8 Bearing Handling

8.1Cleaning and filling with grease

To achieve maximum speed and limited temperature rise with a precision rolling bearing, it is vital to handle the bearing correctly.

The handling of bearings involves cleaning, drying, filling with grease (if necessary), and the running-in operation. For each step, follow the precautions and instructions.

Cleaning means removal of rust-preventive oil. Immerse the bearing in kerosene or a highly volatile solvent such as naphthol and wash it by hand. Then remove the kerosene using benzene or alcohol. Use clean compressed air to blow away the rinsing fluid. (The bearing may be used as delivered for the air-oil lubrication. However, we recommend that after cleaning, the bearing either be coated with the lubricant to be used or a less viscous oil, or be immersed in the lubricant or other low-viscosity oil.)

If the bearing is to be used with grease lubrication, it is necessary to thoroughly dry the bearing to avoid leakage of grease. After drying, be sure to immediately fill the bearing with grease. Drying can be performed by blowing hot air onto the bearing or placing the bearing in a chamber at constant temperature. When drying by hot air, be sure to consider the cleanliness of the air.

The procedures for greasing ball and roller bearings can be found below. For ball bearings, by using an injector or small plastic bag, fill grease between balls in equal amounts, aiming at the inner ring rolling surface. For a bearing with a ring-guided cage, also apply grease to the guide surface of the cage using a spatula or similar tool. If grease cannot be filled into the inner ring rolling surface because of a small gap between the cage and the inner ring, add grease to the outer ring rolling surface. In this case, carefully turn the bearing so that the grease is fully spread on the inner ring side. Please refer to Fig. 8.1~8.3.

For roller bearings, apply grease to the outer (inner) side of rollers, and while turning the rollers with fingers, spread the grease to the inner ring (outer ring) side. Please refer to Fig. 8.4~8.6. If a lump of grease remains on the outer face of cage rib, the running-in operation can take a longer time.

Fig. 8.1 By using an injector or small plastic bag, fill grease between balls in equal amounts, aiming at the rolling surface of the inner ring

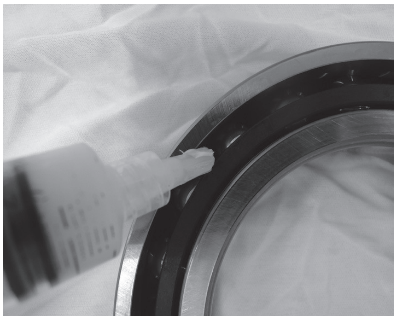


Fig. 8.2 After completion of filling

Fig. 8.3 Turn by hand so that the grease is fully distributed in the bearing. While turning by hand, apply an adequate load to the inner ring

Fig. 8.4 Apply grease to the outer circumference of cage

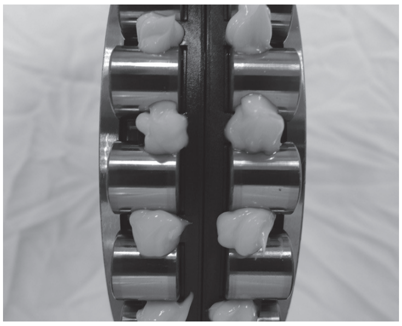


Fig. 8.5 Apply grease to the outer side of the rollers, and while turning the rollers with fingers, spread the grease to the inner ring (outer ring) side

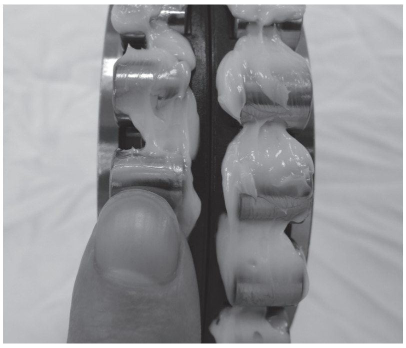
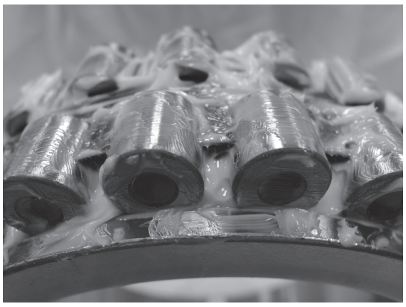


