BEARING HANDLING AND MAINTENANCE

Part B

BEARING HANDLING AND MAINTENANCE

1. BEARING HANDLING

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1.1 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:

(1) Keep Bearings and Surrounding Area Clean

Dust and dirt, even if invisible to the naked eye, have harmful effects on bearings. It is necessary to prevent the entry of dust and dirt by keeping the bearings and their environment as clean as possible.

(2) Careful Handling

Heavy shocks during handling may cause bearings to be scratched or otherwise damaged possibly resulting in their failure. Excessively strong impacts may cause brinelling, breaking, or cracking.

(3) Use Proper Tools

Always use the proper equipment when handling bearings and avoid general purpose tools.

(4) Prevent Corrosion

Since perspiration on the hands and various other contaminants may cause corrosion, keep the hands clean when handling bearings. Wear gloves if possible. Pay attention to rust of bearing caused by corrosive gasses.

1.2 Bearing Storage

To prevent rusting, each bearing is treated and packed with an anticorrosive agent, but depending on the environment of the storing place, the effectiveness of the corrosion countermeasures varies greatly.
Careful attention is necessary to select a suitable place to keep and stock replacement bearings.

1.2.1 Bearing Storage Location

Bearings shall be stocked indoors in a place that is not exposed to wind or rain. Also, an indoor environment where temperature and/or humidity is high would be unsuitable for storage, because such a place would deteriorate the anticorrosion effect. Be sure to stock the bearings in a place where environmental temperature variation is small.

1.2.2 How to Store Bearings

After considering the size and weight of bearing to be stocked, secure enough space and proper carrying equipment to transport the bearing safely. It is recommended to provide proper storing shelves to stock bearings. The lowest tray of the storing shelves shall be at least 30 cm above the floor. Please avoid putting bearings directly on the floor.
The anticorrosive effectiveness of the package varies depending on the storing environment, but it is generally effective for about one to three years. Due to some special reason, if storing of the bearing for a longer time, or even up to nearly ten years is necessary, then a special storage method must be used. One such method is to immerse the bearing in a turbine oil which prevents corrosion.

1.3 Mounting

The method of mounting rolling bearings strongly affects their accuracy, life, and performance, so their mounting deserves careful attention. Their characteristics should first be thoroughly studied, and then they should be mounted in the proper manner. It is recommended that the handling procedures for bearings be fully investigated by the design engineers and that standards be established with respect to the following items:

(1) Cleaning the bearings and related parts.
(2) Checking the dimensions and finish of related parts.
(3) Mounting
(4) Inspection after mounting.
(5) Supply of lubricants.

Bearings should not be unpacked until immediately before mounting. When using ordinary grease lubrication, the grease should be packed in the bearings without first cleaning them. Even in the case of ordinary oil lubrication, cleaning the bearings is not required. However, bearings for instruments or for high speed operation 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 methods depend on the bearing type and type of fit. As bearings are usually used on rotating shafts, the inner rings require a tight fit.
Bearings with cylindrical bores are usually mounted by pressing them on the shafts (press fit) or heating them to expand their diameter (shrink fit). Bearings with tapered bores can be mounted directly on tapered shafts or cylindrical shafts using tapered sleeves.
Bearings are usually mounted in housings with a loose fit. However, in cases where the outer ring has an interference fit, a press may be used. Bearings can be interference-fitted by cooling them before mounting using dry ice. In this case, a rust preventive treatment must be applied to the bearing because moisture in the air condenses on its surface.

1.3.1 Mounting of Bearings with Cylindrical Bores

(1) Press Fits

Fitting with a press is widely used for small bearings. A mounting tool is placed on the inner ring as shown in Fig. 1.1 and the bearing is slowly pressed on the shaft with a press until the side of the inner ring rests against the shoulder of the shaft. The mounting tool must not be placed on the outer ring for press mounting, since the bearing may be damaged. Before mounting, applying oil to the fitted shaft surface is recommended for smooth insertion. The mounting method using a hammer should only be used for small ball bearings with minimally tight fits and when a press is not available. In the case of tight interference fits or for medium and large bearings, this method should not be used. Any time a hammer is used, a mounting tool must be placed on the inner ring.

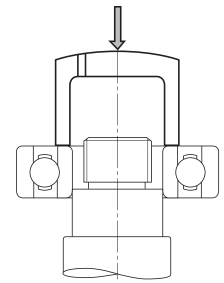


Fig. 1.1 Press Fitting Inner Ring

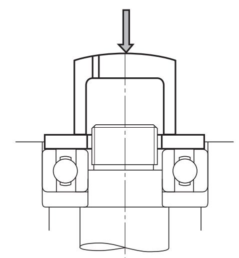


Fig. 1.2 Simultaneous Press Fitting of Inner and Outer Rings

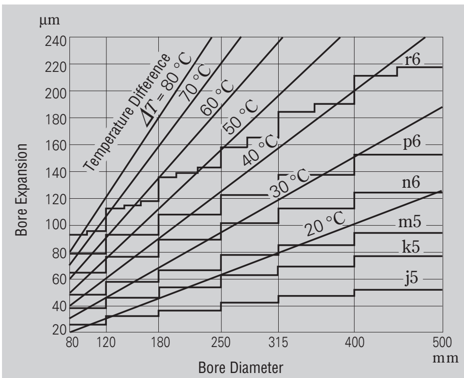


Fig. 1.3 Temperature and Thermal Expansion of Inner Ring

When both the inner and outer rings of non-separable bearings, such as deep groove ball bearings, require tight-fit, a mounting tool is placed on both rings as shown in Fig. 1.2, and both rings are fitted at the same time using a screw or hydraulic press. Since the outer ring of self-aligning ball bearings may deflect a mounting tool such as that shown in Fig. 1.2 should always be used for mounting them.
In the case of separable bearings, such as cylindrical roller bearings and tapered roller bearings, the inner and outer rings may be mounted separately. Assembly of the inner and outer rings, which were previously mounted separately, should be done carefully to align the inner and outer rings correctly. Careless or forced assembly may cause scratches on the rolling contact surfaces.

(2) Shrink Fits

Since press fitting large bearings requires a large force, a shrink fit is widely used. The bearings are first heated in oil to expand them before mounting.
This method prevents an excessive force from being imposed on the bearings and allows mounting them in a short time.
The expansion of the inner ring for various temperature differences and bearing sizes is shown in Fig. 1.3.
The precautions to follow when making shrink fits are as follows:

(a) Do not heat bearings to more than 120˚C.
(b) Put the bearings on a wire net or suspend them in an oil tank in order to prevent them from touching the tank's bottom directly.
(c) Heat the bearings to a temperature 20 to 30˚C higher than the lowest temperature required for mounting without interference since the inner ring will cool a little during mounting.
(d) After mounting, the bearings will shrink in the axial direction as well as the radial direction while cooling. Therefore, press the bearing firmly against the shaft shoulder using locating methods to avoid a clearance between the bearing and shoulder.

NSK Bearing Induction Heaters

Besides heating in oil, NSK Bearing Heaters, which use electromagnetic induction to heat bearings, are widely used.
In NSK Bearing Heaters, electricity (AC) in a coil produces a magnetic field that induces a current inside the bearing that generates heat. Consequently, without using flames or oil uniform heating in a short time is possible, making bearing shrink fitting efficient and clean.
In the case of relatively frequent mounting and dismounting such as cylindrical roller bearings for roll necks of rolling mills and for railway journal boxes, induction heating should be used for mounting and dismounting inner rings.

1.3.2 Mounting of Bearings with Tapered Bores

Bearings with tapered bores are mounted on tapered shafts directly or on cylindrical shafts with adapters or withdrawal sleeves (Figs. 1.4 and 1.5). Large spherical roller bearings are often mounted using hydraulic pressure. Fig. 1.6 shows a bearing mounting utilizing a sleeve and hydraulic nut. Fig. 1.7 shows another mounting method. Holes are drilled in the sleeve which are used to feed oil under pressure to the bearing seat. As the bearing expands radially, the sleeve is inserted axially with adjusting bolts.

Spherical roller bearings should be mounted while checking their radial-clearance reduction and referring to the push-in amounts listed in Table 1.1. The radial clearance must be measured using clearance gauges.

In this measurement, as shown in Fig. 1.8, the clearance for both rows of rollers must be measured simultaneously, and these two values should be kept roughly the same by adjusting the relative position of the outer and inner rings.

When a large bearing is mounted on a shaft, the outer ring may be deformed into an oval shape by its own weight. If the clearance is measured at the lowest part of the deformed bearing, the measured value may be bigger than the true value. If an incorrect radial internal clearance is obtained in this manner and the values in Table 1.1 are used, then the interference fit may become too tight and the true residual clearance may become too small. In this case, as shown in Fig. 1.9, one half of the total clearance at points a and b (which are on a horizontal line passing through the bearing center) and c (which is at the lowest position of the bearing) may be used as the residual clearance. When a self-aligning ball bearing is mounted on a shaft with an adapter, be sure that the residual clearance does not become too small. Sufficient clearance for easy alignment of the outer ring must be allowed.

1.4 Operation Inspection

After the mounting has been completed, a running test should be conducted to determine if the bearing has been mounted correctly. Small machines may be manually operated to assure that they rotate smoothly. Items to be checked include sticking due to foreign matter or visible flaws, uneven torque caused by improper mounting or an improper mounting surface, and excessive torque caused by an inadequate clearance, mounting error, or seal friction. If there are no abnormalities, powered operation may be started.

