Introduction

Mounting Procedure

The method of mounting rolling bearings strongly affects their accuracy, life, and performance.It is recommended that the handling procedures for bearings be fully analyzed by design and engineers and that standards be established with respect to following items:

1. Cleaning the bearings and related parts
2. Checking the dimensions of related parts
3. Mounting procedures
4. Inspection after mounting

Bearings should not be unpacked until immediately before mounting. However, bearings for instruments or for high speed operations must first be cleaned with clean filtered oil in order to remove the anti-corrosion agent.

After the bearings are cleaned with filtered oil, they should be protected to prevent corrosion. Prelubricated bearings must be used without cleaning.

Bearing mounting procedures vary according to the type of bearing and type of fit.

Since precision bearing are widely used for rotating shafts, their inner rings require a tight fit.

Bearings with cylindrical bores are usually mounted by fitting with a press (press fit), or by heating them to expand their inner ring (shrink fit). The outer ring is usually inserted into the housing with a loose fit. In case where the outer ring has an interference fit, a press may be used.

Precautions for Proper Handling of Bearings

Since rolling bearings are high precision machine parts, they must be handled accordingly.

Even if high quality bearings are used, their expected performance cannot be achieved if they are not handled properly. The main precautions to be observed are as follows:

■ Keep bearings and surrounding area clean

Foreign particles, even if invisible to the naked eye, have harmful effects on bearings. Take care to prevent the entry of dirt and debris into the bearing by maintaining a clean working environment.

■ Handle bearings carefully

Avoid any heavy shocks during handling. Shock loads can scratch or otherwise damage a bearing, possibly resulting in failure. An excessively strong impact may cause brinelling, breakage, or cracks.

■ Use proper tools

Always use the proper equipment when handling bearing. Do not use general purpose tools.

■ Prevent corrosion

Handling bearings with bare hands can corrode the bearing surfaces because of the acidic moisture or other contaminations on the hands.

Keep your hands clean when handling bearings, and wear dust free gloves whenever possible. Take measures to prevent rusting of bearing caused by moisture and corrosive gasses.

Storage method

■ Although bearings are coated with an anti-corrosion agent, and then wrapped and packed, it is impossible to completely avoid exposure to the air surrounding the bearings. Store the bearings in a dry location and avoid exposure to moisture and humidity.

■ Bearings should be stored in a clean, dry, and well-ventilated location that also provides protection from direct sunlight. Store the bearings in a locker or on shelves that are at least 30 cm from the floor.

■ When bearings are unpacked for acceptance inspection, take measure to prevent rusting and contamination. After inspection, follow the guidelines given above to ensure proper storage.

1. Cleaning the Bearings

Delivered bearings are coated with an anti-corrosion agent for dustproofing and prevention during transportation.

After opening the package, bearings need to be cleaned in order to remove the anti-corrosion agent.

Some bearings, such as sealed or pregreased bearings, can be used without cleaning.

■ Cleaning method ■

1. Use kerosene or light oil to clean the bearings.
2. Use separate tanks for rough cleaning and final cleaning. Each tank should be equipped with a wire rack to prevent direct contact of the bearing with any contamination that may have settled at the bottom.
3. In the rough cleaning tank, avoid rotating the bearings. After cleaning the outside surfaces with a brush, move the bearings to the final cleaning tank.
4. In the final cleaning tank rotate the bearing by hand. Make sure that the cleaning fluid in the final cleaning tank is kept clean.
5. Remove excess cleaning fluid from the bearings after cleaning.
   Bearings using ordinary grease lubrication need to be packed with grease. Oil lubricated bearings should be mounted on the machine tool spindle while take care not to rotate the bearing. Prior to mounting, slightly coat the bearing inner and outer surface areas with a thin film of lubrication oil.

2. Checking Dimension of Related Parts

Inspection of shaft and housing

■ Mating housing and shaft surfaces should be cleaned and checked for flows or burrs.

■ The dimensions of the shafts and housing bores should be checked to confirm a matching fit with the bearing bore and outer diameter. Recommended fits for shafts and housing bores are listed on Page 166.

■ Take measurements and mount the bearings in a thermostatic chamber. Parts should be left until they have reached a constant and stable temperature. Using a micrometer or cylinder gauge, take measurements at several different points to confirm there are no significant differences in measurement values. Recommended measurements for accuracy of the shafts and housing bores are listed on Page 167.

Inspection of spacers

For main spindle, a spacer parallelism of less than 0.003mm is recommended. Spacer parallelism exceeding this recommendation will tilt the bearings, thus causing inaccuracies and bearing noise.

3. Mounting of Procedures

Grease lubricated bearings and oil-air (oil mist) lubricated bearings which are cleaned are mounted on the shaft and housing bore. Procedures for mounting vary according to the fit requirements of the inner and outer rings. Primarily, it is the inner ring of a machine tool bearing that rotates, thus bearings with cylindrical bores are usually mounted by heating them to expand the inner ring (shrink fit).

Bearing with tapered bores can be mounted directly onto a tapered shaft. For high speed operations, GN gauges are recommended for attaining accurate radial clearance when mounting. Page 184 provides details on how to use GN gauges.

Outer rings are mounted with some clearance; so mounting tool are not usually required. The housing can be heated to make mounting much easier.

3.1. Mounting of Bearings with Cylindrical Bores

(1) Press fit

Fitting with a press is widely used for small bearings. First, apply a thin coat of oil to the mating shaft surface before mounting to help reduce the amount of force required for press fitting.

Next, place a mounting tool against the inner rings as shown in Fig. 1.1. Apply steady pressure from the mounting tool to drive the bearing firmly against the shoulder of the shaft.

Avoid press fitting onto a shaft by applying pressure to the outer rings as this may damege the bearing.

Also, avoid using a hammer when mounting precision bearings.

For separable bearings, such as cylindrical roller bearings, the inner and outer rings can be mounted onto the shaft and into the housing as separate units. When assembling the two units, When assembling the two units, take extra care to align the inner and outer rings correctly. Careless or forced assembly may cause scratches on the rolling contact surfaces.

(2) Shrink fit

Since press fitting large bearings requires a great deal of force, the shrink fitting method is widely used. The bearing are first heated to expand the inner ring before mounting onto the shaft. This method prevents excessive force from being imposed on the bearings and enables mounting them in a short time.

The expansion of the inner ring for various temperature differences and bearing size is shown in Fig. 1.2

The following precautions need to be taken when shrink fitting.

1. Do not heat bearings to more than 120°C.
2. Heat the bearings to a temperature 20°C to 30°C higher than the lowest temperature required for mounting without interference since the inner ring will cool a little during mounting.
3. After mounting, the bearings will shrink in the axial direction as well as the radial direction while cooling. Therefore, drive the bearing firmly up against the shaft shoulder using locating methods to eliminate any clearance between the bearing and shoulder.

Fig. 1.1 Press Fitting Inner Ring

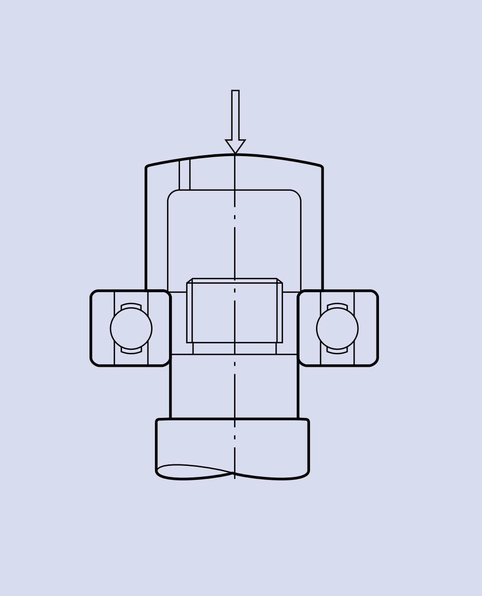
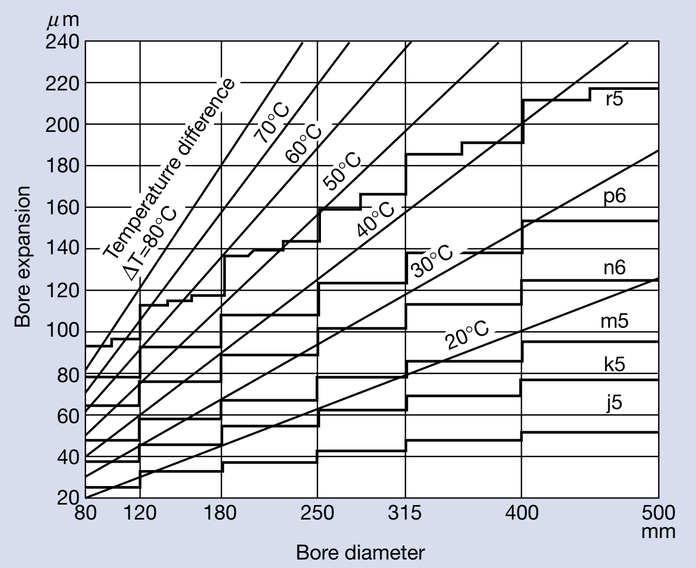


