9 Design of Shaft and Base

9.1 Design of Shaft

For optimal performance of a ball bearing unit, and for maintenance-free operation for an extended period of time, proper shaft selection is very important. The shaft should be straight, of sufficient tensile strength, and free of burrs and scratches.

9.1.1 Dimensional accuracy of shaft

(1) Dimensional tolerance of shaft used for set screw bearings

For bearings with set screws, a relatively looser class of fit makes assembly easier and is perfectly acceptable at low operating speeds. The clearance between the bore of the bearing and the shaft must be decreased as the rotational speed is increased.

Table 9.1 shows the guidelines for the tolerance class for the rotational speed of bearings with set screws.

If the bearing with set screws is exposed to a heavy load ($P_r / C_r > 0.12$), vibration, or heavy impact, use a tighter shaft tolerance than normal.

Table 9.2 shows the tolerances for tight fits.

Table 9.3 shows the recommended roundness and cylindricity for shafting.

Table 9.1 Dimensional tolerance of shaft used for cylindrical bore bearing with set screws (recommended) (clearance fit or intermediate fit)

Unit: μm

Shaft dia. (mm)		Dimensional tolerance of shaft							
		j6		h6		h7		h8	
Over	Incl.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
6	10	+ 7	− 2	0	− 9	0	−15	0	−22
10	18	+ 8	− 3	0	−11	0	−18	0	−27
18	30	+ 9	− 4	0	−13	0	−21	0	−33
30	50	+11	− 5	0	−16	0	−25	0	−39
50	80	+12	− 7	0	−19	0	−30	0	−46
80	120	+13	− 9	0	−22	0	−35	0	−54
120	180	+14	−11	0	−25	0	−40	0	−63
Applicable rotating speed $dn^{1)}$		Over 120,000		Over 100,000, incl. 120,000		Over 60,000, incl. 100,000		Incl. 60,000	

Note [1] $dn = d$ (bearing bore dia., mm) $\times n$ (rotating speed, min^{-1})

Table 9.2 Dimensional tolerance of shaft used for cylindrical bore bearing with set screws (recommended) (intermediate fitting or tight fitting)

Unit: μm

Shaft dia. (mm)		Dimensional tolerance of shaft					
		k6		k7		m6	
Over	Incl.	Max.	Min.	Max.	Min.	Max.	Min.
6	10	+10	+1	+16	+1	+15	+ 6
10	18	+12	+1	+19	+1	+18	+ 7
18	30	+15	+2	+23	+2	+21	+ 8
30	50	+18	+2	+27	+2	+25	+ 9
50	80	+21	+2	+32	+2	+30	+11
80	120	+25	+3	+38	+3	+35	+13
120	180	+28	+3	+43	+3	+40	+15

Table 9.3 Recommended accuracy of shaft used for ball bearing units

Unit: μm

Shaft dia. (mm)		Tolerance of shaft roundness and cylindricity (max.)
Over	Incl.	
6	10	6
10	18	8
18	30	9
30	50	11
50	80	13
80	120	15
120	180	18

(2) Dimensional tolerance of shaft used with tapered bore bearings

Since tapered bore bearings are fixed to the shaft with an adapter, a looser fit is allowable since the adapter sleeve provides excellent concentricity. This makes mounting of the bearing to the shaft much easier.

Table 9.4 shows the dimensional tolerance of the shaft used with tapered bore bearings (with adapters).

Table 9.4 Dimensional tolerance of shaft used for tapered bore bearings (with adapters) (recommended)

Unit: μm

Shaft dia. (mm)		Dimensional tolerance of shaft			
		h8		h9	
Over	Incl.	Max.	Min.	Max.	Min.
18	**30**	0	–33	0	– 52
30	**50**	0	–39	0	– 62
50	**80**	0	–46	0	– 74
80	**120**	0	–54	0	– 87
120	**180**	0	–63	0	–100

(3) Dimensional tolerance of shaft with eccentric locking collar

Eccentric locking collar bearings have greater clearance (more eccentricity) between the shaft and the bore of the bearing when installed. Therefore, the shaft tolerances must be tighter (h5 or j5) to reduce the clearance (eccentricity). The same clearance fits are recommended as with blower bearings as shown in **Table. 2.6**.