Fig. 8.6 With fingers, spread the grease deposited on the outer surface of the rib on the cage



8.2 Running In

For oil lubrication, the running-in operation is relatively simple with oil lubrication because no peak temperature occurs and the bearing temperature stabilizes within a relatively short time. TPI recommends that the speed of bearing is to be increased in steps of 2000 to 3000 min-1 until the maximum speed is reached. Every speed setting should be maintained for about 30 minutes. However, for the speed range where the dmN (pitch circle diameter across rolling elements multiplied by speed) exceeds 1,000,000, increase the bearing speed in steps of 1000 to 2000 min-1 to ensure the stable running.

For a grease-lubricated bearing, a running-in operation is very important in attaining stable temperature rise. During a running-in operation, a large temperature rise (peak) occurs while the bearing speed is increased, and then the bearing temperature eventually stabilizes. Before temperature stabilization, a certain lead time will be needed. For ball bearing, TPI recommends that the bearing speed be increased in steps of 1000 to 2000 min-1 and be further increased only after the temperature has stabilized at the current speed setting. However, for the speed range where the dmN exceeds 400,000, increase the bearing speed in steps of 500 to 1000 min-1 to ensure the stable running. Compared with contact ball bearings, the time to peak temperature or saturation in running-in operation of roller bearings tends to be longer. Also, there will be temperature rise due to whipping of the grease and the temperature rise may be unstable. To cope with this problem, run the roller bearing in the maximum speed range for a prolonged period.

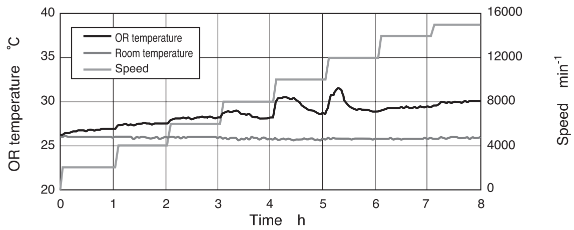
Increase the bearing speed in steps of 500 to 1000 min-1 only after the bearing temperature has stabilized at the current speed setting. For the speed range where the dmN exceeds 300,000, increase the bearing speed in steps of 500 min-1 to ensure safety.

The bearing speed is gradually increased in steps. After the temperature is saturated at each speed setting, the speed is increased to the next step as shown in Fig. 8.7.

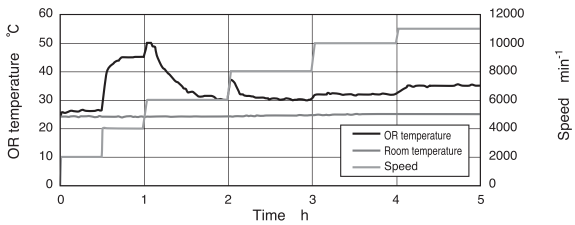
The bearing is run for several minutes up to about the maximum allowable speed limit of the bearing. This cycle is repeated two to three times as needed shown in Fig. 8.8. It can shorten the running-in time, although its starting phase involves a steep increase in bearing temperature, possibly deteriorating the quality of the lubricant.

