<TABLE 6.4> Tapered bore bearing shaft tolerance

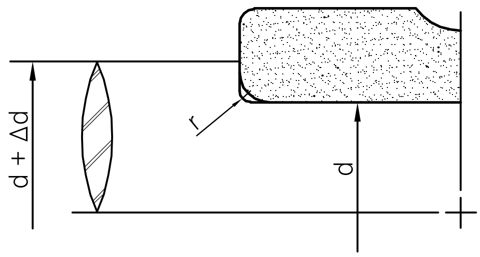
(unit : 0.001mm)

Shaft outside diameter (mm)	Tolerance	Tolerance of roundness (maximum)
	m6	
over 18~30	0 ~ -52	13
over 30~50	0 ~ -62	17
over 50~80	0 ~ -74	20
over 80~120	0 ~ -87	23
over 120~180	0 ~ -100	31

<TABLE 6.5> The stair, r and shaft diameter number

(unit : 0.001mm)

Bearing No.	r (max)	Δd(min)	Bearing No.	r (max)	Δd(min)	Bearing No.	r (max)	Δd(min)
UC201~203	0.6	5	UCX05, X06	1.0	6	UC305, 306	1.0	7
UC204~206	1.0	6	UCX07~X10	1.0	7	UC307~309	1.5	9
UC207~210	1.0	7	UCX11~X15	1.5	9	UC310, 311	2.0	10
UC211~215	1.5	9	UCX16~X18	2.0	10	UC312~316	2.0	12
UC216~218	2.0	10	UCX20	2.0	12	UC317~324	2.5	14



7. Ball bearing unit operating temperature

7.1 Operating temperature range

The ball bearing unit's operating temperature range is based on the minimum and the maximum allowable temperature of the bearing grease and also the seal.

Normal ball bearing unit's operating temperature range is from approximately -20℃ to 100℃. In order to operate outside this range, proper grease type must be used for the intended temperature of operation.

Also the sealing method and the radial clearance must taken into account for proper operation.

7.2 Bearing temperature increase

Increase in bearing temperature is caused by the generation of heat during bearing rotation from internal friction and resistance of grease in the unit. The heat that raises the bearing temperature is from the amount of heat that is left over in the bearing after some of the heat is transferred out of the bearing unit by the housing, the shaft and the body of the machine. Some of the heat is even fanned away by the rotating motion of the bearing. Since the bearing temperature is linked to the ability of the bearing unit to exhaust some of the heat to the surrounding, the ambient temperature around the bearing unit also has an affect on the amount temperature increase that the bearing unit exhibits.

The bearing temperature typically reaches maximum after about 30 minutes to 2 hours of operation. Upon continued operation, the temperature then drops by about 3℃ to 5℃ to reach the final equilibrium temperature.

This drop in temperature from the maximum temperature is due to the stabilization of the grease in the bearing after the grease reaches the maximum temperature and is then allowed to reach equilibrium consistency and quantity inside the bearing. Some of the grease may leak out of the bearing before the unit reaches equilibrium condition. Normally, the standard bearing temperature increase is about 30℃ more than the surrounding temperature for regular operations with regularly sealed bearings. The temperature increase is 35℃ more than the surrounding temperature for the triple seal method bearings. If the bearing temperature increase is greater than these amounts, the bearing operation method or the bearing itself must be checked for improper or irregular conditions.

7.3 Temperature change and radial clearance

The temperature of the inner race and the rotating element is commonly higher than the outer race. The temperature difference between the inner and outer race is large if the operation of the machine involves some heating of the shaft and some cooling of the bearing housing.

The temperature difference between the inner and the outer race reduces the radial clearance of the bearing. The regular radial clearance is good only for normal conditions. If the temperature difference is large due to the heat transfer conditions, large clearance bearings of C3 or C4 classes should be used.

The reduction of radial clearance due to temperature difference can be calculated by the following equation.

$$\delta t \fallingdotseq 12.5 \times 10^{-6} t \left(\frac{4D+d}{5}\right) \cdots\cdots\cdots\cdots (7.1)$$

Here, t : Temperature differance between the inner and the outer race (℃)
d : Inner race inside diameter (mm)
D : Outer race outside diameter (mm)

The axial clearance can also be insufficient when the bearing units are mounted far apart along the shaft. In this case, the axial expansion and ball bearing axial clearance must be carefully matched for proper operation.

