction Y of the shaft
Chamfering of the shaft shoulder, recommended angle 15° to 25°.
The chamfer diameter d3 is listed in the adjacent table.



Damage to the shaft
It is essential that all kinds of damage such as scoring, scratching, dents, cavities, pores or corrosion on the contact surface of the shaft are avoided. This leads to premature failure and leakage. 30% of such failures are caused by incorrect shaft treatment or damage. Shafts should therefore be protected carefully from production to final installation. Transport fixtures or specially moulded or slip-on sleeves made of plastic can be used.

Housing bore

The design of the housing bore is important because the static sealing (second leakage path) by the outer sheath of the rotary shaft seal takes place inside it. To obtain a firm and tight seating in the housing bore it is essential that the following technical requirements are observed:

Tolerances
For the bore diameter d_2 the ISO tolerance field H8 in accordance with DIN ISO 286 is to be allowed for in order to obtain good static sealing performance in combination with the press-fit allowance at the outer sleeve of the rotary shaft seals.

Housing dimensions
The axial housing dimensions and the pertaining corner radii are given in the table in relation to the rotary shaft seal height b:

b	t_1 min.	t_2 min.	R_1
7	5.95	7.3	
8	6.8	8.3	0.5
10	8.5	10.3	
12	10.3	12.3	
15	12.75	15.3	0.7
20	17	20.3	

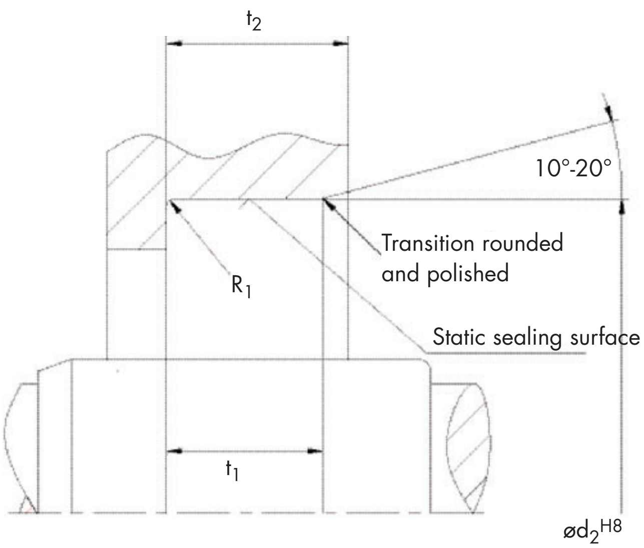
Chamfer on the housing bore
The housing bore should have a chamfer of 10° to 20° and the transitions should be free of burs in order to facilitate problem-free installation of the rotary shaft seal.

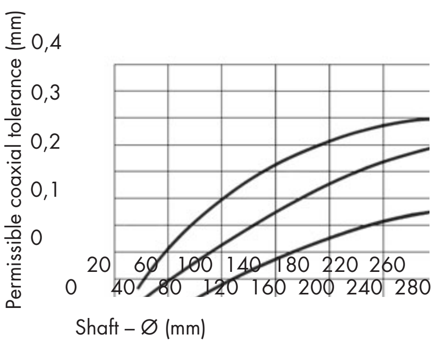
Surface finish of the housing bore
In order to obtain good static tightness and a secure, firm seating in the housing bore, the following roughness values should be observed:

permissible values for types with rubber outer sleeve WA
R_a = 1.6 to 6.3 µm
R_z = 10 to 20 µm
R_{max} ≤ 25 µm

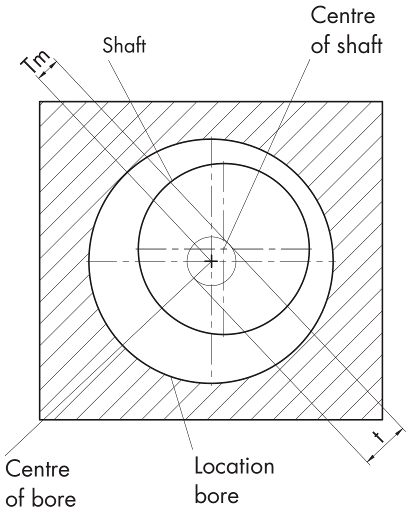
permissible values for types with metal outer sleeve WB, WC
R_a = 0.8 to 3.2 µm
R_z = 6.3 to 16 µm
R_{max} ≤ 16 µm

Rotary shaft seals with metal sheaths and/or application in combination with thin fluid media or gas, a very good surface quality is required, i.e. the surface in the housing bore should be free of damage and treatment marks of any kind, e.g. scratching, scoring, cavities and dents.