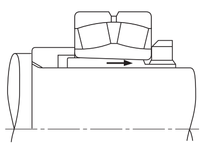


Fig. 1.4 Mounting with Adapter

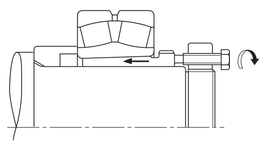


Fig. 1.5 Mounting with Withdrawal Sleeve

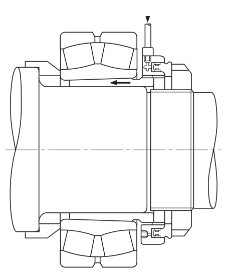


Fig. 1.6 Mounting with Hydraulic Nut

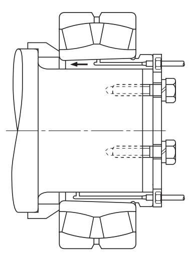


Fig. 1.7 Mounting with Special Sleeve and Hydraulic Pressure

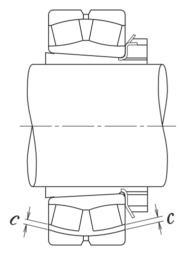


Fig. 1.8 Clearance Measurement of Spherical Roller Bearing

Table 1.1 Mounting of Spherical Roller Bearings with Tapered Bores

Units : mm

Bearing Bore Diameter d		Reduction in Radial Clearance		Push-in amount in axial direction				Minimum Permissible Residual Clearance	
				Taper 1 : 12		Taper 1 : 30		*CN*	*C3*
over	incl.	min.	max.	min.	max.	min.	max.		
30	**40**	0.025	0.030	0.40	0.45	—	—	0.010	0.025
40	**50**	0.030	0.035	0.45	0.55	—	—	0.015	0.030
50	**65**	0.030	0.035	0.45	0.55	—	—	0.025	0.035
65	**80**	0.040	0.045	0.60	0.70	—	—	0.030	0.040
80	**100**	0.045	0.055	0.70	0.85	1.75	2.15	0.035	0.050
100	**120**	0.050	0.060	0.75	0.90	1.9	2.25	0.045	0.065
120	**140**	0.060	0.070	0.90	1.10	2.25	2.75	0.055	0.080
140	**160**	0.065	0.080	1.0	1.3	2.5	3.25	0.060	0.100
160	**180**	0.070	0.090	1.1	1.4	2.75	3.5	0.070	0.110
180	**200**	0.080	0.100	1.3	1.6	3.25	4.0	0.070	0.110
200	**225**	0.090	0.110	1.4	1.7	3.5	4.25	0.080	0.130
225	**250**	0.100	0.120	1.6	1.9	4	4.75	0.090	0.140
250	**280**	0.110	0.140	1.7	2.2	4.25	5.5	0.100	0.150
280	**315**	0.120	0.150	1.9	2.4	4.75	6.0	0.110	0.160
315	**355**	0.140	0.170	2.2	2.7	5.5	6.75	0.120	0.180
355	**400**	0.150	0.190	2.4	3.0	6	7.5	0.130	0.200
400	**450**	0.170	0.210	2.7	3.3	6.75	8.25	0.140	0.220
450	**500**	0.190	0.240	3.0	3.7	7.5	9.25	0.160	0.240
500	**560**	0.210	0.270	3.4	4.3	8.5	11.0	0.170	0.270
560	**630**	0.230	0.300	3.7	4.8	9.25	12.0	0.200	0.310
630	**710**	0.260	0.330	4.2	5.3	10.5	13.0	0.220	0.330
710	**800**	0.280	0.370	4.5	5.9	11.5	15.0	0.240	0.390
800	**900**	0.310	0.410	5.0	6.6	12.5	16.5	0.280	0.430
900	**1 000**	0.340	0.460	5.5	7.4	14.0	18.5	0.310	0.470
1 000	**1 120**	0.370	0.500	5.9	8.0	15.0	20.0	0.360	0.530

Remark The values for reduction in radial internal clearance are for bearings with CN clearance. For bearing with C3 Clearance,the maximum values listed should be used for the reduction in radial internal clearance.

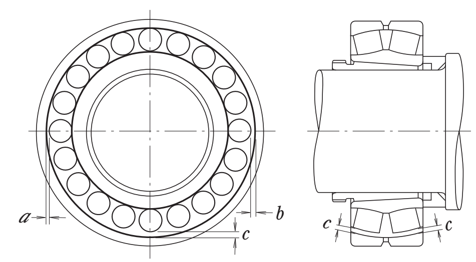


Fig. 1.9 Measuring Clearance in Large Spherical Roller Bearing

Large machines, which cannot be turned by hand, can be started after examination with no load, and the power immediately cutoff and the machine allowed to coast to a stop. Confirm that there is no abnormality such as vibration, noise, contact of rotating parts, etc.

Powered operation should be started slowly without load and the operation should be observed carefully until it is determined that no abnormalities exist, then gradually increase the speed, load, etc. to their normal levels. Items to be checked during the test operation include the existence of abnormal noise, excessive rise of bearing temperature, leakage and contamination of lubricants, etc. If any abnormality is found during the test operation, it must be stopped immediately and the machine should be inspected. If necessary, the bearing should be dismounted for examination.

Although the bearing temperature can generally be estimated by the temperature of the outside surface of the housing, it is more desirable to directly measure the temperature of the outer ring using oil holes for access.

The bearing temperature should rise gradually to the steady state level within one to two hours after the operation starts. If the bearing or its mounting is improper, 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 operation, an incorrect selection of bearing type or lubricating method may also cause an abnormal temperature rise.

The sound of a bearing may be checked with a noise locater or other instruments. Abnormal conditions are indicated by a loud metallic sound, or other irregular noise, and the possible cause may include incorrect lubrication, poor alignment of the shaft and housing, or the entry of foreign matter into the bearing. The possible causes and measures for irregularities are listed in Table 1.2.

Table 1. 2 Causes of and Measures for Operating Irregularities

Irregularities		Possible Causes	Measures
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	Flaws,corrosion,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, select stiffer grease.
		Insufficient or improper lubricant	Replenish lubricant or select a better one.
		Abnormal load	Improve the fit, internal clearance, preload, position of housing shoulder.
		Incorrect mounting	Improve the machining accuracy and alignment of shaft and housing, accuracy of mounting, or mounting method.
		Creep on fitted surface, excessive seal friction	Correct the seals, replace the bearing, correct the fitting or mounting.
Vibration (Axial runout)		Brinelling	Replace the bearing and use care when handling bearings.
		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]) Intermittent squeal or high-pitch noise may be heard in medium- to large-sized cylindrical roller bearings or ball bearings that are operating under grease lubrication in low-temperature environments. Under such low-temperature conditions, bearing temperature will not rise resulting in fatigue nor is grease performance affected. Although intermittent squeal or high-pitch noise may occur under these conditions, the bearing is fully functional and can continue to be used. In the event that greater noise reduction or quieter running properties are needed, please contact your nearest NSK branch office.

1.5 Dismounting

A bearing may be removed for periodic inspection or for other reasons. If the removed bearing is to be used again or it is removed only for inspection, it should be dismounted as carefully as when it was mounted. If the bearing has a tight fit, its removal may be difficult. The means for removal should be considered in the original design of the adjacent parts of the machine. When dismounting, the procedure and sequence of removal should first be studied using the machine drawing and considering the type of mounting fit in order to perform the operation properly.

1.5.1 Dismounting of Outer Rings

In order to remove an outer ring that is tightly fitted, first place bolts in the push-out holes in the housing at several locations on its circumference as shown in Fig. 1.10, and remove the outer ring by uniformly tightening the bolts. These bolt holes should always be fitted with blank plugs when not being used for dismounting. In the case of separable bearings, such as tapered roller bearings, some notches should be made at several positions in the housing shoulder, as shown in Fig. 1.11, so the outer ring may be pressed out using a dismounting tool or by tapping it.

1.5.2 Dismounting of Bearings with Cylindrical Bores

If the mounting design allows space to press out the inner ring, this is an easy and fast method. In this case, the withdrawal force should be imposed only on the inner ring (Fig. 1.12). Withdrawal tools like those shown in Figs. 1.13 and 1.14 are often used.

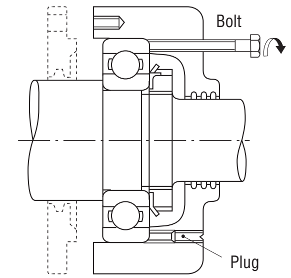


Fig. 1.10 Removal of Outer Ring with Dismounting Bolts

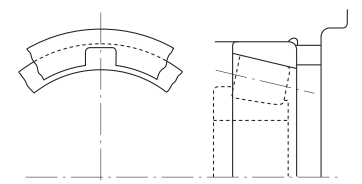


Fig. 1.11 Removal Notches

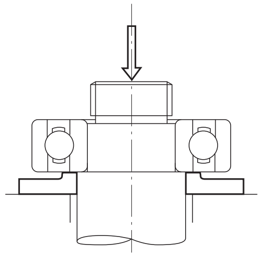


Fig. 1.12 Removal of Inner Ring Using a Press

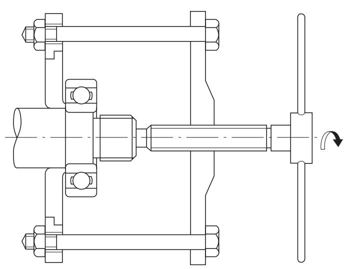


Fig. 1.13 Removal of Inner Ring Using Withdrawal Tool (1)

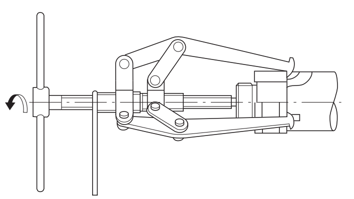


Fig. 1.14 Removal of Inner Ring Using Withdrawal Tool (2)

In both cases, the claws of the tools must substantially engage the face of the inner ring; therefore, it is advisable to consider the size of the shaft shoulder or to cut grooves in the shoulder to accommodate the withdrawal tools (Fig. 1.14).
The oil injection method is usually used for the withdrawal of large bearings. The withdrawal is achieved easily by mean of oil pressure applied through holes in the shaft. In the case of extra wide bearings, the oil injection method is used together with a withdrawal tool.
Induction heating is used to remove the inner rings of NU and NJ types of cylindrical roller bearings. The inner rings are expanded by brief local heating, and then withdrawn (Fig. 1.15). Induction heating is also used to mount several bearings of these types on a shaft.