Fig. 1.2 Temperature and Thermal Expansion of Inner Ring

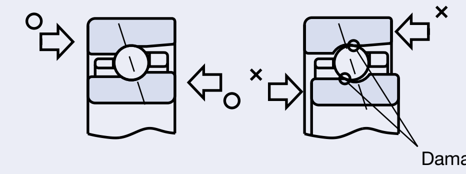


3.2. Precautions for Mounting Angular Contact Ball Bearings

Due to design restriction, an angular contact ball bearing can sustain loads in only one direction. Therefore, when mounting angular contact ball bearings onto the shaft or into the housing, it is imposing any loads in the wrong direction.

Pay special attention to the order of mounting for combination bearings. Mounting onto the shaft and into the housing is different for back-to-back and face-to-face arrangements.

Fig. 1.3 Direction of Load for Angular Contact Ball Bearings

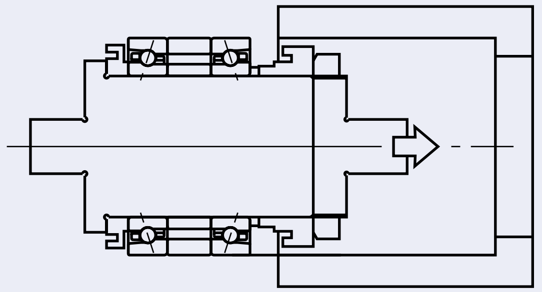


Load applied in direction "x" results in damage to the bearing.

Back-to-back arrangement:

① Press the bearing onto the shaft.
② Tighten the bearing locknut for preloading.
③ Insert the bearing and the shaft into the housing, and attach the retaining cover.

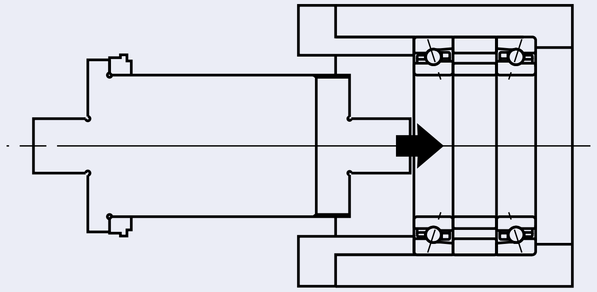
Fig. 1.4 Mounting of Back-to-back Arrangement



Face-to-face arrangement:

① Press the bearing into the housing.
② Secure the retaining cover for preloading.
③ Insert the shaft into the inner ring and tighten the bearing locknut.

Fig. 1.5 Mounting of Face-to-face Arrangement



Reverse the order of each step for dismounting.

3.3. Securing the bearing

(1) Securing the inner ring

The inner ring is usually secured onto the shaft by tightening the bearing locknut, which explains why perpendicularity of the threads and end face are very important. Even if accuracy as a single component is good, the gap between the shaft and locknut can result in runout of the locknut, causing the shaft and bearing to bend. (see Fig. 1.21, Page 189) Therefore, making adjustments are necessary to ensure constant running accuracy.

It is also important that the locknut be completely tightened so as to eliminate any possibility of it becoming loose. Seating torque information for bearing locknuts is shown in Table 1.1.

There is a risk of unbalance due to face and runout of the locknut or a minor inaccuracy of the mating parts. Here, sleeves are widely used in high speed, high precision machine tool spindles to secure the bearing to the shaft by a large interference fit between the shaft and sleeve bore. However, the sleeve tends to become loose after continuous operation, so it must be checked periodically.

When a wide spacer is used between combined angular contact ball bearings, and the seating torque of the locknut is excessive, the inner ring spacer may become deformed and alter the preload to a level higher than expected. It is necessary to consider this deformation when the preload is set.

(2) Securing the outer ring

A retaining cover held by bolts is generally used to secure the bearing outer ring axially. If a bolt is tightened excessively or a combination of bolts is tightened unevenly, the bearing outer ring may become deformed.

For example, Fig. 1.6 shows possible deformation of the outer diameter of the outer ring caused by uneven tightening of the retaining cover, when the outer ring end face is pressed as a pilot ring.

Fig. 1.7 shows an example of poor retaining cover tightening for a fixed end bearing resulting in outer ring deformation.

Fig. 1.8 shows deformation of an outer ring raceway surface caused by tightening of a double row cylindrical roller bearing.

The amount of deformation depends on the clearance of the mating parts. It is recommended that the clearance between the retaining cover and housing end face be adjusted to about 0.01 to 0.05 mm before the bolts are completely tightened.

Fig. 1.6 Raceway Surface Deformation Caused by Excessive Tightening

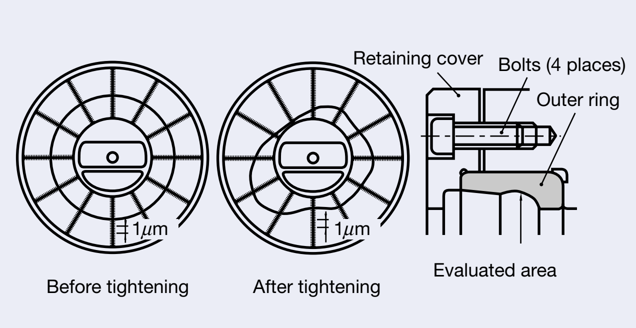


Fig. 1.7 Raceway Surface Deformation Caused by Excessive Tightening

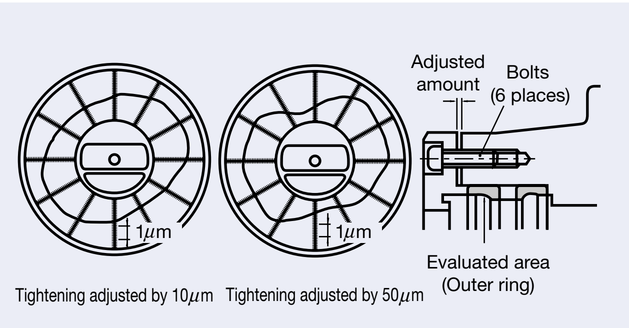


Fig. 1.8 Deformation of the Outer Ring of a Double Row Cylindrical Roller Bearing Caused Excessive Tightening

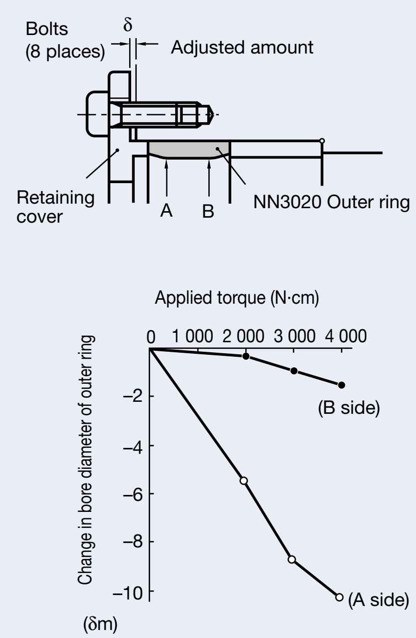


Table 1.1 Bearing Locknut Tightening Torque and Clearance between Retaining Cover and Housing

Nominal bearing bore (mm)	Locknut tightening force (N)	Locknut tightening torque Reference (N·m)	Clearance between retaining cover and housing (mm)
6		2	
8	1 500	2	
10		3	
12		7	
15	3 000	8	
17		9	
20		17	
25	4 900	21	
30		25	
35		57	
40	9 800	64	
45		72	
50		80	
55		132	0.01
60		142	–0.03
65	14 700	153	
70		166	
75		176	
80		251	
85		267	
90		281	
95		296	
100	19 600	311	
105		327	
110		343	
120		371	
130		403	
140		649	
150		695	
160		745	
170	29 400	796	
180		841	
190		886	0.03
200		932	–0.05
220		–	
240		–	
260	39 200	–	
280		–	
300		–	

When interference fit of the shaft increases under high speed operations, the amount of tightening torque applied to the locknut must also be increased.