(4) Dimensional tolerance of shaft used for concentric locking collar

Regarding the shaft used for concentric locking collar bearings, the same clearance (h5 or j5) fits are recommended as with air handling bearings as shown in **Table 2.6**.

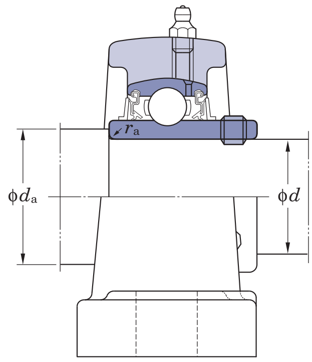
9.1.2 Dimensions of shouldered shafts

When using a set screw or eccentric locking collar bearing that is exposed to a high axial load, excessive vibration, or impact, a shouldered shaft may be used. The inner ring of the bearing is then tightened in place with a locknut, if the shaft is threaded, or with a locking ring otherwise.

However, if after mounted units used a shouldered shafts, between the inner ring end face and shouldered shafts, on clearances of 2 mm or more is recommended.

Table 9.5 shows the shoulder diameter and the fillet radius of the shouldered shaft.

Table 9.5 Recommended shoulder diameter and fillet radius of a shouldered shaft



Unit: mm

Bore dia. code	Nominal bearing bore dia. d	Diameter Series[1)] UC200, UCX00 Shoulder dia. d_a	Diameter Series[1)] UC200, UCX00 Fillet roundness radius r_a (max.)	Diameter Series[1)] UC300 Shoulder dia. d_a	Diameter Series[1)] UC300 Fillet roundness radius r_a (max.)
01	**12**	17	0.6		
02	**15**	20	0.6		
03	**17**	22	0.6		
04	**20**	30	1	–	–
05	**25**	35	1	35	1
06	**30**	40	1	40	1
07	**35**	45	1	45	1.5
08	**40**	50	1	50	1.5
09	**45**	55	1	55	1.5
10	**50**	60	1	60	2
11	**55**	65	1.5	65	2
12	**60**	70	1.5	75	2
13	**65**	75	1.5	80	2
14	**70**	80	1.5	85	2
15	**75**	85	1.5	90	2
16	**80**	90	2	95	2
17	**85**	95	2	100	2.5
18	**90**	100	2	105	2.5
19	**95**	–	–	110	2.5
20	**100**			115	2.5
21	**105**			120	2.5
22	**110**			125	2.5
24	**120**			135	2.5
26	**130**			150	3
28	**140**			160	3

The basic bearing size number consists of the duty code (2, X, or 3) followed by the inner ring size code (07, 10, 24, etc.)

9.1.3 High temperature applications

In general, two bearing units are used per shaft. If the distance between the bearings is small, or if the temperature change of the shaft is small, both bearings may be fixed in position.

However, if the distance between the bearings is large and the shaft is exposed to heat, then only one bearing should be fixed and the opposing bearing must be free to float in the axial direction.

This is because shaft expansion due to temperature change of the shaft causes a high axial load and can cause failure of fixed bearings. The amount of shaft expansion due to temperature change may be calculated by using **Formula (9.1)**.

$$\Delta_\ell = \alpha \cdot \Delta_t \cdot l \quad \cdots\cdots (9.1)$$

Whereas,

Δ_ℓ: Expansion of shaft, mm

α: Linear expansion coefficient of shaft in the case of ordinary steel, $11 \sim 12 \times 10^{-6}$

Δ_t: Temperature increase, °C

l: Installation distance of unit, mm

Proper installation procedures for a shaft exposed to temperature changes are shown below.

