11. Design of Surrounding Structure

11-1 Precision of Shaft and Housing

The recommended IT Tolerance Classes, required to be observed when machining the mating components based on the Tolerance Classes of bearings, are shown in the Table 11-1, and their values in the Appendix.

In the Table 11-1, the tolerances of cylindricity and shoulder of fitting surfaces in axial direction need to be one IT Class higher than that of their diameter. Form tolerances, t_5 and t_6, to the shaft or housing seating should be determined only after analyzing the alignment of each bearing. At this time, tilting of shaft and housing caused by elasticity modulus should also be taken into account.

To satisfy the cylindricity, t_1 and t_3, following values are recommended to be met in the measured area(Width of bearing seating).

Straightness	$0.8 \cdot t_1$ or $0.8 \cdot t_3$
Roundness	$0.8 \cdot t_1$ or $0.8 \cdot t_3$
Parallel	$1.6 \cdot t_1$ or $1.6 \cdot t_3$

The bearings with tapered inner diameter are mounted directly on the tapered shaft, or on adapter or withdrawal sleeves. Decision to apply tight fitting should not be made based on the shaft tolerances, but on the axial insertion magnitude of tapered seating, just like the bearings with cylindrical bore diameter.

The seating tolerances of adapter or withdrawal sleeves could be larger than the diameter tolerances of cylindrical shaft, but form tolerances

Table 11-1 Recommended Machining Tolerance and Roughness of Bearing Seating

Bearing Tolerance Class	Seating	Machining Tolerances	Roughness Class
Normal, P6X	Shaft	IT6 (IT5)	N5...N7
	Housing	IT7 (IT6)	N6...N8
P5	Shaft	IT5	N5...N7
	Housing	IT6	N6...N8
P4, HW	Shaft	IT4	N4...N6
	Housing	IT5	N5...N7
P2	Shaft	IT3	N3...N5
	Housing	IT4	N4...N6

The higher Roughness Class should be applied, when the diameter gets bigger.

Table 11-2 Roughness Classes Based on ISO 1302

Roughness Class	N3	N4	N5	N6	N7	N8	N9	N10
	Unit : μm							
Average Roughness Value R_a	0.1	0.2	0.4	0.8	1.6	3.2	6.3	12.5
Depth of Roughness $R_z \approx R_t$	1	1.6	2.5	6.3	10	25	40	63

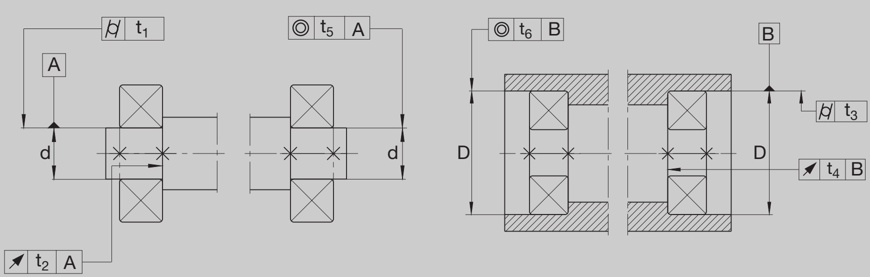

Fig. 11-1 Machining of Bearing Seating

should be smaller than diameter tolerances.

Roughness of bearing seating should be in proportion to its Tolerance Class. The average roughness value, R_a, should not be too large, so that interference reduction may be within its limit.

11-2 Sealing

The seals are used so as to prevent dust, moisture, metal fragments, and other contaminants from entering into bearing, and also to prevent lubricants from being leaked.

The seals have to be able to serve their functions under all operating conditions, and should not produce any abnormal friction, and should not result in any seizure. Also, they have to be easy to mount/dismount and repair/maintain, and also reasonably economical. Therefore, it is necessary to examine the different lubricating methods suitable for each bearing's requirements at the same time when selecting the seals.

11-2-1 Non-Contact Seals

These are the ones that do not come in contact with shaft, and they utilize the centrifugal force or narrow sealing gap to tightly block out inside from outside. These can be applied to the bearings with high speed or under high temperature, because they are free of heat generation, wear and tear of seals, or increase of friction torque.

(1) Narrow Gap Sealing

This is done by having a narrow gap between shaft and housing, and sometimes, they increase the sealing effectiveness by installing several oil grooves of same size in the housing bore.

Also, there is another method of recovering the leaking oil by making the spiral grooves on the shaft outer surface that touches the housing inner surface. When making the grooves, its spiral direction should be decided considering the rotating direction of the shaft.

If it is decided to use the narrow gap sealing method, then it is better to have as narrow gap between shaft and housing as possible, and the gaps should be between 0.2～0.4mm for bearing shaft diameter smaller than 50mm, and 0.5～1mm for the ones larger than 50mm.

Also, the groove width of 2～3mm is ideal, and the depth of 4～5mm. The number of grooves should be three or more, if no other additional sealing methods are employed.

When a narrow gap sealing method is applied to the oil lubrication, it alone might not be enough to provide sufficient anti-leakage performances, so it is recommended to use it along with other sealing methods. For example, if the grease of worked penetration 200 is applied to the grooves, dust can be blocked out fairly well.