The tightening force of Angular contact thrust ball bearing for ball screw support should be 2.5–3.0 times of the preload.

■ Conversion equation of locknut tightening torque

$$T=0.5F\left\{d_p\cdot\tan(p^*+\beta)+d_w\cdot\mu_w\right\}\quad[\text{N·mm}]$$

The values of locknut tightening torque in the table are calculated by friction coefficient of 0.15.

T :Locknut tightening torque [N·mm]
F :Locknut tightening force [N]
d_p :Effective diameter of locknut [mm]
p^* :Friction angle of locknut surface
$p^*=\tan^{-1}\mu_S$
μ_S :Friction coefficient of locknut surface
d_w :Frictional torque equivalent diameter at locknut surface [mm]
μ_w :Friction coefficient of locknut surface
β :Lead angle of nut
$\beta=\tan^{-1}(\text{pitch}/(3.142\cdot dp))$

■ Equation of push up force

$$K=\mu\cdot p_m\cdot\pi\cdot d\cdot B\quad[\text{N}]$$

$$p_m=\frac{E}{2}\frac{\Delta d}{d}\frac{(1-k^2)(1-k_0^2)}{1-k^2k_0^2}$$

μ :Friction coefficient at fitting surface [=0.12]
p_m :Surface pressure [MPa]
d :Shaft diameter [mm]
B :Bearing width [mm]
Δd :Effective interference [mm]
E :Young's modulus of steel [MPa]
k :Wall thickness ratio ($k=d/D_i$)
D_i :Raceway diameter of inner ring [mm]
k_0 :Wall thickness ratio of hollow shaft ($k_0=d_0/d$)
d_0 :Bore diameter of hollow shaft [mm]

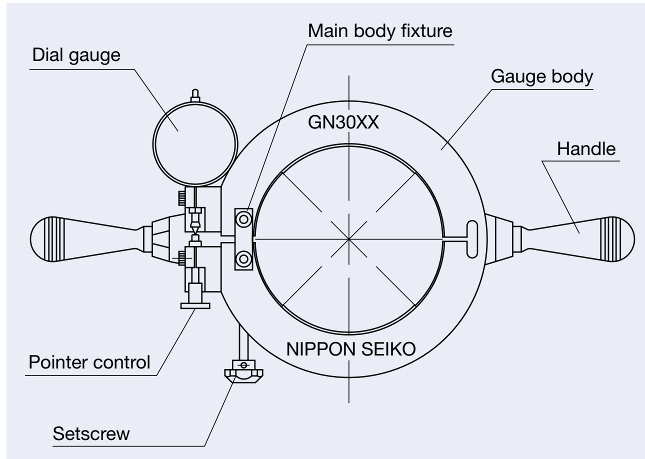
3.4. Mounting of Cylindrical Roller Bearings

(1) Measuring radial clearance of cylindrical roller bearings

A GN gauge is an instrument for matching the tapered section of a shaft to the tapered bore of a bearing when mounting a cylindrical roller bearing with a tapered bore onto a machine tool spindle. After mounting, the GN gauge is used for precise control of the bearing's radial internal clearance. This instrument is especially effective when a cylindrical roller bearing is used with radial preload.

Fig. 1.9 describes the GN gauge components.

Fig. 1.9 GN Gauge



How to use a GN gauge

① Insert outer ring into housing.

The recommended fit between outer ring and housing is:

Clearance 2μm - Interference 2μm

② Zero setting of cylinder gauge

Confirm that the temperatures are the same for the outer ring (inserted into the housing), the inner ring, and the shaft. Then, measure the bore diameter of the outer ring at about four different locations. Determine the average for the measurements and the cylinder gauge to zero (see Fig. 1.10).

Fig. 1.10 Zero Setting of Cylinder Gauge

③ Adjust the inscribed diameter of GN gauge

Loosen the bolt of the main body fixture on the GN gauge. Apply the cylinder gauge to the inscribed diameter surface of the GN gauge and adjust the setscrew to the setting of the dial on the cylinder gauge to zero (see step ②)

(Use the GN gauge in an upright position to avoid inaccuracies due to its own weight.)

④ Correction of GN gauge

Using the results from step ③, use the pointer control on the dial gauge to adjust the pointer on the GN gauge to the red mark for gauge correction. Confirm that the short needle is near 2 on the dial.

(Gauge correction corrects for elastic deformation of the roller due to measuring pressure on the gauge. The amount of correction for each gauge is determined upon shipment a gauge.)

Fig. 1.11 Adjust the Inscribed Diameter of the GN Gauge

⑤ Mounting of inner ring

Mount the inner ring onto the shaft and tighten the locknut lightly. Art this time, the bearings should be cleaned, but not yet coated with grease.

⑥ Setting of GN gauge

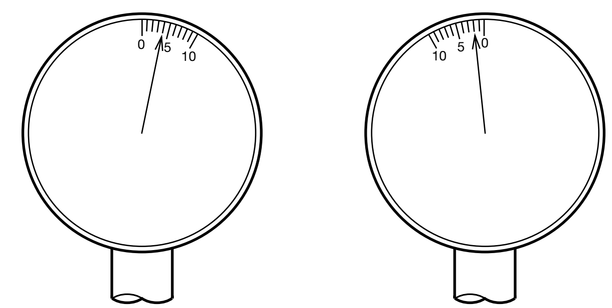
Adjust the setscrew on the GN gauge (0.2mm to 0.3mm on the dial face) to spread open the dial on the GN gauge. The GN gauge is placed in the center of inner ring and the setscrew is loosened.

⑦ Reading of the scale

Read the scale on the dial gauge of the GN gauge at this time.

Example 1: A half-shift of the dial from zero in the clockwise direction indicates positive clearance.

Example 2: A half-shift of the dial from zero in the counter-clockwise direction indicates negative clearance.



Example 1: Pointing to "4" in the clockwise direction indicates a radial crealance of +0.002mm

Example 2: Pointing to "2" in the counter-clockwise direction indicates a radial clearance of –0.001mm

⑧ Adjustment

In addition to procedures given in step ⑥, use the screw to spread the dial of the GN gauge. Remove the gauge from inner ring and tighten the locknut. Repeat steps ⑥ through ⑧ until the scale of the dial gauge reaches the target clearance value.

⑨ Adjustment of spacer

Measure the clearance between the shaft shoulder and the end face on the large diameter side of NN30XXKR by using block gauge. Measure more than three places on circumference to both an average and the finish width of spacer for that average.