(1) Installation with a dog point set screw on the free side

To accommodate shaft expansion in the axial direction, the bearing must be installed so that the shaft can move freely through the bore in either axial direction.

To accomplish this, the shaft must be grooved for a full dog point set screw (suffix code: G6). This should be done on the free side only. The dog point screw allows free movement in the axial direction and provides force to rotate the bearing in the radial direction.

Fig. 9.1 shows an example of the structure of a bearing with a key groove on the shaft and a full dog point set screw. **Table 9.6** shows the dimensions of the key groove for the full dog point set screw. Note that the full dog point set screw in the image is also capped so that it may be tightened against the bearing, not the shaft. A full dog point set screw with a jam nut will also work to achieve this function.

The tolerance class of the shaft to be used is h7.

If the temperature of the shaft is higher than that of the bearing, then a looser fit tolerance class is specified.

When using this method to allow for free expansion, there is the possibility of fretting between the shaft and the inner race. In order to prevent fretting, a high temperature grease must be applied to the inner ring of the bearing and the shaft prior to installation.

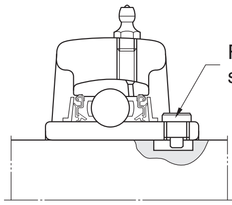


Fig. 9.1 Use on free side with full dog point set screw

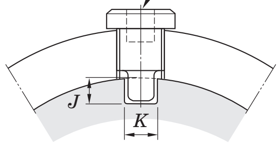


Table 9.6 Dimensions of key groove for full dog point set screw (use on free side)

Nominal size of set screw	Dimensions of key groove (mm)		Applicable nominal bearing code		
	J	K	UC200	UCX00	UC300
M6 × 0.75	5	4	201–206	X05	305, 306
M8 × 1	6	6	207–209	X06–X08	307
M10 × 1.25	6.5	7	210–212	X09–X11	308, 309
M12 × 1.5	7	9	213–218	X12–X17	310–314
M14 × 1.5	7	10		X18	315, 316
M16 × 1.5	8	12		X20	317–319
M18 × 1.5	8	13			320–324
M20 × 1.5	8	15			326, 328

Allowable tolerance of key groove dimension "K" (Recommended value: 0~+0.2mm)

(2) Installation of cartridge type units on the free side

If the rotational speed is high or if the bearing is exposed to high vibration, the cartridge type unit is recommended on the free side. In this case, the housing of the cartridge unit is free to move axially within the mounting bore and the bearing insert is rigidly attached to the shaft.

Fig. 9.2 shows the required structure for the cartridge type unit on the free side.

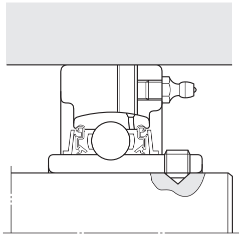


Fig. 9.2 Use of cartridge type units on free side

If, in addition to the expansion of the shaft, the ball bearing itself is exposed to heat, then a calculation of the decrease in internal clearances of the bearing must be made. The appropriate bearing internal clearance must be specified. (see **"7 Operating temperature and bearing specifications"**).

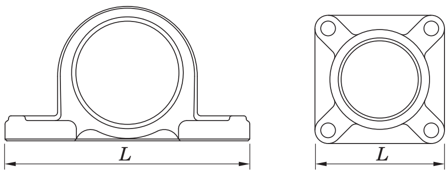
9.2 Mounting Base Design

9.2.1 Rigidity of base and flatness of mounting Surface

If rigidity of the base on which a ball bearing unit is to be mounted is not sufficient, or if the flatness of the mounting surface is poor, then vibration or abnormal noise may occur during operation. This may lead to premature bearing failure since the strength of the housing is diminished from improper support.

The mounting surface must be accurately machined to eliminate deformation of the housing.

Fig. 9.3 shows the recommended values for flatness of the mounting surface on which the ball bearing unit is to be installed.