1.5.3 Dismounting of Bearings with Tapered Bores

When dismounting relatively small bearings with adapters, the inner ring is held by a stop fastened to the shaft and the nut is loosened several turns. This is followed by hammering on the sleeve using a suitable tool as shown in Fig. 1.18. Fig. 1.16 shows one procedure for dismounting a withdrawal sleeve by tightening the removal nut. If this procedure is difficult, it may be possible to drill and tap bolt holes in the nut and withdraw the sleeve by tightening the bolts as shown in Fig. 1.17.
Large bearings may be withdrawn easily using oil pressure. Fig. 1.19 illustrates the removal of a bearing by forcing oil under pressure through a hole and groove in a tapered shaft to expand the inner ring. The bearing may suddenly move axially when the interference is relieved during this procedure so a stop nut is recommended for protection. Fig. 1.20 shows a withdrawal using a hydraulic nut.

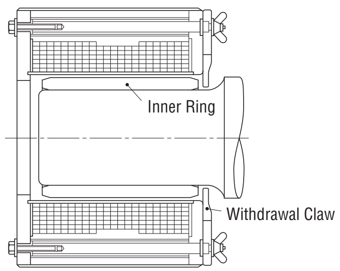


Fig. 1.15 Removal of Inner Ring Using Induction Heater

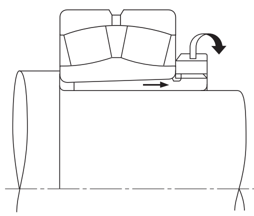


Fig. 1.16 Removal of Withdrawal Sleeve Using Withdrawal Nut (1)

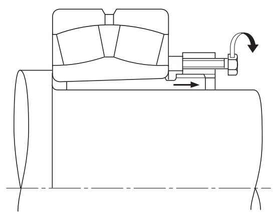


Fig. 1.17 Removal of Withdrawal Sleeve Using Withdrawal Nut (2)

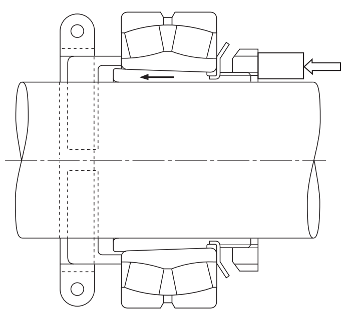


Fig. 1.18 Removal of Adapter with Stop and Axial Pressure

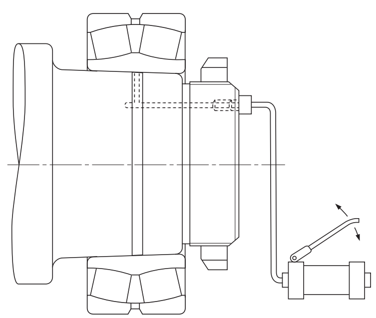


Fig. 1.19 Removal Using Oil Injection Hydraulic Pump

1.6 Inspection of Bearings

1.6.1 Bearing Cleaning

When bearings are inspected, the appearance of the bearings should first be recorded and the amount and condition of the residual lubricant should be checked.
After the lubricant has been sampled for examination, the bearings should be cleaned. In general, light oil or kerosene may be used as a cleaning solution.
Dismounted bearings should first be given a preliminary cleaning followed by a finishing rinse. Each bath should be provided with a metal net to support the bearings in the oil without touching the sides or bottom of the tank. If the bearings are rotated with foreign matter in them during preliminary cleaning, the raceways may be damaged. The lubricant and other deposits should be removed in the oil bath during the initial rough cleaning with a brush or other means. After the bearing is relatively clean, it is given the finishing rinse. The finishing rinse should be done carefully with the bearing being rotated while immersed in the rinsing oil. It is necessary to always keep the rinsing oil clean.

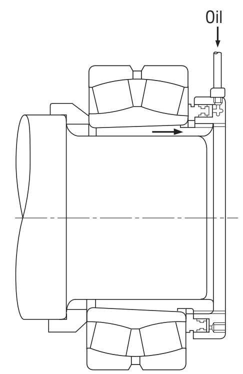


Fig. 1.20 Removal Using Hydraulic Nut

1.6.2 Inspection and Evaluation of Bearings

After being thoroughly cleaned, bearings should be examined for the condition of their raceways and external surfaces, the amount of cage wear, the increase in internal clearance, and degradation of tolerances. These should be carefully checked, in addition to examination for possible damage or other abnormalities, in order to determine the possibility for its reuse.
In the case of small non-separable ball bearings, hold the bearing horizontally in one hand, and then rotate the outer ring to confirm that it turns smoothly.
Separable bearings such as tapered roller bearings may be checked by individually examining their rolling elements and the outer ring raceway.
Large bearings cannot be rotated manually; however, the rolling elements, raceway surfaces, cages, and contact surface of the ribs should be carefully examined visually. The more important a bearing is, the more carefully it should be inspected.
The determination to reuse a bearing should be made only after considering the degree of bearing wear, the function of the machine, the importance of the bearings in the machine, operating conditions, and the time until the next inspection. However, if any of the following defects exist, reuse is impossible and replacement is necessary.

(a) When there are cracks in the inner or outer rings, rolling elements, or cage.
(b) When there is flaking of the raceway or rolling elements.
(c) When there is significant smearing of the raceway surfaces, ribs, or rolling elements.
(d) When the cage is significantly worn or rivets are loose.
(e) When there is rust or scoring on the raceway surfaces or rolling elements.
(f) When there are any significant impact or brinell traces on the raceway surfaces or rolling elements.
(g) When there is significant evidence of creep on the bore or the periphery of the outer ring.
(h) When discoloration by heat is evident.
(i) When significant damage to the seals or shields of grease sealed bearings has occurred.

1.7 Checking of Shaft and Housing

1.7.1 Checking of Shaft

(a) Cylindrical Shaft

(1) Dimensional check of shaft
Measure the shaft size at the place where the bearing will be mounted to confirm that the bearing size is correct. The measurement positions are shown in Fig. 1.21. Use an outside micrometer.

(2) Observation of the shaft outside surface
Observe the surface of shaft where the bearing was mounted to check whether there are scratches, dents, rust or stepped wearing.
- When there are scratches, dents
  Round edge with oil stone and/or sand paper to smoothen the surface.
- When there is rust
  Remove rust with oil stone and/or sand paper to smoothen the surface.
- When there is stepped wearing
  After the dimensional measurement of the shaft, decide whether correction is possible.

(3) Anticorrosive agent
After completion of check, apply an anticorrosive agent.

(b) Tapered Shaft

(1) Check of shaft shape
Measure the shape of shaft where the bearing will be mounted to confirm that its shape is correct. The measurement positions are shown in Fig. 1.22. As for the measurement instrument, use a taper gauge (sine bar system). (Fig. 2.2 and Fig. 1.22)

(2) Observation of the shaft outside surface
Observe the shaft surface where the bearing was mounted to check whether there are scratches, dents, rust or stepped wearing.

- When there are scratches, dents
  Round edge with oil stone and/or sand paper to smoothen the surface.
- When there is rust
  Remove rust with oil stone and/or sand paper to smoothen the surface.
  (In this case if the zone to be corrected is wide, it is necessary to inspect the shape of the tapered part by using a taper gauge. The inspection method is: apply a thin coat of bluing over the entire surface of taper gauge bore face, insert it slowly after adjusting the taper gauge to the shaft center tapered shaft, then, do a run-in by moving back-and-forth. Then, pull the taper gauge out slowly when adjusting to the shaft center. Observe where blue dye is attached to the surface of tapered shaft.
  If the blue ares is bigger than 80%, the shaft may be reused. When using a taper gauge (sine-bar type), follow the instructions given in the Operation Manual issued by the manufacturer).
- When there is stepped wearing
  After the dimensional measurement of the shaft, decide whether correction is possible.

(3) Anticorrosive agent
After completion of check, apply an anticorrosive agent.