The shaft expansion. $\Delta\ell$, can be calculated by the following equation.

$$\Delta \ell = \alpha \cdot \Delta t \cdot \ell \cdots\cdots\cdots\cdots (7.2)$$

Here, α : expansion coefficient (1/℃)
t : temperature difference (℃)
ℓ : distance between units (mm)

8. Bearing life

8.1 Life

Bearing life is defined for each bearing as the total number of revolutions made by the bearing before failure. The failure is usually due to rolling fatigue on the orbiting races or on the balls. It can also be defined as the total number of hours of operation before failure when the bearing is operated at a constant speed.

8.2 Rated life

Rated life for a bearing unit is defined from a set of identical bearings operating in identical conditions. It is the total number of revolutions (or number of hours when operated at the same speed) made by the bearing before failure that is exhibited by 90% of the bearing in the tested set.

8.3 Dynamic radial load rating

Dynamic radial load rating for a bearing is determined by applying a constant radial load during rotation of the inner race with the outer race in fixed position. It is the radial load in constant direction and magnitude that gives the bearing a rated life of 1 million revolutions.

In other words, the dynamic radial load rating for a bearing is the maximum allowable load that gives the bearing a rated life of 1 million revolutions.

8.4 Relationship between rated life and dynamic radial load rating

The following relationship exists for the ball bearing unit's rated life, the dynamic radial load rating (or basic load rating) and the actual load on the bearing.

$$L = \left(\frac{C}{P}\right)^3 \cdots\cdots\cdots\cdots (8.1)$$

Here, L : Rated life (unit 10^6 revolution)
P : Bearing load (equivalent radial load) Kg
C : Dynamic radial load rating Kg

Or, since the rated life is easier to express in terms of operating time rater than in number of revolutions, the following equation applies.

$$Lh = \frac{10^6 \cdot L}{60 \cdot n} = \frac{10^6}{60 \cdot n} \cdot \left(\frac{C}{P}\right)^3 = \frac{50000}{3 \cdot n} \cdot \left(\frac{C}{P}\right)^3 \cdots\cdots (8.2)$$

Here, n : Rotation speed (rpm)
Lh : Reted life (h)

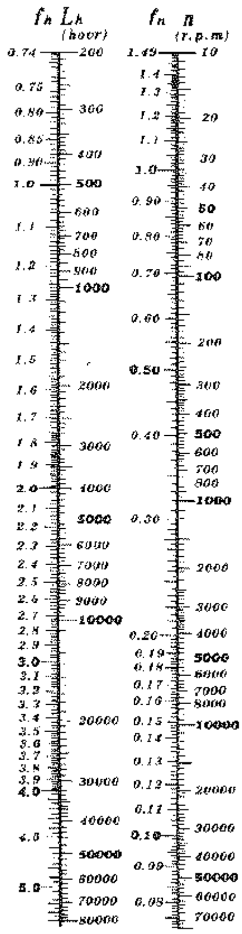
The above equation can be expressed in easier forms for use in real designing problems.

$$Lh = 500 \cdot fh^3 \cdots\cdots (8.3)$$

$$fh = \frac{C}{P} \cdot fn \cdots\cdots\cdots (8.4)$$

$$fn = \left(\frac{33.3}{n}\right)^{\frac{1}{3}} \cdots\cdots\cdots (8.5)$$

Here, fh and fn are life and speed factors, respectively. The rated life time can be approximately determined from fh, fn and rotation speed by referring to the scale shown in figure 8.1



[FIGURE 8.1]

8.5 Static radial load rating

Static radial load rating is the static load that permanently deforms the contact point (maximum stress point) between the race diameter and the ball by 0.0001 times the ball diameter.

$$Po\ max = \frac{Co}{Sf} \cdots\cdots\cdots (8.6)$$

Here,
Po max : Maximum static equivalent radial load (Kg)
Co : Static radial load (Kg)
Sf : Safety factor