Fig. 8.7 The bearing speed is gradually increased in steps

Bearing	5S-7006CDLLBDB (ϕ30× ϕ55×13×2 rows)
Mounted preload	180N (Fixed-position preload)
Jacket cooling	Yes



Bearing	5S-2LA-BNS020LLBDB (ϕ100× ϕ150×24×2 rows)
Mounted preload	4kN (Constant pressure preload)
Jacket cooling	Yes



Bearing	NN3020HSK (ϕ100× ϕ150×37)
Mounted radial clearance	-5 μm
Jacket cooling	Yes

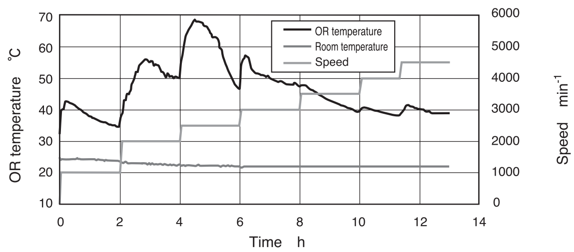
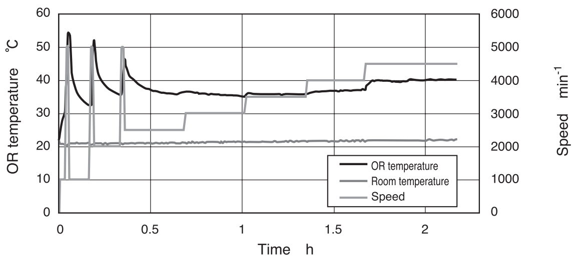


Fig. 8.8 The bearing is run for several minutes up to about the maximum allowable speed limit of the bearing

Bearing	NN3020HSK（ϕ100×ϕ150×37）
Mounted radial clearance	-5μm
Jacket cooling	Yes



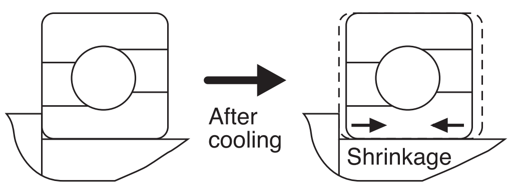
8.3 Mounting

When mounting a bearing to a shaft, frequently use a constant temperature chamber, bearing heater or the like. Assuming linear expansion coefficient 12.5×10^{-6}, heating temperature ΔT, inner ring bore diameter ϕd, and interference fit □=$12.5\times10^{-6}\times d\times\Delta T$. Note that in practice , the lower-temperature shaft will cool the bearing, causing it to shrink. Consequently the bearing may need to be heated by more than 30℃ for assembly.

If a resin material is used for the cage of angular contact ball bearing, do not excessively heat the bearing (approx. 80℃ max.).

As a result of heating bearings after cooling, the inner ring will axially shrink, and there will be clearance between the bearing side face and shaft shoulder illustrated in Fig. 8.9. For this reason, keep the bearing and shaft forced together with a press or the like until the unit returns to normal temperature. After cooling, check that the bearing is mounted to the shaft correctly.

Fig. 8.9 Cooling after mounting by heating bearings

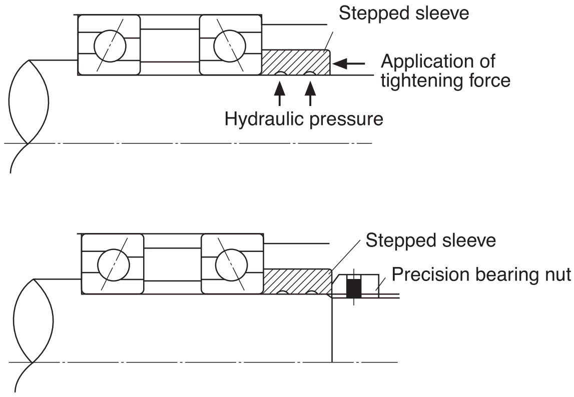


8.4 Tightening of inner and outer ring

When mounting and securing a bearing to a main spindle, the inner ring side face is usually clamped with a stepped sleeve or precision bearing nut, and the front cover situated on the outer ring side face is bolted down. The stepped sleeve is designed that the hydraulically expanded sleeve is inserted over the shaft, and a predetermined drive-up force (tightening force) is applied to the shaft. Then the hydraulic pressure is released in order to secure the sleeve onto shaft and provide a tightening force to the bearing. This technique is a relatively simple locking method. Note however after being locked in position by interference with the shaft, the sleeve can come loose because of deflection of the shaft or a moment load applied to the shaft.