Fig. 1.12 Insertion of Inner Ring

Fig. 1.13 Setting of GN Gauge

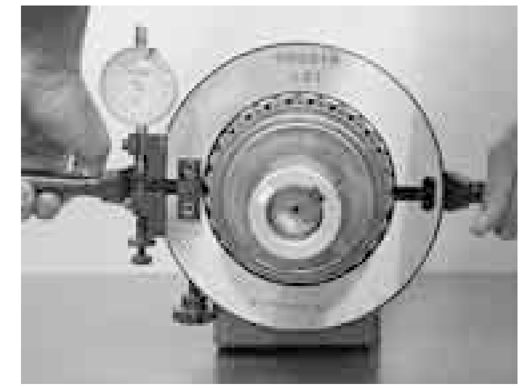
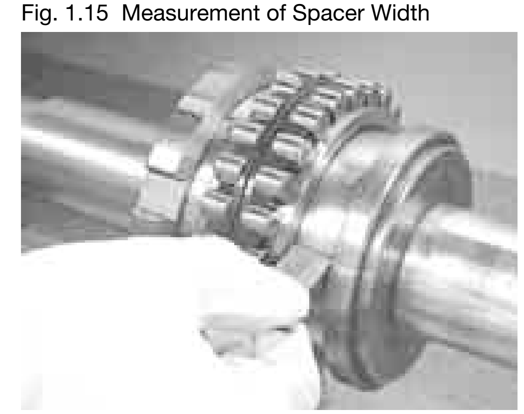


Fig. 1.14 Reading of the Scale

Fig. 1.15 Measurement of Spacer Width



(2) Measuring radial clearance of cylindrical roller bearings (GN gauge is not used)

When the GN gauge is not used, it is necessary to adjust the spacer width by considering the following two items:

- · Shrinkage of outer ring raceway diameter due to fitting in housing (Δr_e)
- · Expansion of the inner ring raceway diameter due to fitting, which includes a hollow shaft ratio. (Δr_i)

■ Calculation of Δr

The finish dimension (La) of the spacer, which is used for setting the post-mounting radial clearance of Δr, can be calculated as follows:

$$L_a = L - K(\Delta r_m - \Delta r + \Delta r_e)$$

Table 1.2 Hollow Shaft Ratio and Coefficient K

Hollow shaft Ratio k_0	Coefficient K
45–55%	14
55–65%	15
65–75%	16

L_a :Finish dimension of spacer for setting post mounting radial clearance
L :Width of block gauge (Measured result from step ⑤ on Page 187.)
Δr_m :Movement of the outer ring in radial direction (Measured result from step ④ on Page 187.)
Δr :Radial clearance after mounting
Δr_e :Shrinkage of outer ring raceway diameter due to fitting
K :Coefficient (Converted value which includes shrinkage of a hollow shaft with a 1/12 tapered hole)
k_0 :A/B×100
A: Shaft bore diameter B: Shaft outer diameter

■ Calculation of Δr_e

$$\Delta r_e = (D_h - D) \times h$$

when $\Delta r_e \geqq 0$ assume $\Delta r_e = 0$

D_h :Housing bore diameter
D :Outer diameter of outer ring (Refer to bearing inspection sheet)
h :Shrinkage rate of the outer ring raceway diameter
(0.62 for NN30 and N10 series)
(0.7 for NN39 and NN49 series)

Measuring of radial clearance of Δr_m

① Mount the inner ring onto the tapered section of the shaft. (At this point, degrease the tapered section of the shaft and internal surface of the inner ring with organic solvent.)

② Place the outer ring on circumscribing part of the rollers and apply the dial gauge to outer diameter of the outer ring.

③ Tighten the spacer and the locknut now to expand the inner ring. (see Fig. 1.16)

④ Push the outer ring in up and down and measure the radial movement of the outer ring with dial gauge (*1). Repeat steps ③ and ④ until play of the outer ring (Δr_m) becomes about 0.005mm. (*2) (Fig. 1.17)

⑤ When Δr_m is set at about 0.005mm, measure the distance from shaft shoulder to the inner ring end face (Dimension L) with block gauge and the thickness gauge. (*3) (see Fig. 1.18)

Remarks

(*1) If the measurement takes too long, the temperature of the outer ring may have risen to body temperature resulting in an erroneous measurement. Wearing gloves is recommended to for making a quick measurement.

(*2) If there is an excessive amount of play, the outer ring may have deformed into an ellipse when pressed by hand. This would result in an erroneous measurement. Therefore, 0.005mm of play is acceptable. (0.005mm is the target value, but 0.001mm to 0.002mm is also acceptable.)

(*3) For the measurement of dimension L, the value obtained is produced by inserting the block gauge in the left half of the zone shown in Fig. 1.18 (This is due to tilting that occurs between the shaft shoulder and inner ring end face.)

Fig. 1.16 Insertion of Outer Ring

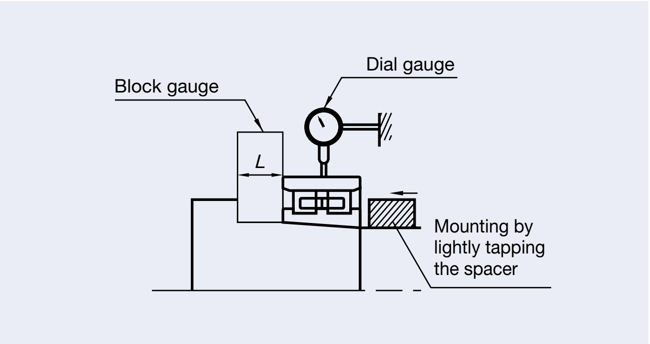


Fig. 1.17 Measuring Outer Ring Movement

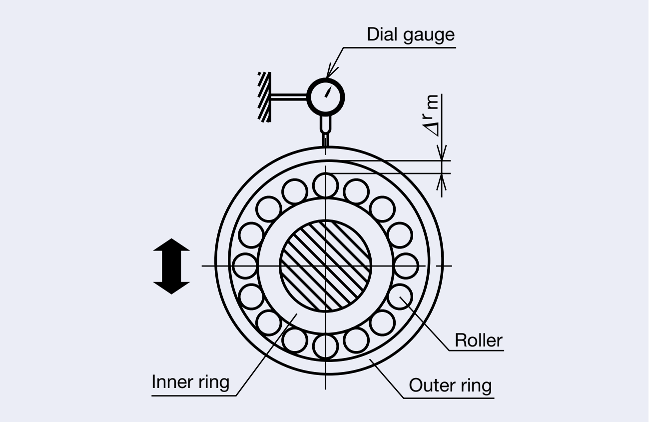
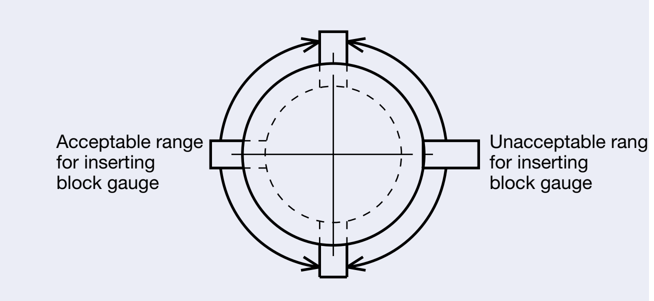


Fig. 1.18 Measuring Width Dimension with Block Gauge



(Example of calculation)

Setting radial clearance to Δr=–0.002mm for NN3020MBKR after mounting.

Shrinkage of outer ring raceway diameter due to fitting: Δr_e=–0.004 (Interference) (When $\Delta r_e \geqq 0$ assume Δr_e=0)
Movement of outer ring (Measured value in step ④) Δr_m=0.007mm
Block gauge width (Measured value in step ⑤) L=20.55mm

Finish spacer width dimension L_a=20.55–15×(0.007–(–0.002)–0.004)
=20.55–0.075
=20.475

Note the code!

3.5. Grease Packing

Procedure for packing grease after cleaning bearings

A rapid rise in temperature may occur during initial running in due to improper packing of grease. This can result in a long running in period, or lead to seizure and bearing failure. Following proper procedures for packing grease and using the correct amount of grease deserves careful attention. Recommended procedures are as follows:

(1) Pre-inspection

Check to ensure there is no foreign matter in the bearing interior. Bearings for high speed spindle shafts should be cleaned, degreased, and packed with grease. For other applications, remove any anti-corrosion agent adhering to interior surfaces of the bearings.

(2) Grease dispensers

Use a grease dispenser, such as a plastic syringe for precision grease dispensing. If possible, use a dispenser that comes with a gauge for packing accurate amounts of grease.

(3) Amount of grease

Recommended amounts of grease packing for precision bearings:

Angular contact ball bearings for high speed machine tool spindles: 15%±2% of internal space

Cylindrical roller bearings for high speed machine tool spindle: 10%±2% of internal space

Ball bearings for motors: 20% to 30% of internal space

Recommendation of grease amount for various bearing types and numbers is shown on Page 157.

■ Packing method for ball bearings

(1) Pack grease evenly between the balls. If an outer ring guided cage is used, such as a phenolic resin cage, apply a light coating of grease on the guided surface.

(2) Rotate the bearing by hand to spread grease evenly on the surfaces of the raceway, ball, and cage.

■ Packing method for cylindrical roller bearings

(1) Coat about 80% of the grease amount evenly on roller rolling surface. Avoid putting too much grease on the cage bore. Grease on the cage bore is difficult disperse during the running in period, which can result in a rapid rise in temperature or a long running in period.