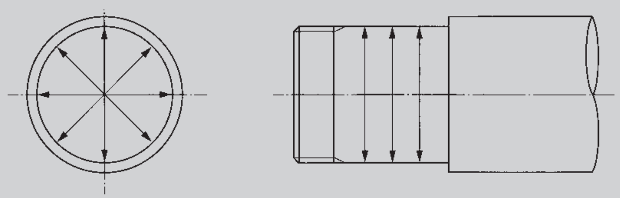


Fig. 1.21 Cylindrical shaft

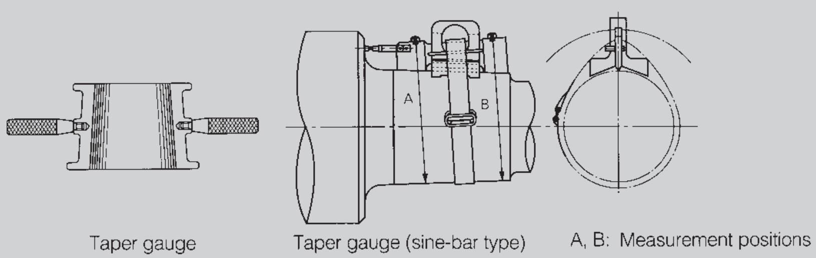


Fig. 1.22 Tapered shaft

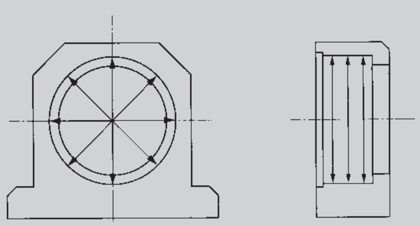


Fig. 1.23 Integrated housing

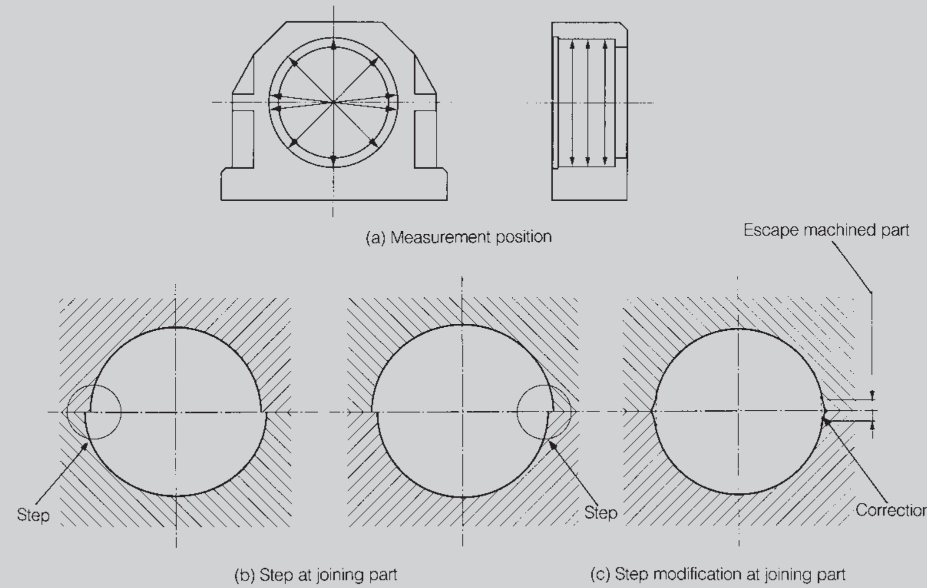


Fig. 1.24 Split housing

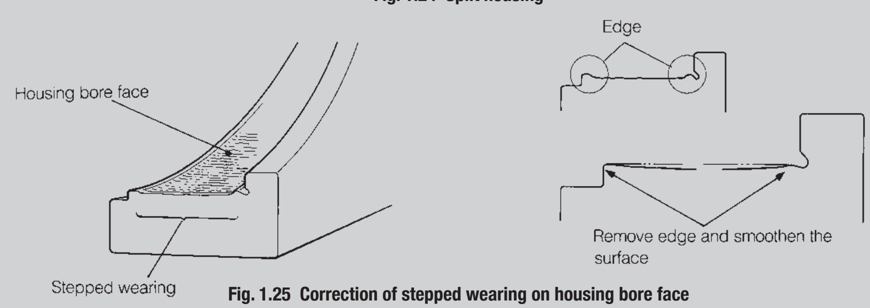


Fig. 1.25 Correction of stepped wearing on housing bore face

1.7.2 Checking of Housing

(a) Integrated Type Housing

(1) Check of bore size of housing
Measure the housing bore size where the bearing will be mounted to confirm that the size is correct. The measurement position is shown in Fig. 1.23. As for the measurement instrument, use an inside micrometer.

(2) Observation of housing bore face
Observe the surface of the housing bore where the bearing was mounted to check whether there are scratches, dents, rust or stepped wearing.
- When there are scratches, dents
Round edge with oil stone and/or sand paper to smoothen the surface.
- When there is rust
Remove rust with oil stone and/or sand paper to smoothen the surface.
- When there is stepped wearing (Fig. 1.25)
After the dimensional measurement of the housing bore, decide whether correction and reuse is possible. In this case, if the measured value of the housing bore is within its tolerance, remove the stepped worn part with oil stone and/or sand paper, etc. and smoothen the surface, then, reuse. If the stepped wearing is severe, either plate or apply thermal spraying to reconstitute to the correct housing size before reusing.

(3) Anticorrosive agent
After completion of check, apply an anticorrosive agent.

(b) Split Housing

(1) Check of the housing bore size
In case of a split housing, assemble correctly the housing without bearing, and measure its bore dimension at the place where the bearing will be mounted to confirm that the dimension is correct. The measurement position is shown in Fig. 1.24 (a). As for the measurement instrument, an inside micrometer shall be used.

(2) Observation of housing bore face
Observe the surface of the housing bore where the bearing was mounted to check whether there are scratches, dents, rust or stepped wearing.
- When there are scratches, dents
Round edge with oil stone and/or sand paper to smoothen the surface.
- When there is rust
Remove rust with oil stone and/or sand paper to smoothen the surface.
- When there is stepped wearing (Fig. 1.25)
After the dimensional measurement of the housing bore, decide whether correction is possible.
In this case, if the measured value of housing bore is within its tolerance, remove the stepped worn portion with oil stone and/or sand paper, etc. and smoothen the surface, then, reuse.
- When the stepped wearing is severe
If the stepped wearing is severe, either plate or apply thermal spraying to reconstitute to the correct housing size and reuse.
- When there is a step
As step may occur at the joining part of the split halves housing, confirm whether there is a step. If a step is found, correct it in the way as shown in Fig. 1.24 (c).

(3) Anticorrosive agent
After completion of check, apply an anticorrosive agent.

1.8 Maintenance and Inspection

1.8.1 Detecting and Correcting Irregularities

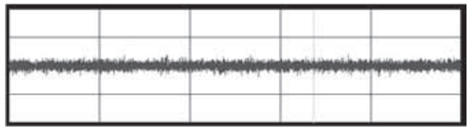
In order to maintain the original performance of a bearing for as long as possible, proper maintenance and inspection should be performed. If proper procedures are used, many bearing problems can be avoided and the reliability, productivity, and operating costs of the equipment containing the bearings 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 1.2.
If necessary, the bearing should be dismounted and examined in detail. As for the procedure for dismounting and inspection, refer to Section 1.6, Inspection of Bearings.

1.8.2 Diagnosis with Sound and Vibration

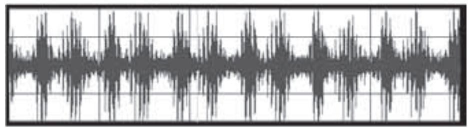
Classification of sounds and vibrations

Sound and vibration accompany the rotation of rolling bearings. The tone and amplitude of such sound and vibration vary depending on the type of bearing, mounting conditions, operational conditions, etc. The sound and vibration of a rolling bearing can be classified under the following four chief categories and each category can be further classified into several sub-categories, as described in Table 1.3 below. Boundaries between groups are, however, not definite. Even if some types of sounds or vibrations are inherent in the bearings, the volume might be related to the manufacturing process, while some types of sounds or vibrations, even if they arise due to manufacturing, cannot be eliminated even in normal conditions.

By recording sounds and vibrations of a rotating machine and analyzing them, it is possible to infer the cause. As can be seen from figures on the next page, a mechanically normal bearing shows a stable waveform. However, a bearing with a scratch, for example, shows a waveform with wide swings indicating large-amplitude sounds at regular intervals. (Refer to Figs.1.26 and 1.27)



Sound waveform of a normal bearing



Sound waveform of a scratched bearing

Fig. 1.26

When there is damage on an inner-ring raceway surface
Bore diameter: 100 mm Recording and analysis method: Envelope analysis result of sounds of a test machine recorded by a microphone Number of rotations: 50 min^{-1}