Max.: L / 1,000 mm

Fig. 9.3 Flatness of mounting surface of base (recommended value)

9.2.2 Mounting cartridge type units in high temperature applications

Cartridge units are designed to fit into an accurately bored cylindrical opening in the mounting base. Under ordinary operating conditions, H7 is an adequate choice for the tolerance class of the cylindrically bored hole.

In instances where both the bearing and the shaft are heated during operation, select G7 as the tolerance class of the cylindrical bore.

If the bearing is exposed to excessive vibration or impact, then an even tighter tolerance class must be specified.

Table 9.7 shows the dimensional requirements for the cylindrical bore.

Table 9.7 Dimensional tolerance of cylindrical bore for mounting cartridge type units (recommended values)

Unit: μm

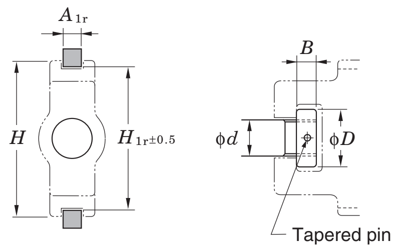
Nominal bore dia. of cylindrical bore (mm)		Dimensional tolerance of cylindrical bore			
		H7		G7	
Over	Incl.	Max.	Min.	Max.	Min.
50	**80**	+30	0	+40	+10
80	**120**	+35	0	+47	+12
120	**180**	+40	0	+54	+14
180	**250**	+46	0	+61	+15
250	**315**	+52	0	+69	+17
315	**400**	+57	0	+75	+18

9.2.3 Installation of take-up units

A take-up unit is positioned between two guide rails and enables linear adjustment by means of the threaded rod and bolt.

Table 9.8 shows the dimensions of the guide rail, adjuster bolt, and fixed nut.

Table 9.8 Dimensions relative to installation of take-up type units (recommended values)



Unit: mm

Nominal bearing code	Dimensions of guide rail			Dimensions of adjuster bolt and round nut		
	A_{1r}	H_{1r}	H (Reference)	d	D	B
T204 T205	11	77	89	16	28	14
T206 T207	11	90	102	18	32	14
T208	15	103	114	24	42	16
T209 T210	15	103	117	24	42	16
T211 T212	20	131	146	30	55	20 27
T213 T214 T215	24	152	167	36	60	27
T216	24	166	184	36	60	27
T217	28	174	198	42	60	30
TX05 TX06	11	90	102	18	32	14
TX07	15	103	114	24	42	16
TX08 TX09	15	103	117	24	42	16
TX10 TX11	20	131	146	30	55	20 27
TX12 TX13 TX14	24	152	167	36	60	27
TX15	26	166	184	36	60	27
TX16 TX17	26	174	198	42	60	30

Remark This table is also applicable to stainless steel housings.

Unit: mm

Nominal bearing code	Dimensions of guide rail			Dimensions of adjuster bolt and round nut		
	A_{1r}	H_{1r}	H (Reference)	d	D	B
T305	11	81	89	22	32	12
T306 T307	15	91 101	100 111	24 26	36 40	14
T308 T309	16	113 126	124 138	28 30	45 50	16 18
T310	18	141	151	32	55	20
T311 T312	20	151 161	163 178	34 36	60 65	22 24
T313 T314 T315	24	171 181 193	190 202 216	38 40 40	65 80 80	26 28 28
T316	28	205	230	46	90	34
T317 T318	30	216 230	240 255	46 50	90 95	34 38
T319	32	242	270	50	95	38
T320 T321	32	262	290	52	100	40
T322	36	287	320	55	110	44
T324	42	322	355	60	120	50
T326 T328	47	352 382	385 415	65 70	130 140	55 60

9.3 Dowel Pins for Accurate Unit Mounting

The pillow type, square flange type, and oval flange type housings all have a dowel pin seat on the mounting base. If accurate positioning of the housing is required, then the bottom of the housing may be drilled for dowel pins which fit into corresponding holes in the mounting surface. The dimensions for the hole and pin sizes can be found in **Appendix table 5** in the back of the catalog.