(2) Coat roller surfaces with a thin film of grease, including the roller end faces, roller cage contact points, and along the face edges of each cage pocket.

(3) Using the remaining 20% of grease, apply a thin film of grease to the raceway surface of the outer ring.

Fig. 1.19 Grease Packed Angular Contact Ball Bearing

Fig. 1.20 Grease Packed Cylindrical Roller Bearing

4. Inspection after Mounting

4.1. Runout accuracy

Accurate mounting and related parts are indispensable to ensure precision and accuracy of the machine tool spindle.

1: Assembled bearing outer ring face runout with raceway for angular contact ball bearings

Adjust to 0.002mm or less by tapping on the outer ring end face.

2: Variation of bearing outside surface generatrix inclination with outer ring reference face for angular contact ball bearings

Adjust to 0.005mm or less tilting the locknut. (see Fig. 1.21)

3. Concentricity of rear side housing 0.010mm or less

If these accuracies cannot be met, disassembled the bearings and check the accuracy of parts again.

Fig. 1.21 Tilting the Shaft Locknut

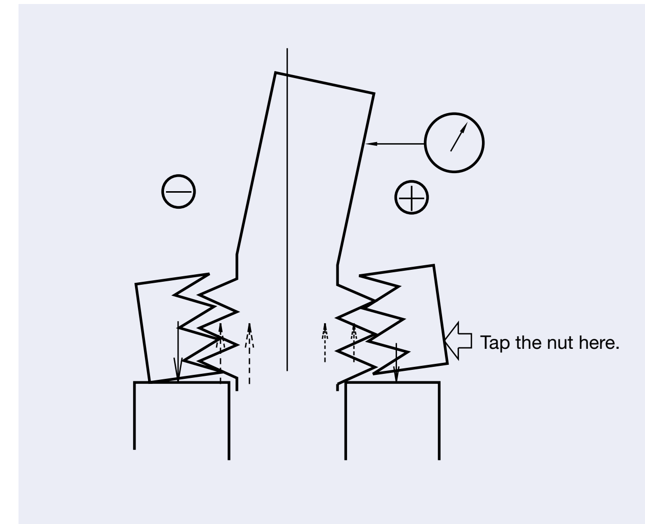
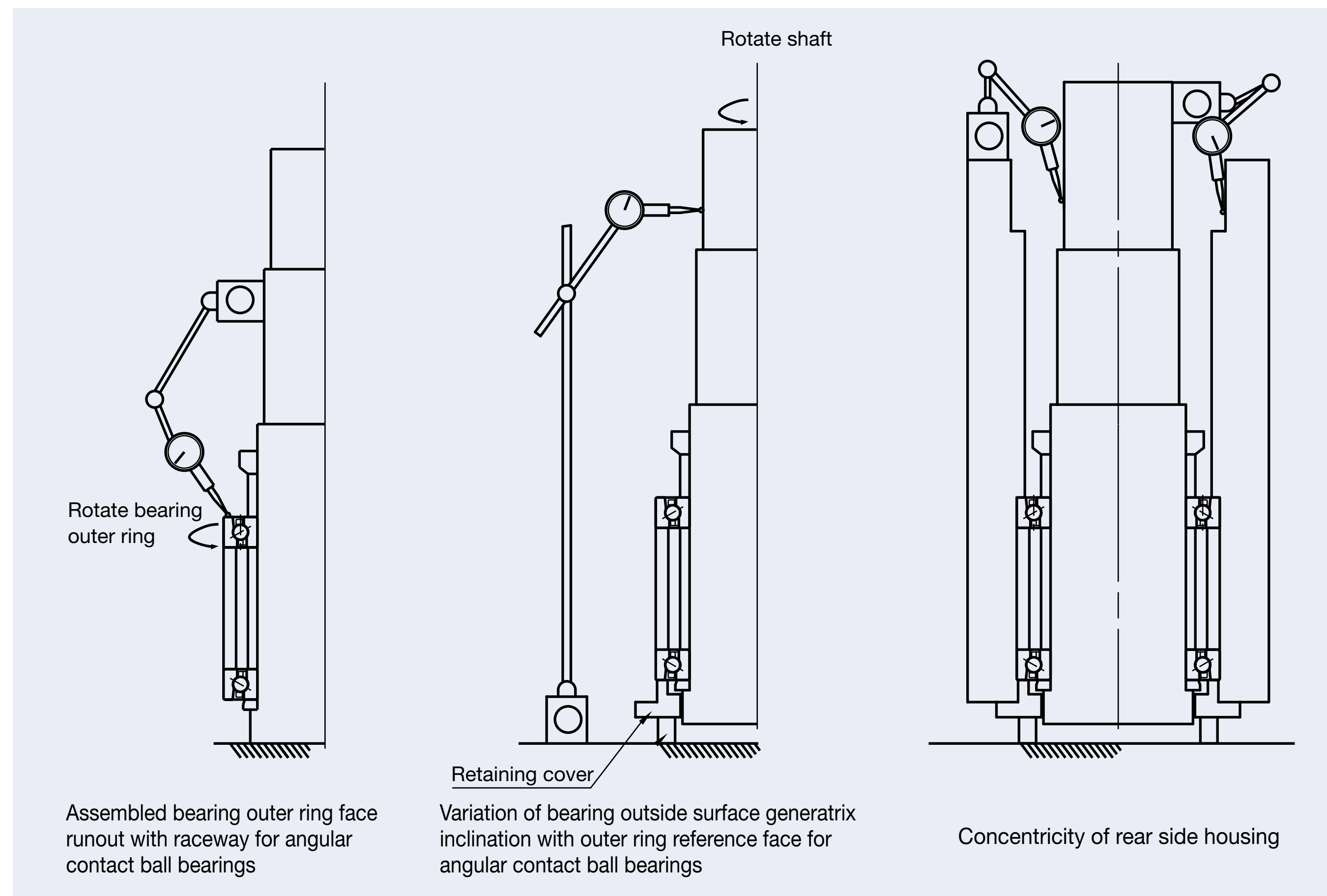


Fig. 1.22 Runout Accuracy of Machine Tool Spindle



4.2. Control of Preload after Mounting of Bearing

If the preload of rolling bearing is set larger, the rigidity of bearing is increased, but heat generation is also increased, and in extreme cases, seizure may occur. Therefore, it is necessary to control optimum preload carefully in response to operating condition. Measuring method of preload for angular contact ball bearing is introduced below. For the preload of cylindrical roller bearing, it is recommended to control by using GN gauge at mounting process. (see Page 184)

Measuring of preload for angular contact ball bearing

There are three methods for checking preload of bearings after mounting onto main shaft, such as starting torque method, thrust static rigidity method, and natural frequency method.
Features of these methods are summarized in Table 1.3.

Table 1.3

	Starting torque method	Thrust static rigidity method	Natural frequency method
Advantage	**Used for heavy preload,** If starting torque is high, measurement error is small.	**Used for light preload**	**Measurement accuracy is high. Good repeatability.**
Disadvantage	**Not good for light preload.** If starting torque is small, variation of measurement is large.	**Not good for heavy preload.** Loading equipment is too large scale. Affected easily by deformation of contact part other than bearing.	**Influence of spindle fixing condition should not be ignored.**

(1) Starting torque method

[Characteristic]

High speed main shaft spindle bearings are often used with light preload so that starting torque is low and measurement error is large.

[Method]

Starting torque is obtained mainly by measuring tangential force. (see Fig. 1.23)
Preload is obtained from the relationship between measured starting torque and preload. (see Fig. 1.24)

When oil film formation in rolling contact area is unstable during measurement, sticking occurs. (Rotation does not start even under tangential force and rotation starts suddenly when tangential force is increased gradually). The torque at such occasion tends to be higher than predicted calculated torque so that excessive measurement result needs to be excluded.