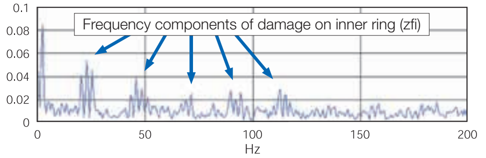


Fig. 1.27

Table 1.3 Classification of Sounds and Vibrations in a Rolling Bearing

	sound		Vibration		Features	Generated frequency (frequency analysis): FFT of original wave – Radial (angular) direction	FFT of original wave – Axial direction	FFT after envelope (basic No.)	Source	Measures
Structural	Race noise		Free vibration of raceway ring		Continuous noise, basic unavoidable noise which all bearings generate	f_{RiN} , f_{MI}	f_{AiN} , f_{AM}	—	Selective resonance of waviness (rolling friction)	Improve rigidity around the bearings, appropriate radial clearance, high-viscosity lubricant, high-quality bearings
	Click noise		Free vibration of raceway ring, free vibration of cage		Regular noise at a certain interval, large bearings and horizontal shaft, radial load and low rpm	f_{RiN} , f_{MI} Natural frequency of cage	f_{AiN} , f_{AM}	Zf_c	Collision of rolling elements with inner ring or cage	Reduce radial clearance, apply preload, high-viscosity oil
	Squeal noise		Free vibration of raceway ring		Intermittent or continuous, mostly large cylindrical roller bearings, radial load, grease lubrication, at particular speed	(≈ f_{R2N} , f_{R3N})	—	?	Self-induced vibration caused by sliding friction at rolling surface	Reduce radial clearance, apply preload, change the grease, replace with countermeasured bearings
	Cage noise	"CK" noise	Free vibration of cage		Regular noise at a certain interval, all bearing types generate it	Natural frequency of cage		f_c	Collision of cage with rolling elements or rings	Apply preload, high-viscosity lubricant, reduce mounting error
		"CG" noise	Vibration of cage		Intermittent or continuous, lubrication with particular grease	Natural frequency of cage		?	Self-induced vibration caused by friction at cage guide surface	Change of grease brand, replace with countermeasured cage
		Tapping noise	Free vibration of cage		Certain interval, but a little irregular under radial load and during initial stage	Natural frequency of cage		Zf_c	Collision of cage and rolling element caused by grease resistance	Reduce radial clearance, apply preload, low-viscosity lubricant
	—		Rolling element passage vibration		Continuous, all bearing types under radial load	Zf_c	—	—	Displacement of inner ring due to rolling element passage	Reduce radial clearance, apply preload
Manufacturing	Waviness noise		Vibration due to waviness	Inner ring	Continuous noise	$nZf_i \pm f_r$ ($nZ \pm 1$ peaks)	nZf_i (nZ peaks)	—	Inner ring raceway waviness, irregularity of shaft exterior	High-quality bearings, improve shaft accuracy
				Outer ring	Continuous noise	nZf_c ($nZ \pm 1$ peaks)	nZf_c (nZ peaks)	—	Outer ring raceway waviness, irregular bore of housing	High-quality bearings, improve housing bore accuracy
				Rolling element	Continuous with rollers, occasional with balls	$2nf_b \pm f_c$ ($2n$ peaks)	$2nf_b$ ($2n$ peaks)	—	Rolling element waviness	High-quality bearings
Handling	Flaw noise		Vibration due to flaw	Inner ring	Regular noise at a certain interval	f_{RiN} , f_{MI}	f_{AiN} , f_{AM}	Zf_i	Nicks, dents, rust, flaking on inner ring raceway	Replacement and careful bearing handling
				Outer ring				Zf_c	Nicks, dents, rust, flaking on inner ring raceway	Replacement and careful bearing handling
				Rolling element				$2f_b$	Nicks, dents, rust, flaking on rolling elements	Replacement and careful bearing handling
	Contamination noise		Vibration due to contamination		Irregular	f_{RiN} , f_{MI}	f_{AiN} , f_{AM}	Irregular	Entry of dirt and debris	Washing, improve sealing
Others	Seal noise		Free vibration of a seal		Contact seal	Natural frequency of seal		(f_r)	Self-induced vibration due to friction at seal contact area	Change the seal, change the grease
	Lubricant noise		—		Irregular	?	?	Irregular	Lubricant or lubricant bubbles crushed between rolling elements and raceways	Change the grease
	—		Runout	f_r	Continuous	f_r	—	—	Irregular inner ring cross-section	High-quality bearings
				f_c	Continuous	f_c	—	—	Ball variation in bearing, rolling elements non-equidistant	High-quality bearings
				$f_r - 2f_c$	Continuous	$f_r - 2f_c$	—	—	Non-linear vibration due to rigid variation by ball variation	High-quality bearings

n: Positive integer (1, 2, 3...)
Z: Number of rolling elements
f_{RiN}: Ring natural frequency in radial bending mode, Hz
f_{MI}: Natural frequency in the mode of angular vibration in inertia of outer ring-spring system, Hz
f_r: Rotation frequency of inner ring, Hz
f_c: Orbital revolution frequency of rolling elements, Hz
f_{AiN}: Ring natural frequency in axial bending mode, Hz
f_{AM}: Natural frequency in the mode of axial vibration in mass of outer ring-spring system, Hz
f_i: $f_i = f_r - f_c$, Hz
f_b: Rotation frequency of rolling element around its center, Hz

2. BEARING DAMAGE AND MEASURES (Bearing Doctor)

2. BEARING DAMAGE AND MEASURES (Bearing Doctor)

2.1 Bearing Damage

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 of premature failure, may include insufficient lubrication, use of improper lubricant, faulty lubrication 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 the 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.

2.2 Running Traces and Applied Loads

As the bearing rotates, the raceways of the inner ring and outer ring make contact with the rolling elements. This results in a wear path on both the rolling elements and raceways. Running traces are useful, since they indicate the loading conditions, and should be carefully observed when the bearing is disassembled.
If the running traces are clearly defined, it is possible to determine whether the bearing is carrying a radial load, axial load or moment load. Also, the roundness condition of the bearing can be determined. Check whether unexpected bearing loads or large mounting errors occurred. Also, determine the probable cause of the bearing damage.

Fig. 2.2 shows the running traces generated in deep groove bearings under various load conditions. Fig. 2.2 (a) shows the most common running trace generated when the inner ring rotates under a radial load only. Figs. 2.2 (e) through (h) show several different running traces that result in a shortened life due to their adverse effect on the bearings.
Similarly, Fig. 2.2 shows different roller bearing running traces: Fig. 2.2 (i) shows the outer ring running trace when a radial load is properly applied to a cylindrical roller bearing which has a load on a rotating inner ring. Fig. 2.2 (j) shows the running trace in the case of shaft bending or relative inclination between the inner and outer rings. This misalignment leads to the generation of slightly shaded (dull) bands in the width direction. Traces are diagonal at the beginning and end of the loading zone. For double-row tapered roller bearings where a single load is applied to the rotating inner ring, Fig. 2.2 (k) shows the running trace on the outer ring under radial load while Fig. 2.2 (l) shows the running trace on the outer ring under axial load. When misalignment exists between the inner and the outer rings, then the application of a radial load causes running traces to appear on the outer ring as shown in Fig. 2.2 (m).

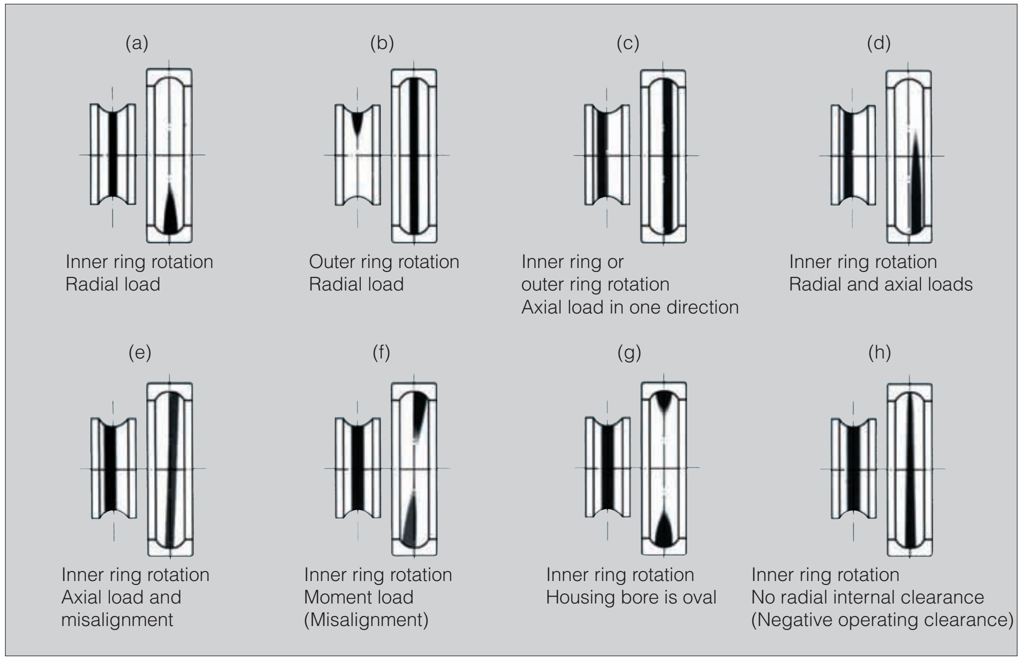


Fig. 2.2 Typical Running Traces of Deep Groove Ball Bearings

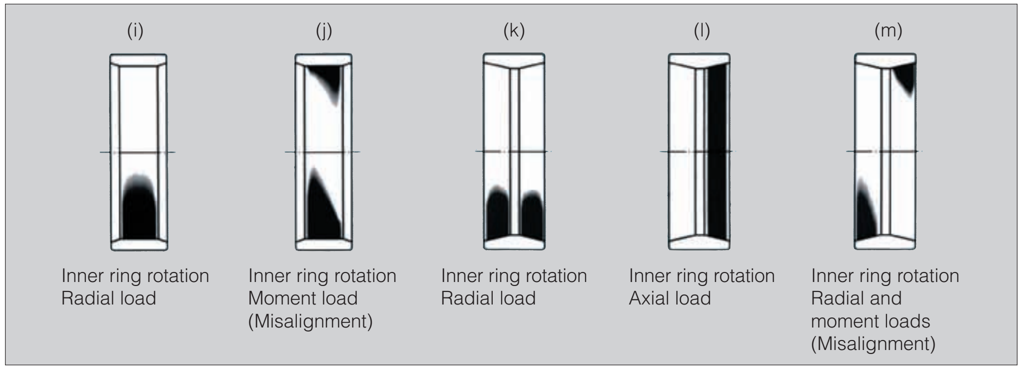


Fig. 2.2 Typical Running Traces on Roller Bearings

2.3 Bearing Damage and Measures

In general, if rolling bearings are used correctly, they will survive to their predicted fatigue life. Bearings, however, often fail prematurely due to avoidable mistakes. In contrast to fatigue life, this premature failure is caused by improper mounting, mishandling, poor lubrication, entry of foreign matter or abnormal heat generation.
For example, one cause of premature failure is rib scoring which is due to insufficient lubrication, use of improper lubricant, faulty lubrication system, entry of foreign matter, bearing mounting error, excessive deflection of the shaft or some combination of these. If all conditions are known for the times both before and after the failure, including the application, the operating conditions, and environment, then a measure can be determined by studying the nature of the failure and its probable causes. A successful measure will reduce similar failures or prevent them from happening again.
Sections 2.3.1 through 2.3.18 give various type of bearing damage and measures. Please consult these sections when trying to determine the cause of bearing damage. By the way, the bearing diagnostic chart in the Appendix may be useful as a quick reference guide.