The permissible coaxiality tolerance between the housing bore and the shaft



Coaxiality tolerances

Coaxiality tolerances in the housing bore

The permissible coaxiality tolerance (concentricity deviation) between the housing bore and the shaft/bearing position is shown in the adjacent table. Coaxiality leads to the uneven distribution of contact pressure at the circumference. This results on the one hand in greater strain on the sealing edge which leads to premature wear. On the other hand there is too little contact pressure of the sealing edge on the shaft which can lead to an impairment of the sealing function and thereby cause leakage. It should be noted that shorter sealing lips (pressurisable type WAY/WASY) require smaller permissible values. With special elastomers, more flexible sealing lip mountings and longer sealing lips the coaxiality tolerance can be increased. The coaxiality deviation should be kept as small as possible in order to obtain even specific radial force/line pressure.

Materials for housings

The following materials are used for housings and housing covers/flanges that hold the rotary shaft seal:

– steel and heat-treatable steel common in mechanical engineering
– cast iron materials, e.g. GGG, GG, GS, GTS
– nonferrous metals and nonferrous metal alloys, e.g. G-AlMg
– plastics, e.g. thermoplasts and duroplasts

When selecting the rotary shaft seal type and the housing material it is essential to take the heat dissipation coefficient into consideration as this varies greatly in the materials given above.

Thermal expansion

The thermal expansion behaviour (thermal expansion coefficient) of the rotary shaft seal and housing materials are of key importance to the static sealing process in the housing bore (second leakage path). During operation, considerable temperature differences can occur that then result in different linear dimensional changes in the different materials. The linear dimensional changes can be calculated using the generally valid law of linear extension:

$$\varnothing L = \alpha \cdot \varnothing T \cdot L_0 \text{ [mm]}$$

The differences in the thermal expansion coefficients of steel, cast iron materials, nonferrous metals, plastics (thermoplasts) and elastomers are sometimes very large and thus cause various problems. If there is a rise in temperature between a nonferrous metal or plastic housing and a rotary shaft seal with a metal casing, the prestressing decreases due to the very different thermal expansion coefficients and the seal may be pushed out. The use of rotary shaft seals with rubber casing (e.g. type WA) is therefore recommended for nonferrous metal or plastic housings. These are designed with a larger press-fit allowance and can follow the expansion of the housing better because of their much higher thermal expansion coefficient. Rotary shaft seals with a grooved, rubber-encased outer surface (type WAK) are designed with an even higher press-fit allowance and can therefore cover even larger gaps. Housings made of steel or cast-iron material in combination with a rotary shaft seal with a rubber outer sleeve offer the greatest advantages from a thermal point of view.

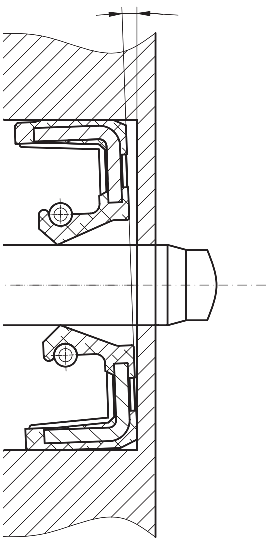


Illustration of skew

Permissible skew
The installed rotary shaft seal must be as central and vertical to the shaft as possible. The right-angle tolerance should not exceed the values in the adjacent table. Larger deviations (skew) lead to a pumping action and have a negative influence on the sealing function. Furthermore, excessive one-sided wear on the sealing lip is to be expected with rough surfaces.

Shaft diameter/mm	Right-angle tolerance/mm
up to 25	0.1
over 25 up to 80	0.2
over 80	0.3

Rigidity
For economic reasons, mount housings are frequently designed with very thin walls. When installing rotary shaft seals in thin-walled housing bores or mount housings with low stability there is a danger of the mount housing being considerably enlarged, which can lead to leakage. The enlargement of the housing bore must therefore be kept within the limits possible by the selection of the correct rotary shaft seal type in order to guarantee the wringing fit necessary for static tightness.

We recommend using rotary shaft seals with a rubber sleeve (e.g. WA) or applying a larger housing bore tolerance.

Split housings
In split housings, static tightness can also be obtained at the partition lines with the type WA (rubber outer sleeve).

Due to the good elastic deformability of the elastomer and its mould filling capacity, the required static tightness is obtained with the type WA. This means that split mount housings with different partition levels and possible offset at the partition lines can also be securely sealed.