Fig. 1.23 Starting Torque Method

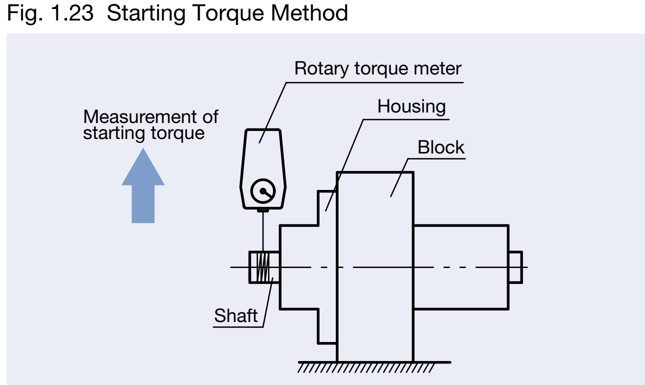
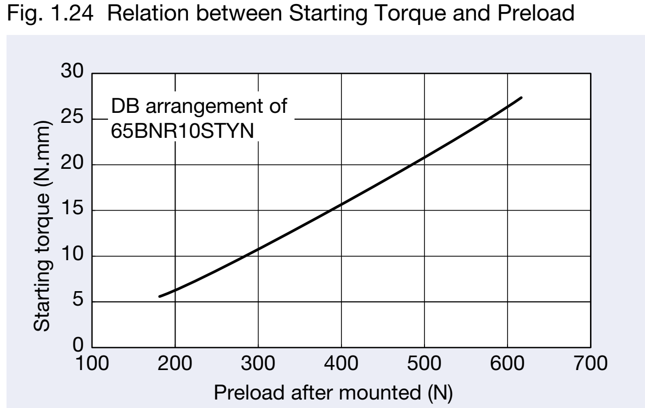


Fig. 1.24 Relation between Starting Torque and Preload



(2) Thrust static rigidity method

[Characteristic]

When axial rigidity of the bearing is high, axial force necessary for measurement becomes very high and loading equipment is necessary. (Example: If axial rigidity is 200N/μm, 2 000N load is needed to generate 10μm displacement.) When measurement load is large, besides elastic deformation of bearing interior, effect of surface deformation and elastic deformation of other related parts are added. Measured rigidity tends to be lower than theoretical value and error often occurs.

[Method]

Thrust load is applied to shaft and its axial displacement is measured for obtaining preload. (see Fig. 1.25 1.26)

(3) Natural frequency method

[Characteristic]

Measuring sensitivity is the highest and repeatability is good, but tend to be affected by spindle fixing condition.

[Method]

Shaft is vibrated in axial direction and resonance frequency of shaft is measured at the same time. Preload can be obtained by the resonance frequency. (see Figs. 1.27 and 1.28)

Measurement of resonance frequency (F_z) for main shaft in axial direction

↓ Convert

Axial spring constant of main shaft

↓ Convert

Preload after mounted

$$F_z = \frac{1}{2\pi}\sqrt{\frac{K_a}{m}} \times 1\,000$$

K_a : Axial spring constant of bearing (N/μm)
F_z : Resonance frequency (Hz)
m : Mass of rotating body (kg)

Fig. 1.25 Thrust Static Rigidity Method

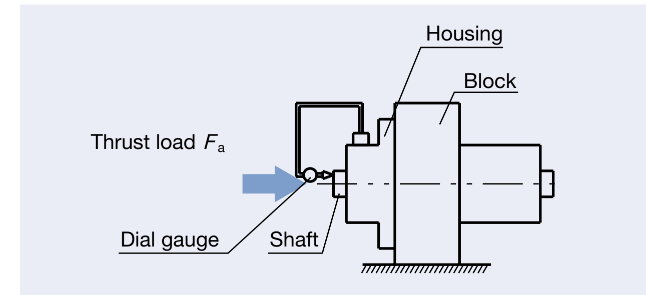


Fig. 1.26 Relation between Axial Displacement and Preload

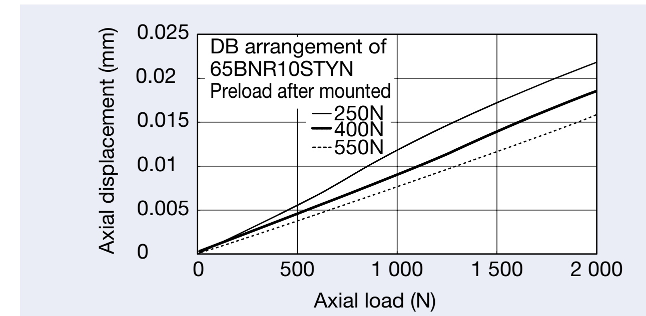


Fig. 1.27 Natural Frequency Method

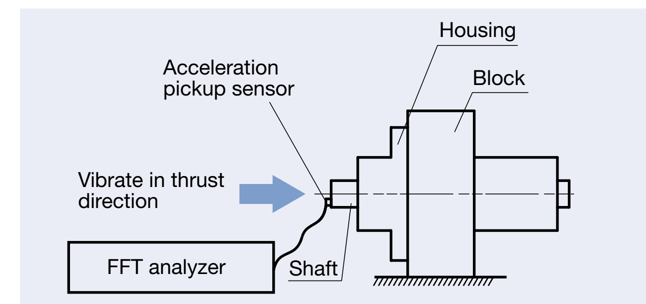
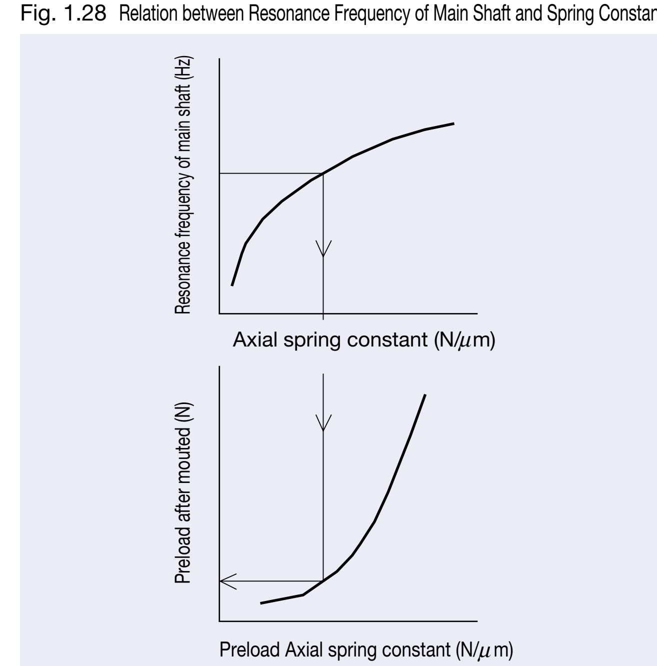


Fig. 1.28 Relation between Resonance Frequency of Main Shaft and Spring Constant



Mounting

Preparations

The following running in procedures are necessary after properly mounting of bearing.

■ Balance of Shaft and Assmbly

Any unbalance of rotating components will cause repeated stress or excessive vibrations due to centrifugal force. This is especially true for spindles, which are operated at a $d_m n$ value of 1 000 000 or higher. Therefore, it is imperative that both the shaft assembly are well balanced.

■ Spindle Assembly

Spindle assemblies with a V-belt drive should have misalignment of the spindle pulley center and motor pully center corrected to a target of 0.1mm or less. Coupling joints should have misalignment of the spindle shaft center and motor shaft center corrected to a target of 0.01mm or less.

Initial Running Procedure Method

If operating speed is suddenly increased after the bearing is mounted, the operating temperature will rise abruptly and bearing failure may occur. Grease lubricated bearings, especially, require that you follow proper running in procedures. Increase operating speed gradually to completely orient the initially filled grease on each contact surface raceway. Running should be conducted under ambient temperature conditions (15°C to 25°C) while monitoring bearing temperature.

Maximum operating temperature of the spindle housing exterior should be targeted at about 50°C. Do not to exceed 55°C. If a rapid temperature increase occurs, temporarily stop the running in process or decelerate to lower the temperature. Some spindle assemblies incorporate both cylindrical roller bearings and angular contact ball bearing. Since cylindrical roller bearings tend to experience a more rapid temperature increase in comparison with ball bearings, timing of speed increases must be set to correspond with the roller bearings.

[Caution]

Spindle assemblies operating under oil mist and oil air lubricating conditions risk a sudden temperature rise at initial operation, or after the spindle assembly has not been operated for a long time. Excess oil that has collected in the oil lines of the lubrication system may suddenly flood the bearing interior, causing a temperature spike. Performing running in procedures for bearings with these lubricating systems require much less time than grease-based systems, and is highly recommended.