2.3.1 Flaking

Damage Condition	Possible Cause	Measures
Flaking occurs when small pieces of bearing material are split off from the smooth surface of the raceway or rolling elements due to rolling fatigue, thereby creating regions having rough and coarse texture.	Excessive load Poor mounting (misalignment) Moment load Entry of foreign debris, water penetration Poor lubrication, Improper lubricant Unsuitable bearing clearance Improper precision for shaft or housing, unevenness in housing rigidity, large shaft bending Progression from rust, corrosion pits, smearing, dents (Brinelling)	● Reconfirm the bearing application and check the load conditions ● Improve the mounting method ● Improve the sealing mechanism, prevent rusting during non-running ● Use a lubricant with a proper viscosity, improve the lubrication method ● Check the precision of shaft and housing ● Check the bearing internal clearance

Photo 1-1
Part: Inner ring of an angular contact ball bearing
Symptom: Flaking occurs around half of the circumference of the raceway surface
Cause: Poor lubrication due to entry of cutting coolant into bearing

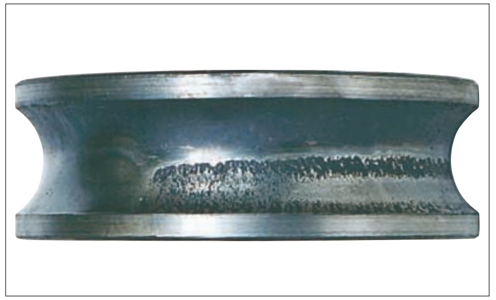


Photo 1-2
Part: Inner ring of an angular contact ball bearing
Symptom: Flaking occurs diagonally along raceway
Cause: Poor alignment between shaft and housing during mounting

Photo 1-3
Part: Outer ring of Photo 1-4
Symptom: Flaking of raceway surface at ball pitch
Cause: Dents due to shock load while stationary

Photo 1-4
Part: Balls of Photo 1-3
Symptom: Flaking of ball surface
Cause: Dents due to shock load while stationary

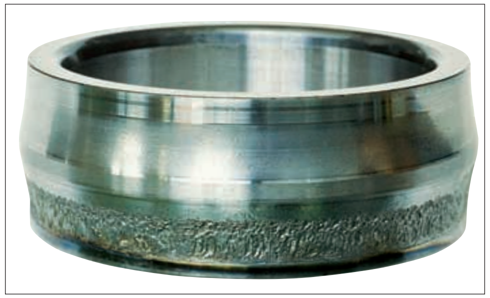


Photo 1-5
Part: Inner ring of a spherical roller bearing
Symptom: Flaking of only one raceway over its entire circumference
Cause: Excessive axial load

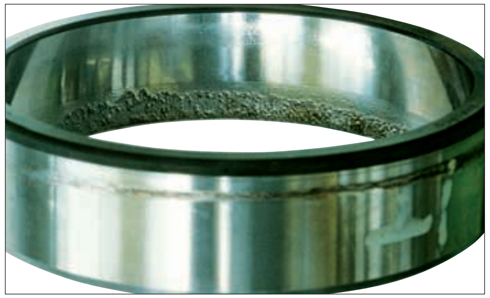


Photo 1-6
Part: Outer ring of Photo 1-5
Symptom: Flaking of only one raceway over its entire circumference
Cause: Excessive axial load

Photo 1-7
Part: Inner ring of a spherical roller bearing
Symptom: Flaking of only one row of raceway
Cause: Poor lubrication

Photo 1-8
Part: Rollers of a cylindrical roller bearing
Symptom: Premature flaking occurs axially on the rolling surfaces
Cause: Scratches caused during improper mounting

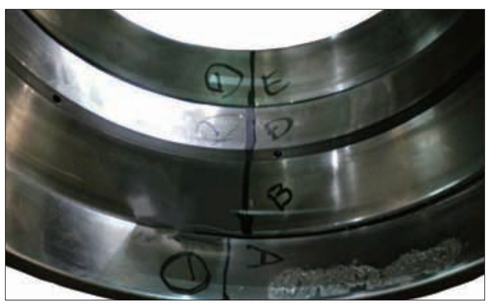


Photo 1-9
Part: Outer ring of a four-row tapered roller bearing
Symptom: Flaking of raceway(Loading area)
Cause: Excessive moment load

Photo 1-10
Part: Enlargement of raceway surface in Photo 1-9
Symptom: Flaking of one-side of the raceway
Cause: Excessive pressure due to be misalignment

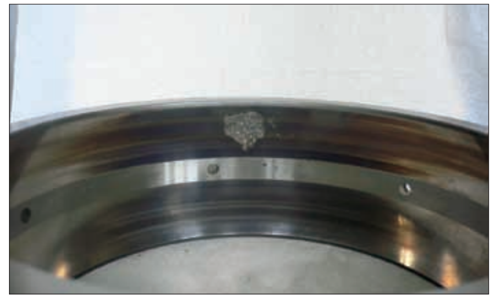


Photo 1-11
Part: Outer ring of a spherical roller bearing
Symptom: Discoloration and flaking occur on outer ring raceway surface
Cause: Poor lubrication under high temperatures

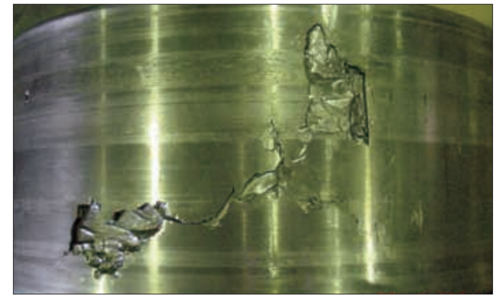


Photo 1-12
Part: Outer ring of a cylindrical roller bearing for sendzimir Mills
Symptom: Flaking occurs on outside surface
Cause: Progression of fatigue in outer ring material (Long period of grinding on outer ring outside surface)

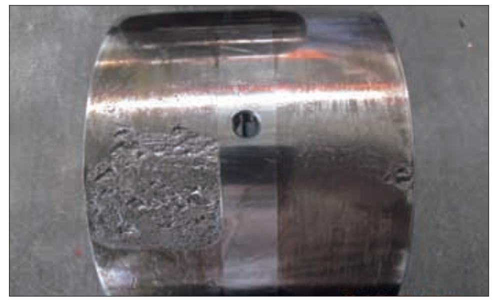


Photo 1-13
Part: Inner ring of a cylindrical roller bearing for sendzimir Mills
Symptom: Flaking occurs on the raceway surface
Cause: Severe operating conditions and oil lubrication of low viscosity

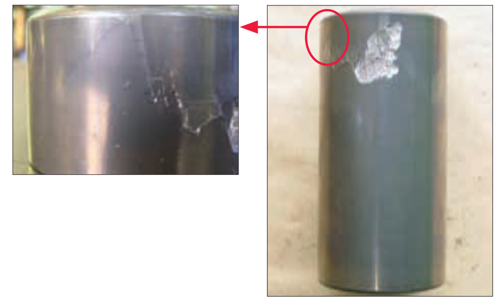


Photo 1-14
Part: Roller of a cylindrical roller bearing
Symptom: Flaking of rolling surfaces
Cause: Origin from flaw or crack in roller during mounting of outer ring and roller

Photo 1-15
Part: Inner ring of deep groove ball bearing
Symptom: Flaking of raceway at ball pitch
Cause: Dents due to shock load during mounting

Photo 1-16
Part: Inner ring of an angular contact ball bearing
Symptom: Flaking of raceway at ball pitch
Cause: Dents due to shock load while stationary

—Example of flaking and other damage combined 1—

Photo 1-15
Part: Outer ring of a cylindrical roller bearing
Symptom: Rust, flaking and crack occur on raceway surface
Cause: Rust at the pitch interval leads to flaking during operation⇒ Further operation results in cracking

—Example of flaking and other damage combined 2—

Photo 1-16
Part: Outer ring of a spherical roller bearing
Symptom: Example of flaking, cracking, and wear combined on the outer ring raceway
Cause: Wear in two places due to poor lubrication (primary damage) progresses to flaking in one spot (secondary damage) that later becomes a crack (tertiary damage)

2.3.2 Peeling

Damage Condition	Possible Cause	Measures
Dull or cloudy spots appear on surface along with light wear. From such dull spots, tiny cracks are generated downward to a depth of 5 to 10 μm. Small particles fall off and minor flaking occurs widely.	Unsuitable lubricant Entry of debris into lubricant Rough surface due to poor lubrication Surface roughness of mating rolling part	● Select a proper lubricant ● Improve the sealing mechanism ● Improve the surface finish of the rolling mating parts

Photo 2-1
Part: Inner ring of a spherical roller bearing
Symptom: Round shaped peeling pattern occurs on the center of the raceway surface
Cause: Poor lubrication

Photo 2-2
Part: Enlargement of pattern in Photo 2-1

Photo 2-3
Part: Convex rollers of Photo 2-1
Symptom: Round shaped peeling pattern occurs on the center of the rolling surfaces
Cause: Poor lubrication

Photo 2-4
Part: Outer ring of a spherical roller bearing
Symptom: Peeling occurs near the shoulder of the raceway over the entire circumference
Cause: Poor lubrication

BEARING DOCTOR

2.3.3 Scoring

Damage Condition	Possible Cause	Measures
Scoring is surface damage due to accumulated small seizures caused by sliding under improper lubrication or under severe operating conditions. Linear damage appears circumferentially on the raceway surface and rolling surface. Cycloidal shaped damage on the roller end. Scoring on rib surface contacting roller end.	Excessive load, excessive preload Poor lubrication Particles are caught in the surface Inclination of inner and outer rings Shaft bending Poor precision of the shaft and housing	● Check the size of the load ● Adjust the preload ● Improve the lubricant and the lubrication method ● Check the precision of the shaft and housing