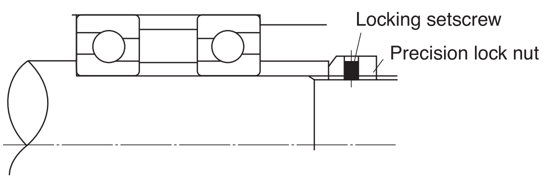
For this reason, in many cases, a stepped sleeve is used together with a bearing nut as illustrated in Fig. 8.10.

Fig. 8.10 Tightening with stepped sleeve



Tightening with a precision bearing nut (precision lock nut) provides a predetermined tightening force by controlling the bearing torque shown in Fig 8.11. When locking the bearing with a precision bearing nut, make sure that the squareness between the bearing surface and the shaft centerline is 3 μm or less so that adequate bearing accuracies are maintained.

Fig. 8.11 Tightening with stepped sleeve + precision be aring nut



Because the thread face of the precision bearing nut, the thread face of the shaft and the bearing surface and nut constitute sliding surfaces, the correlation between tightening torque and tightening force will vary depending on the friction coefficient. Therefore, the nut needs to be thoroughly run on the shaft thread in advance to ensure smooth and uniform tightening. It is also necessary to determine the correlation between tightening torque and tightening force by using a load washer or the like in advance.

$$F = \frac{M}{(d/2)\tan(\beta + \rho) + r_n \mu_n}$$

F : Thread tightening force N
M : Nut tightening torque N-mm
d : Effective diameter of thread mm
ρ : Friction angle of thread face

$$\tan \rho = \frac{\mu}{\cos \alpha}$$

β : Lead angle of thread
$\tan \beta$ = number of threads × pitch/ πd
r_n : Average radius of bearing nut surface mm
μ_n : Friction coefficient of bearing nut surface
$\mu_n \cong 0.15$
μ : Friction coefficient of thread face $\mu \cong 0.15$
α : Half angle of thread

When securing an angular contact ball bearing onto a main spindle, the inner ring tightening force causes the spacer to develop elastic deformation in the axial direction, varying the axial clearance on the bearing. In the case of a back-to-back duplex bearing (DB, DTBT or DBT) for a main spindle in particular, the inner ring tightening force will decrease the bearing clearance, possibly leading to an increased posta ssembly preload and operating preload. A possible inner ring tightening force-derived axial deformation can develop in the form of deformation of both the inner ring and inner ring spacer. However, experience has shown in Table 8.1 that only the elastic deformation on inner ring spacers needs to be considered.

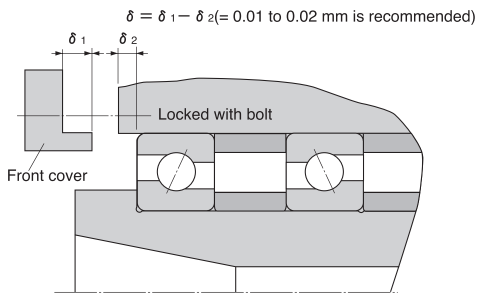
The bearing outer ring is tightened and locked between the shoulder of the housing and front cover at the main spindle front section. The front cover is installed by utilizing bolt holes (6 to 8 positions) on its flange. The usual pressing allowance on the outer ring and the front cover, which falls in a range of 0.01 to 0.02 mm. Too large a pressing amount on the outer ring or a smaller number of fastening bolts may lead to poor roundness of the bearing ring.

Table 8.1 Nut tightening force

Bearing bore diameter (mm)	Nut tightening force (N)	Front cover drive-up (mm)
20	2940~4900	0.01~0.02
25		
30		
35		
40	4900~9800	
45		
50		
55	9800~14700	
60		
65		
70		
75		
80	14700~24500	
85		
90		
95		
100		
105		
110		
120		
130		
140	24500~34300	
150		
160		
170		
180		
190		
200		

NOTE 1) TPI has specified the nut tightening forces in this table based on experiences from reviewing and assessing the drawings from users.
NOTE 2) When the fitting amount between a shaft and an inner ring is large, the tightening force needed is about twice as large as the calculated press-fitting force of the inner ring.