(1) Continuous running procedure

[Feature]

Continuous running works by gradually increasing operating speed from the low speed zone. Although somewhat time consuming, this procedure helps machine operators to detect potential problems related to the main shaft, thus avoiding costly damege to the bearings.

[Method]

Maximum operating speed of the application is achieved by repeating several steps in a cycle.

Step 1. Begin at a reasonably low operating speed.

Step 2. Monitor for temperature rise.

Step 3. Stable temperature is reached.

Step 4. Continue incremental increases of operating speed.

Continue repeating the above cycle until an equilibrium temperature is reached at the maximum operating speed and divide it into ten stages to determine the target speed for each stage. Then, repeat above cycle for one or two hours until the target speed is reached for that stage. Move up to the next stage and repeat the above cycle until you reach the next target speed.

Fig. 2.1 Temperature Change of Constant Speed running Operation

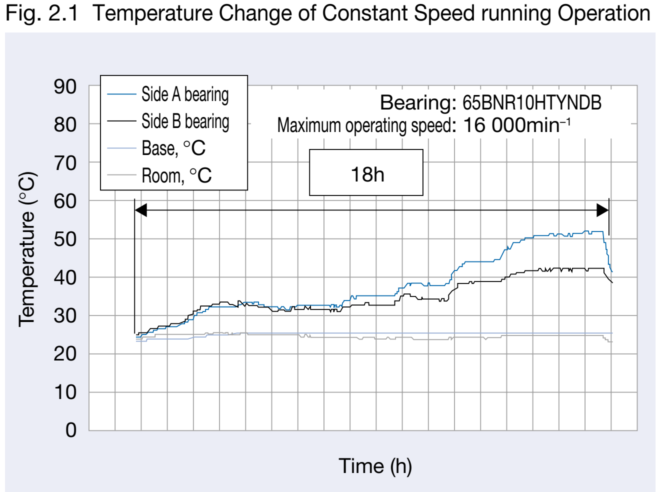
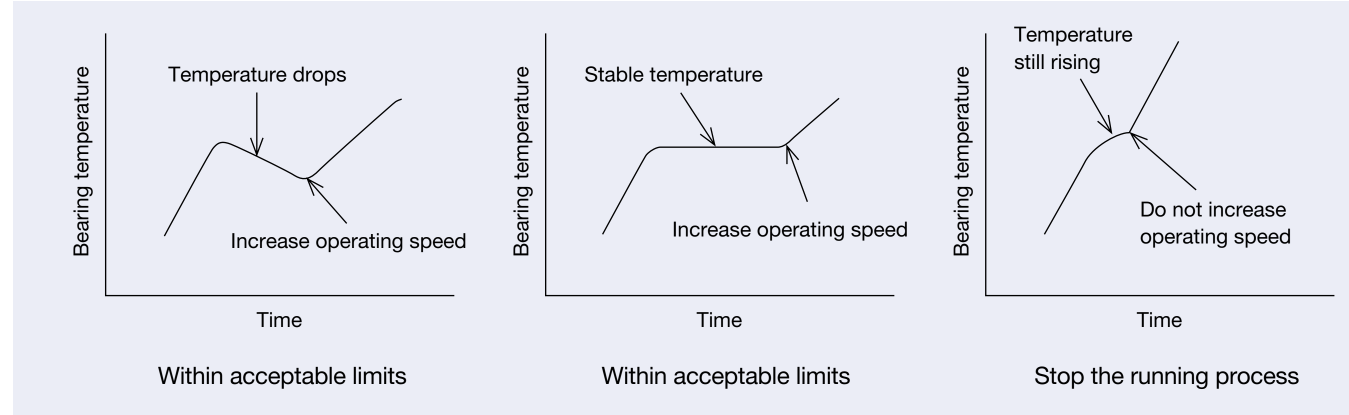


Fig. 2.2 Increase of Operating Speed Continuous Running



Increase operating speed when temperature rise characteristics are within limits.

(2) Intermittent Running procedure

[Feature]

Intermittent Running in works by stopping operation and stabilizing temperatures before there is a rapid temperature rise, which is caused by a sudden supply of grease to the bearing interior during initial operation. This procedure allows us to shorten the amount of time required for running in. Procedures for intermittent running in vary from machine to machine and bearing arrangements. Be sure to confirm the bearing arrangement for each spindle application.

[Method]

First, take the maximum operating speed and divide it into eight or ten stages to determine the maximum target speed for each stage. Each stage is divided into 10 cycles that are approximately one minute long.

During each cycle, rapidly accelerate the spindle assembly to the target speed for the current stage decelerate back to zero. Repeat this cycle about 10 times. Move up to the next stage and repeat the above cycle 10 times for the target speed of that stage.

Fig. 2.3 shows temperature rise data for a bearing with a maximum operating speed of 16 000min^{-1}. The maximum speed was divided into 8 stages with 10 cycles each of rapid acceleration and deceleration. Fig. 2.4 shows an example of 1 cycle. And it is desirable to make it rotate slowly by about 500min^{-1} for 15 minutes, and to familiarize grease and before operating start. As for after an operation end, it is desirable tp perform fixed operation about 1 hour at maximum speed.

Fig. 2.3 Temperature Change of Intermittent Running Operation

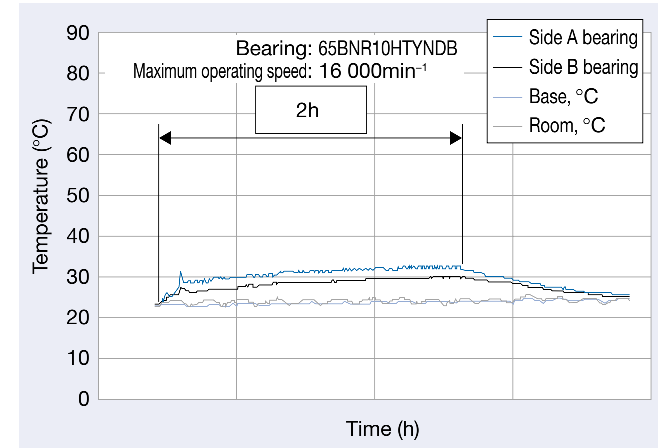
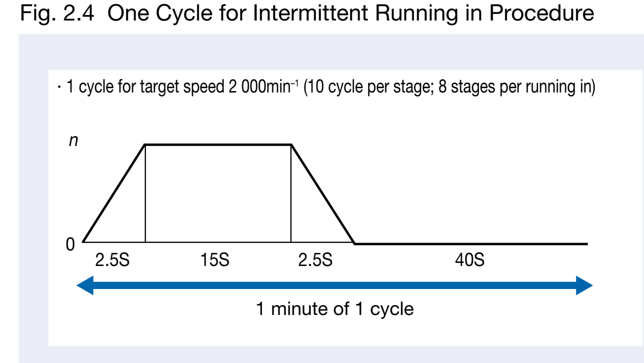


Fig. 2.4 One Cycle for Intermittent Running in Procedure



Operating Inspection

After mounting has been completed, a test run should be conducted to determine if the bearing has been mounted correctly. Small equipment may be manually operated to assure that they rotate smoothly. Items to be checked include sticking due to foreign matter, visible flaws, uneven torque caused by improper mounting, or an improper mounting surface. Other items include excessive torque caused by an inadequate clearance, mounting errors, or seal friction.

If there are no abnormalities, then a powered test run can be started. For high-speed equipment, perform running in procedures before a powered test run (Page 192-193). A powered test run should be started slowly without load. Make close observations to determine whether or not abnormalities exist. If everything seems satisfactory, then gradually increase the speed, load, erc., until normal operating conditions are reached.

During a test run operation, check for abnormal noise, excessive rise of bearing temperature, leakage and contamination of lubricants, etc. If any abnormality is found, stop the test run immediately and inspect the machinery. If necessary, the bearing should be dismounted for examination as well. Although the temperature of the outside surface of the housing can generally help determine bearing temperature, it is better to directly measure the temperature of the outer ring using oil holes for access. The bearing temperature should rise gradually to a steady level within one or two hours after operation starts. If the bearing experiences trouble, or if an error was made in mounting, the bearing temperature may increase rapidly and become abnormally high. The cause of this abnormal temperature may be an excessive amount of lubricant, insufficient bearing clearance, incorrect mounting, or excessive friction of the seals. In the case of high speed operations, an incorrect selection of bearing type or lubricating method may also cause an abnormal temperature rise.