Photo 3-1
Part: Inner ring of a spherical roller bearing
Symptom: Scoring on large rib face of inner ring
Cause: Roller slipping due to sudden acceleration and deceleration

Photo 3-2
Part: Convex rollers of Photo 3-1
Symptom: Scoring on roller end face
Cause: Roller slipping due to sudden acceleration and deceleration

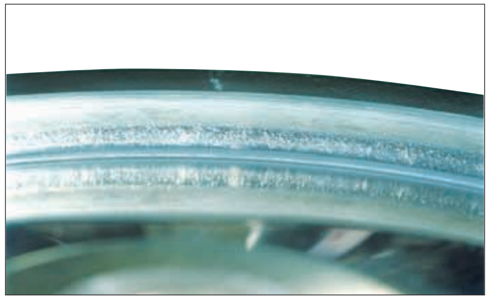


Photo 3-3
Part: Inner ring of a tapered roller thrust bearing
Symptom: Scoring on the face of inner ring rib
Cause: Worn particles become mixed with lubricant, and breakdown of oil film occurs due to excessive load

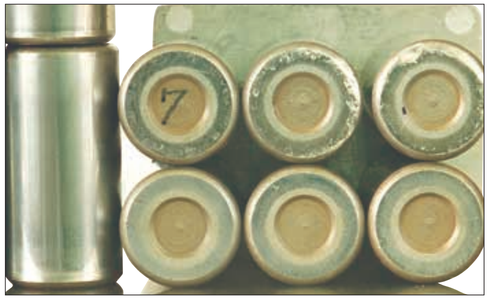


Photo 3-4
Part: Rollers of a double-row cylindrical roller bearing
Symptom: Scoring on the roller end face
Cause: Poor lubrication and excessive axial load

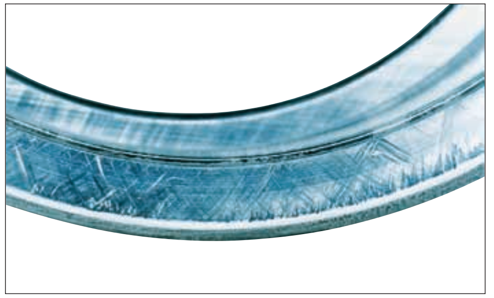


Photo 3-5
Part: Inner ring of a spherical thrust roller bearing
Symptom: Scoring on the rib face of inner ring
Cause: Debris, which is caught in surface, and excessive axial loading

Photo 3-6
Part: Convex rollers of Photo 3-5
Symptom: Scoring on the roller end face
Cause: Debris, which is caught in surface, and excessive axial loading

Photo 3-7
Part: Cage of a deep groove ball bearing
Symptom: Scoring on the pressed-steel cage pockets
Cause: Entry of debris

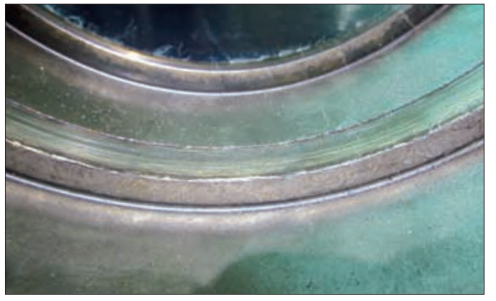


Photo 3-8
Part: Outer ring a double-row cylindrical roller bearing
Symptom: Notable scoring on the face of outer ring rib
Cause: Excessive axial loading

2.3.4 Smearing

Damage Condition	Possible Cause	Measures
Smearing is surface damage which occurs from a collection of small seizures between bearing components caused by oil film rupture and/or sliding. Surface roughening occurs along with melting.	High speed and light load Sudden acceleration/deceleration Improper lubricant Entry of water	● Improve the preload ● Improve the bearing clearance ● Use a lubricant with good oil film formation ability ● Improve the lubrication method ● Improve the sealing mechanism

Photo 4-1
Part: Inner ring of a cylindrical roller bearing
Symptom: Smearing occurs circumferentially on raceway surface
Cause: Roller slipping due to excessive grease filling

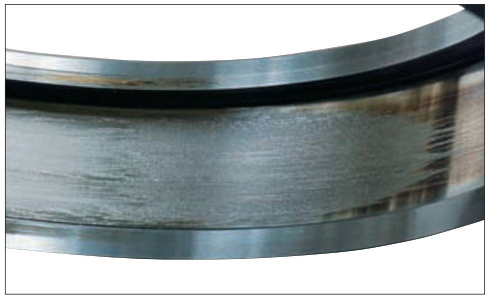


Photo 4-2
Part: Outer ring of Photo 4-1
Symptom: Smearing occurs circumferentially on raceway surface
Cause: Roller slipping due to excessive grease filling

Photo 4-3
Part: Inner ring of a spherical roller bearing
Symptom: Smearing occurs circumferentially on raceway surface
Cause: Poor lubrication

Photo 4-4
Part: Outer ring of Photo 4-3
Symptom: Smearing occurs circumferentially on raceway surface
Cause: Poor lubrication

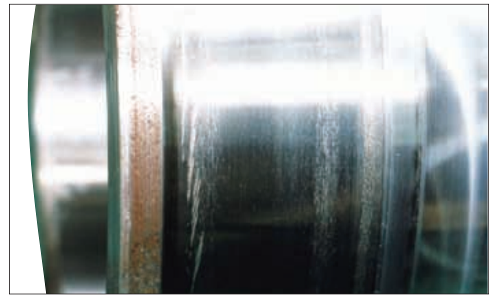


Photo 4-5
Part: Inner ring of a spherical roller bearing
Symptom: Partial smearing occurs circumferentially on raceway surface
Cause: Poor lubrication

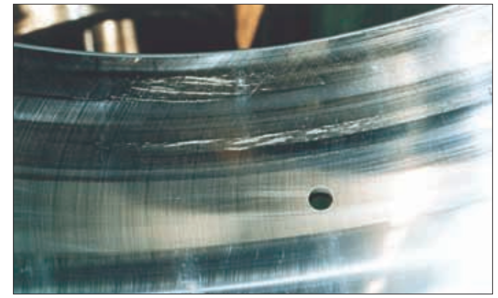


Photo 4-6
Part: Outer ring of Photo 4-5
Symptom: Partial smearing occurs circumferentially on raceway surface
Cause: Poor lubrication

Photo 4-7
Part: Convex rollers of Photo 4-5
Symptom: Smearing occurs at the center of the rolling surface
Cause: Poor lubrication

Photo 4-8
Part: Rollers of a large cylindrical roller bearing
Symptom: Smearing occurs on rolling surface
Cause: Light load and poor lubrication

Photo 4-9
Part: Outer ring of a large tapered roller bearing
Symptom: Smearing occurs on outer ring raceway surface
Cause: High speed, light load and poor lubrication

2.3.5 Fracture

Damage Condition	Possible Cause	Measures
Fracture refers to small pieces which were broken off due to excessive load or shock load acting locally on a part of the roller corner or rib of a raceway ring.	Impact during mounting Excessive load Poor handling such as dropping	● Improve the mounting method (Shrink fit, use of proper tools) ● Reconsider the loading conditions ● Provide enough back-up and support for the bearing rib

Photo 5-1
Part: Inner ring of a double-row cylindrical roller bearing
Symptom: Chipping occurs at the center rib
Cause: Excessive load during mounting

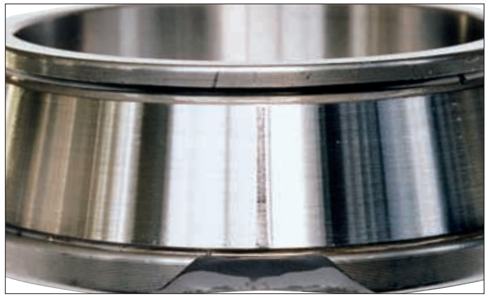


Photo 5-2
Part: Inner ring of a tapered roller bearing
Symptom: Fracture occurs at the cone back face rib
Cause: Large shock during mounting

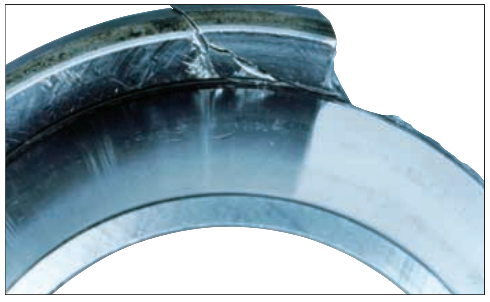


Photo 5-3
Part: Inner ring of a spherical thrust roller bearing
Symptom: Fracture occurs at the large rib
Cause: Repeated load

Photo 5-4
Part: Outer ring of a solid type needle roller bearing
Symptom: Fracture occurs at the outer ring rib
Cause: Roller inclination due to excessive loading (Needle rollers are long compared to their diameter. Under excessive or uneven loading, rollers become inclined and push against the ribs.)