Fig. 8.12 Front cover pressing allowance



8.5 Starting Torque of BS Bearings

The BS type is mainly installed on ball screws of machine tool feed systems, and two to four row arrangements are used in many cases. This type is popular because greased sealed angular contact ball bearings are easy to handle. The starting torque can be altered depending on the bearing arrangement and preload. Reference starting torque values for BS bearings with normal preload are shown in Table 8.2.

Table 8.2 Starting torque of BS bearings with various arrangements

	Starting torque(reference) N·mm			
Bearing/ Arrangement	DF DB	DFT DBT	DTFT DTBT	DFTT DBTT
BS2047	175	245	355	275
BS2562	305	420	615	470
BS3062	305	420	615	470
BS3572	380	510	755	590
BS4072	380	510	755	590

8.6 Clearance adjustment for cylindrical roller bearing

When incorporating a cylindrical roller bearing into a main spindle of a machine tool such as an NC turning machine or machining center, and setting the internal clearance to zero or to a negative clearance, the inner ring of the bearing usually has a tapered bore.

The internal clearance is adjusted by fitting the tapered bore bearing onto the tapered portion of the main spindle and driving the bearing in the axial direction to expand the inner ring. For adjusting the internal clearance, two methods are available: a method consisting of clearance measurement for each bearing and adjustment with a spacer(s), and a method with a post-mounting internal clearance adjustment gage.

8.6.1 Method with clearance measurement and adjustment with spacer (s)

(a) Calculation of outer ring shrinkage ΔG with the formula:

$$\Delta G = \Delta deff \cdot \frac{D_0}{D} \cdot \frac{1-(D/D_h)^2}{1-(D_0/D)^2 \cdot (D/D_h)^2}$$

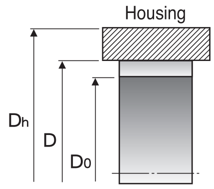
where，ΔG :Outer ring shrinkage mm

D_h :Housing bore diameter mm

D :Bearing outer ring outside diameter mm

D_0 : Bearing outer ring bore diameter mm

Δ_{deff} :Interference at fitting area mm



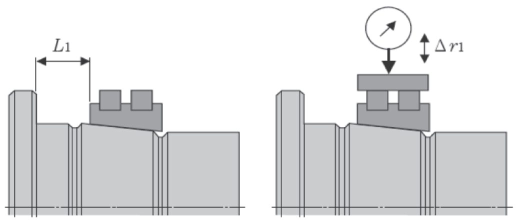
(b) Mount the bearing inner ring with the cage and rollers onto the tapered shaft shown in Fig. 8.13. In this process, force the inner ring until its tapered bore face is fully seated, and check that the bearing side face is square to the main spindle centerline. Calculate the estimated bearing clearance Δ1 after press-fitting the outer ring into the housing with the following formula:

$$\Delta_1 = \Delta_{r1} - \Delta G$$

where，Δ_1: Internal clearance after mounting μm

Δ_{r1}: Estimated bearing clearance μm

Fig.8.13 Measurement of bearing position and radial clearance



(c) To adjust the bearing clearance to a predetermined target value (δ) after mounting, determine the spacer width Ln with the following formula (Value f in the formula refer to Table 8.3)