Bearing noise can be checked with an acoustic or other instruments. Abnormal conditions are indicated by a loud metallic sound, or other irregular noise. Possible causes include incorrect lubrication, poor alignment of the shaft and housing, or the entry of foreign matter into the bearing. Possible causes and countermeasures for irregularities are listed in Table 3.1.

■NSK Bearing Monitor■

Bearing abnormality detector

It is important to detect signs of irregularities early on during operations before damege becomes severe. The NSK Bearing Monitor is an instrument that monitors the condition of bearing and issues a warning of possible abnormalities. It can prevent serious trouble. The NSK Bearing Monitor enhances proper maintenance and reduces costs.

Table 3.1 Cause and Countermeasures for Operating Irregularities

Irregularities		Possible cause	Countermeasures
Noise	Loud metallic sound (1)	Abnormal load	Improve the fit, internal clearance, preload,position of housing shoulder, etc.
		Incorrect mounting	Improve the machining accuracy and alignment of shaft and housing, accuracy of mounting method.
		Insufficient or improper lubricant	Replenish the lubricant or select another lubricant.
		Contact of rotating parts	Modify the labyrinth seal, etc.
	Loud regular sound	Dents generated by foreign matters, corrosion, flaws, or scratches on raceways	Replace or clean the bearing, improve the seals, and use clean lubricant.
		Brinelling	Replace the bearing, and use care when handling bearings.
		Flaking on raceway	Replace the bearing.
	Irregular sound	Excessive clearance	Improve the fit, clearance, and preload.
		Penetration of foreign particles	Replace or clean the bearing, improve the seals, and use clean lubricant.
		Flaws or flaking on balls	Replace the bearing.
Abnormal temperature rise		Excessive amount of lubricant	Reduce amount of lubricant, or select stiffer grease.
		Insufficient or improper lubricant	Replenish lubricant or select a better one.
		Abnormal load	Improve the fit, internal clearance, preload, or position of housing shoulder.
		Incorrect mounting	Improve the machining accuracy and alignment of the shaft and housing, accuracy of mounting, or mounting method.
		Creep on fitted surface, excessive seal friction	Correct the seals, replace the bearing, or correct the fitting or mounting.
Vibration (Radial runout of shaft)		Brinelling	Replace the bearing and use care when handling bearing.
		Flaking	Replace the bearing.
		Incorrect mounting	Correct the squareness between the shaft and housing shoulder or side of spacer.
		Penetration of foreign particles	Replace or clean the bearing, improve the seals.
Leakage or discoloration of lubricant		Too much lubricant. Penetration by foreign matter or abrasion chips	Reduce the amount of lubricant, select a stiffer grease. Replace the bearing or lubricant. Clean the housing and adjacent parts.

Note (1) Squeaking may arise from grease lubricated ball bearings or cylindrical roller bearings (medium to large sized). This is especially true during winter when temperatures are low. In general, even though squeaking may occur, the bearing temperature will not rise, leaving fatigue or grease life unaffected. Consequently, such a bearing can continue to be used. If you concerns regarding squeaking noise, please contact NSK.

Maintenance, Inspection and Correcting Irregularities

In order to maintain the original performance of a bearing for as long as possible, proper maintenance and inspection should be performed. If proper procedures are used, many bearing problems can be avoided and the reliability, productivity, and operating costs of the equipment containing the bearings are all improved. It is suggested that periodic maintenance be done following the procedure specified. This periodic maintenance encompasses the supervision of operating conditions, the supply or replacement of lubricants, and regular periodic inspection.

Items that should be regularly checked during operation include bearing noise, vibration, temperature, and lubrication. If an irregularity is found during operation, the cause should be determined and the proper corrective actions should be taken after referring to Table 3.1.

If necessary, the bearing should be dismounted and examined in detail.

Bearing Failure and Countermeasures

In general, if rolling bearings are used correctly they will survive to their predicted fatigue life.

However, they often fail prematurely due to avoidable mistakes. In contrast to fatigue life, this premature failure is caused by improper mounting, handling or lubrication, entry of foreign matter, or abnormal heat generation. For instance, the causes of rib scoring, as one example, use of improper lubricant, faulty lubricant system, entry of foreign matter, bearing mounting error, excessive deflection of the shaft, or any combination of these. Thus, it is difficult to determine the real cause of some premature failures. If all the conditions at that time of failure and previous to the time of failure are known, including the application, the operating conditions, and environment; then by studying the nature of the failure and its probable causes, the possibility of similar future failures can be reduced. The most frequent types of bearing failure, along with their causes and corrective actions, are listed in Table 3.2.

Table 3.2 Causes and Countermeasure for Bearing Failure

Type of failure	Probable causes	Countermeasures
Flaking		
Flaking of one-side of the raceway of radial bearing	Abnormal axial load.	A loose fit should be used when mounting the outer ring of free-end bearings to allow axial expansion of the shaft.
Flaking pattern inclined relative to the raceway in radial ball bearings Flaking near the edge of the raceway and rolling surface in roller bearing	Improper mounting, deflection of shaft, inadequate tolerances for shaft and housing.	Use care in mounting and centering, select a bearing with a large clearance, and correct the shaft and housing shoulder.
Flaking of raceway with same spacing as rolling element	Large shock load during mounting, rusting while bearing is out of operation for prolonged period.	Use care in mounting and apply a rust preventive when machine operation is suspended for a long time.
Premature flaking of raceway and rolling element	Insufficient clearance, excessive load, improper lubrication, rust, etc.	Select proper fit, bearing clearance, and lubricant.
Premature flaking of duplex bearings	Excessive preload.	Adjust the preload.
Scoring		
Scoring or smearing between raceway and rolling surface	Inadequate initial lubrication, excessively hard grease and high acceleration when starting.	Use a softer grease and avoid rapid acceleration.
Scoring or smearing between the end face of the end face of the rollers and guide rib	Inadequate lubrication, incorrect mounting and large axial load.	Select proper lubricant and modify the mounting.
Cracks		
Crack in outer or inner ring	Excessive shock load, excessive interference in fitting, poor surface cylindricity, improper sleeve taper, large fillet radius, development of thermal cracks and advancement of flaking.	Examine the loading conditions, modify the fit of bearing and sleeve. The fillet radius must be smaller than the bearing chamfer.
Crack in rolling element Broken rib	Advancement of flaking, shock applied to the rib during mounting or dropped during handling.	Be careful in handling and mounting.
Fracture cage	Abnormal loading of cage due to incorrect mounting and improper lubrication.	Reduce the mounting error and review the lubricating method and lubricant.
Indentations		
Indentations in raceway in same pattern as rolling elements	Shock load during mounting or excessive load when not rotating.	Use care in handling.
Indentations in raceway and rolling elements.	Foreign matter such as metallic chips or sand.	Clean the housing, improve the seals, and use a clean lubricant.
Abnormal wear		
False brinelling (phenomenon similar to brinelling)	Vibration of the bearing without rotation during shipment or rocking motion of small amplitude.	Secure the shaft and housing, use oil as a lubricant and reduce vibration by applying a preload.
Fretting Limited part wear with reddish-brown wear dust at fitting surface	Slight wear of the fitting surface.	Increase interference and apply oil.
Wearing of raceway, rolling elements, rib, and cage	Penetration by foreign matter, incorrect lubrication, and rust.	Improve the seals, clean the housing, and use a clean lubricant.
Creep Scoring wear at fitting surface	Insufficient interference, Insufficient tightened sleeve.	Increase interference, proper tightening of sleeve.
Seizure		
Discoloration and melting of raceway, rolling elements and ribs	Insufficient clearance, incorrect lubrication, or improper mounting.	Review the internal clearance and bearing fit, supply an adequate amount of the proper lubricant and improve the mounting method and related parts.
Corrosion & Rust		
Rust and corrosion of fitting surfaces and bearing interior	Condensation of water from the air, or fretting. Penetration by corrosive substance (especially vanish-gas, etc).	Use care in storing and avoid high temperature and high humidity, treatment for rust prevention is necessary when operation is stopped for long time. Selection of vanish and grease.