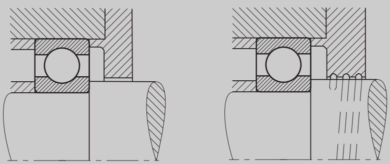

Fig. 11-2 Narrow Gap Sealing

(2) Flinger

This method is to prevent oil leakage or to force out the dusts by utilizing the centrifugal force of a mounted rolling element, flinger, on the shaft.

There are two types of flingers. One is installed inside the housing to prevent the leakage of lubricant by the centrifugal force generated from its rotation, and the other is installed outside the housing to force out the foreign materials, such as dust and water.

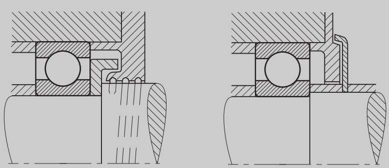

Fig. 11-3 Flinger

(3) Labyrinth Seals

This employs the labyrinth shaped seals with narrow gaps to make the passage to outside comparatively longer to increase the sealing effect.

When the gaps are filled with grease, sealing is more effective. And, if the environment is dirty, it is recommended to press grease from the inside into the sealing gaps in shorter time intervals.

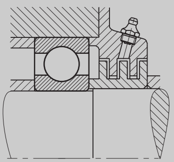

Fig. 11-4 Labyrinth Seals

Table 11-3 Shaft and Gaps of Labyrinth Seals

Nominal Dimension of Shaft (mm)	Labyrinth Gap Radial Direction	Axial Direction
50 up to	0.25...0.4	1...2
50...200	0.5...1.5	2...5

(4) Lamellar Rings

Lamellar rings made of steel spring disks require some mounting space to both inside and outside of the rings. Lamellar rings can prevent the oil leakage and block out the foreign materials, and they can also serve as a secondary seal when water is often splashed outside bearings.

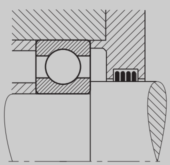

Fig. 11-5 Lamellar Rings

11-2-2 Contact Seals

Contact seals, made of elastic materials, such as synthetic rubber, synthetic resin, or felt, etc., directly rub against the shaft to produce high sealing effect, although there exists a danger of heat generation and increase of rotating torque, due to friction with contact area.

(1) Oil Seals

This is the most commonly used method, and their various sizes and shapes are standardized(KS B 2804).

These seals are usually used, where threat of foreign materials, such as dust and water, etc., being penetrated into is high. And, the eccentricity of shaft can be also corrected, up to a certain degree, by seal lip of synthetic rubber or coil spring in the oil seal.

Because wear and hardening of oil seals varies depending on the circumferential velocities and temperatures of the applied parts, it is important to select a seal of appropriate material. To assist the readers to select the appropriate seals, Table 11-4 shows the permissible speeds and operating temperature ranges for each type of materials.

Table 11-4 Permissible Speeds and Operating Temperature Ranges by Oil Seal Materials

Seal Material		Permissible Speed(m/s)	Operating Temperature(℃)
Synthetic Rubber	Nitril-series rubber	Up to 16	-25...+100℃
	Acryl-series rubber	Up to 25	-15...+130℃
	Silicon-series rubber	Up to 32	-70...+200℃
	Fluorine-series rubber	Up to 32	-30...+200℃
PTFE Resin		Up to 15	-50...+200℃

If the circumferential velocity or the inside pressure is high, it is necessary to smoothen the contact surface of the shaft, and also to keep the eccentricity of the shaft less than 0.02 ~0.05mm.

Table 11-5 Circumferential Velocity of Shaft and Contact Surface Roughness

Circumferential Velocity(m/s)	Surface Roughness R_a	R_{max}
up to 5	0.8a	3.2s
5...10	0.4a	1.6s
over 10	0.2a	0.8s

Also, the shaft surface should have the hardness above H_{RC} 40, which can be obtained by applying heat-treatment or plating with hard chrome. The standard values of contact surface roughness required in accordance with circumferential speeds of the shaft are shown in the Table 11-5.

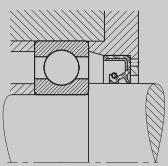

Fig. 11-6 Oil Seals

(2) Felt Rings

Felt rings are simple sealing elements which prove to be particularly successful with grease lubrication. However, they can not provide perfect protection against oil penetration or leaking, so they are usually used, in case of grease lubrication, just for prevention of dust or foreign materials from being entered, and they are generally soaked in oil before mounting for considerably better sealing effect.

If environmental conditions are adverse, two felt rings can be arranged side by side.

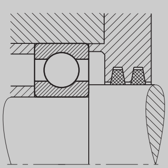

Fig. 11-7 Felt Ring

(3) V-Ring

V-ring is a lip seal with axial effect. During mounting, this one-piece rubber ring is pushed onto the shaft under tension until its lip contacts the housing wall. The sealing lip also acts as a flinger ring.

Axial lip seals are insensitive to radial misalignment and slight shaft inclinations.

With grease lubrication, rotating V-rings are suitable for circumferential velocities of up to 12m/s, stationary ones up to 20m/s. For circumferential velocities over 8m/s, V-rings must be axially supported and for those with 12m/s or more they must also be radially encased. V-rings are frequently used as assisting seals in order to keep dirt away from a radial shaft seal.

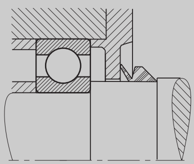

Fig. 11-8 V-Ring