$$L_n = L_1 + f(\delta - \Delta_1)$$

$(n=2, 3, 4 \ldots\ldots)$

where，L_1 : Distance between the shaft shoulder and inner ring side face mm

L_n: Spacer width mm

Fig.8.14 Clearance measurement after insertion of spacer

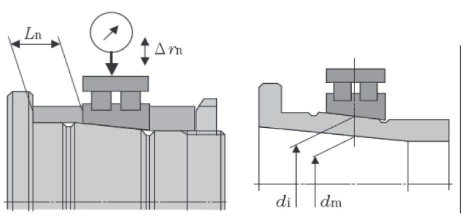


Table 8.3 Value *f*

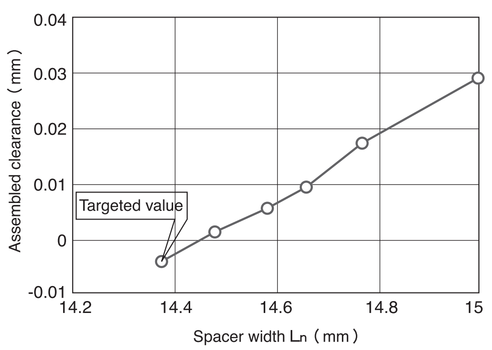
Value *dm / di*	Value *f*
0 ～0.2	13
0.2～0.3	14
0.3～0.4	15
0.4～0.5	16
0.5～0.6	17
0.6～0.7	18

(d) Insert a spacer that satisfies the spacer width Ln between the shoulder and inner ring determined in the previous step, and tighten the inner ring until the spacer does not move. Next, move the bearing outer ring up and down by hand and measure the internal clearance after mounting (post-mounting internal clearance) Δrn. The estimated bearing clearance Δn after press-fitting of the outer ring into the housing is determined with the formula below:

$$\Delta n = \Delta rn - \Delta G$$

(e) Repeat the steps above to gradually decrease the spacer width Ln so as to adjust the postmounting bearing clearance to the targeted clearance. By plotting the correlation between the spacer width and post-mounting clearance as illustrated in Fig. 8.15, the spacer width for the final targeted clearance will be more readily obtained.

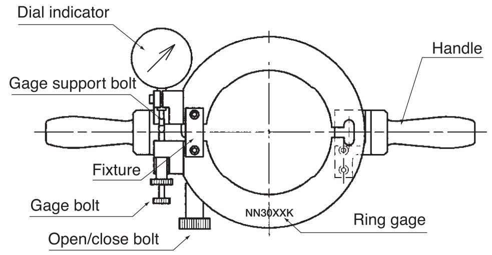
Fig.8.15 Correlation between spacer width *Ln* and post-mounting clearance Δn



8.6.2 Method with internal clearance gage

The mounted internal clearance gage has a cylindrical ring, which has a cut-out so that the ring can be opened and closed. The bore surface of the ring is used as a location for measurement. The clearance at the location for measurement is proportional to the reading on the dial indicator. As illustrated in Fig. 8.16, the clearance gage consists of a ring gage, dial indicator, and attachment components. Its fixture protects the interference gage against possible deformation when not in use. For the measuring operation, detach the fixture.

Fig.8.16 Internal clearance gage



Mount the outer ring into the housing and then measure the outer ring raceway diameter. Place the cylinder gage, onto the bore surface of clearance adjustment gage and adjust it with the open/close bolt. Insert the gage into the outside diameter portion of the roller set in the inner ring as shown in Fig.8.17. Be careful not to damage the rollers.

Tighten the shaft nut of the main spindle. This should be done gradually to prevent shock loading. Tightening the nut further until the reading on the dial of the clearance adjustment gage becomes at default value. Once the reading on gage gets zero, carefully swing the adjustment gage again to check that the measurement value is correct. By using a block gage, measure the distance between the inner ring side face and shaft shoulder (dimension l in Fig.8.17). Measure this dimension in at least three locations, and finally adjust the spacer width R to the average of three measurements.

It is note that the procedures for internal clearance gage should be referred to the instruction manual for the gauge. Besides, because of the structure of the mounted internal clearance adjustment gage, the ratio of the clearance reading on location for measurement to the reading on dial indicator is a specific value(clearance indication factor).

Fig.8.17 Spacer width dimension