2.3.6 Cracks

Damage Condition	Possible Cause	Measures
Cracks in the raceway ring and rolling elements. Continued use under this condition leads to larger cracks or fractures.	Excessive interference Excessive load, shock load Progression of flaking Heat generation and fretting caused by contact between mounting parts and raceway ring Heat generation due to creep Poor taper angle of tapered shaft Poor cylindricality of shaft Interference with bearing chamfer due to a large shaft corner radius	● Correct the interference ● Check the load conditions ● Improve the mounting method ● Use an appropriate shaft shape

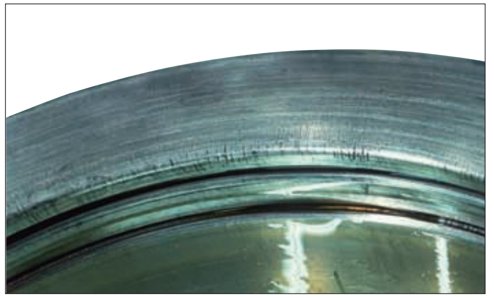


Photo 6-1
Part: Outer ring of a double-row cylindrical roller bearing
Symptom: Thermal cracks occur on the outer ring side face
Cause: Abnormal heat generation due to contact sliding between mating part and face of outer ring

Photo 6-2
Part: Roller of a tapered roller thrust bearing
Symptom: Thermal cracks occur at large end face of roller
Cause: Heat generation due to sliding with the inner ring rib under poor lubrication

Photo 6-3
Part: Outer ring of a double-row cylindrical roller bearing
Symptom: Cracks propageted outward in the axial and circumferential directions from the flaking origin on the raceway surface
Cause: Flaking from a flaw due to shock

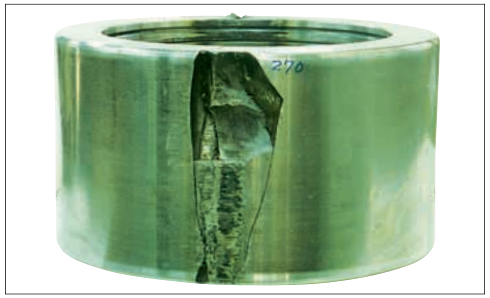


Photo 6-4
Part: Outer ring of a double-row cylindrical roller bearing used for outer ring rolling (Outer ring rotation)
Symptom: Cracks occur on outside surface
Cause: Flat wear and heat generation due to non-rotation of the outer ring

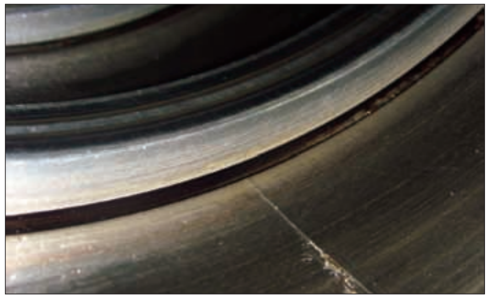


Photo 6-5
Part: Outer ring of a cylindrical roller bearing for sendzimir Mills
Symptom: Fatigue crack occurs on outer ring raceway surface
Cause: Bending stress (Large rotating outer ring load)

Photo 6-6
Part: Inner ring of a spherical roller bearing
Symptom: Axial cracks occur on raceway surface
Cause: Large fitting stress due to temperature difference between shaft and inner ring

Photo 6-7
Part: Cross section of a fractured inner ring in Photo 6-6
Symptom: Origin is directly beneath the raceway surface

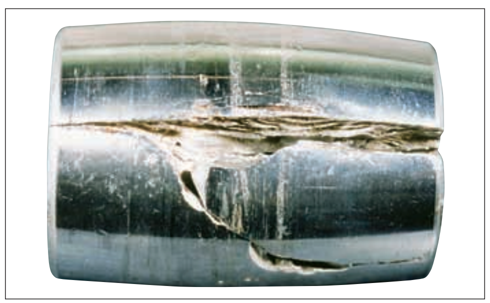


Photo 6-8
Part: Roller of a spherical roller bearing
Symptom: Axial cracks occur on rolling surface

Photo 6-9
Part: Outer ring of four-row tapered roller bearing
Symptom: Secondary damage after flaking occurs on outer ring raceway surface

2.3.7 Cage Damage

Damage Condition	Possible Cause	Measures
Cage damage includes cage deformation, fracture, and wear Fracture of cage pillar Deformation of side face Wear of pocket surface Wear of guide surface	Poor mounting (Bearing misalignment) Poor handling Large moment load Shock and large vibration Excessive rotation speed, sudden acceleration and deceleration Poor lubrication Temperature rise	● Check the mounting method ● Check the temperature, rotation, and load conditions ● Reduce the vibration ● Select a cage type ● Select a lubrication method and lubricant

Photo 7-1
Part: Cage of a deep groove ball bearing
Symptom: Fracture of pressed-steel cage-pocket

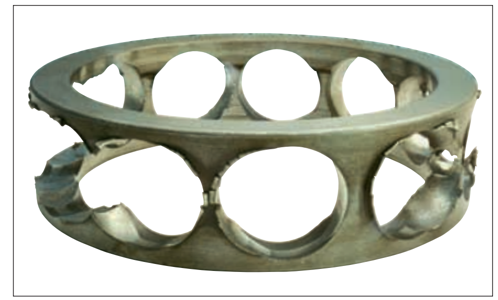


Photo 7-2
Part: Cage of an angular contact ball bearing
Symptom: Pocket pillar fractures from a cast iron machined cage
Cause: Abnormal load action on cage due to misaligned mounting between inner and outer rings

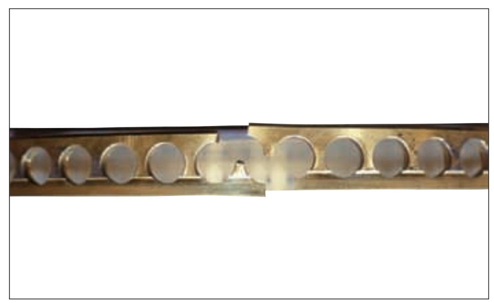


Photo 7-3
Part: Cage of an angular contact ball bearing
Symptom: Fracture of machined high-tension brass cage

Photo 7-4
Part: Cage of a tapered roller bearing
Symptom: Pillar fractures of pressed-steel cage

Photo 7-5
Part: Cage of an angular contact ball bearing
Symptom: Pressed-steel cage deformation
Cause: Shock load due to poor handling

Photo 7-6
Part: Cage of a cylindrical roller bearing
Symptom: Deformation of the side face of a machined high-tension brass cage
Cause: Large shock during mounting

Photo 7-7
Part: Cage of a cylindrical roller bearing
Symptom: Deformation and wear of a machined high-tension brass cage

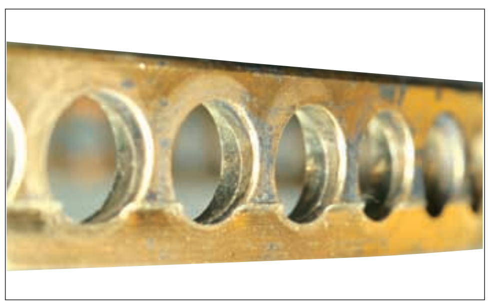


Photo 7-8
Part: Cage of an angular contact ball bearing
Symptom: Stepped wear on the outside surface and pocket surface of a machined high-tension brass cage

2.3.8 Denting

Damage Condition	Possible Cause	Measures
When debris such as small metallic particles are caught in the rolling contact zone, denting occurs on the raceway surface or rolling element surface. Denting can occur at the rolling element pitch interval if there is a shock during the mounting (Brinell dents).	Debris such as metallic particles are caught in the surface Excessive load Shock during transport or mounting	● Wash the housing ● Improve the sealing mechanism ● Filter the lubrication oil ● Improve the mounting and handling methods

Photo 8-1
Part: Inner ring of a double-row tapered roller bearing
Symptom: Frosted raceway surface
Cause: Debris caught in the surface

Photo 8-2
Part: Outer ring of a double-row tapered roller bearing
Symptom: Indentations on raceway surface
Cause: Debris caught in the surface

Photo 8-3
Part: Inner ring of a tapered roller bearing
Symptom: Small and large indentations occur over entire raceway surface
Cause: Debris caught in the surface

Photo 8-4
Part: Tapered rollers of Photo 8-3
Symptom: Small and large indentations occur over the rolling surface
Cause: Debris caught in the surface

2.3.9 Pitting

Damage Condition	Possible Cause	Measures
The pitted surface has a dull luster which appears on the rolling element surface or raceway surface.	Debris becomes caught in the lubricant Exposure to moisture in the atmosphere Poor lubrication	● Improve the sealing mechanism ● Filter the lubrication oil thoroughly ● Use a proper lubricant

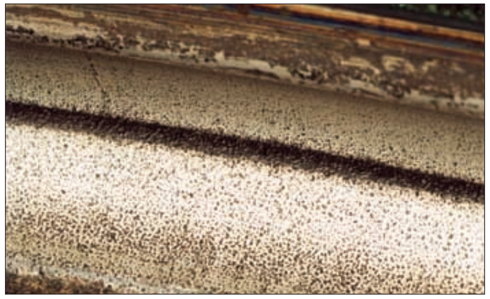


Photo 9-1
Part: Outer ring of a slewing bearing
Symptom: Pitting occurs on the raceway surface
Cause: Rust at bottoms of indentations

Photo 9-2
Part: Ball of Photo 9-1
Symptom: Pitting occurs on the rolling element surface

2.3.10 Wear

Damage Condition	Possible Cause	Measures
Wear is surface deterioration due to sliding friction at the surface of the raceway, rolling elements, roller end faces, rib face, cage pockets, etc.	Entry of debris Progression from rust and electrical corrosion Poor lubrication Sliding due to irregular motion of rolling elements	● Improve the sealing mechanism ● Clean the housing ● Filter the lubrication oil thoroughly ● Check the lubricant and lubrication method ● Prevent misalignment

Photo 10-1
Part: Inner ring of a cylindrical roller bearing
Symptom: Many pits occur due to electrical corrosion and wave-shaped wear on raceway surface
Cause: Electrical corrosion

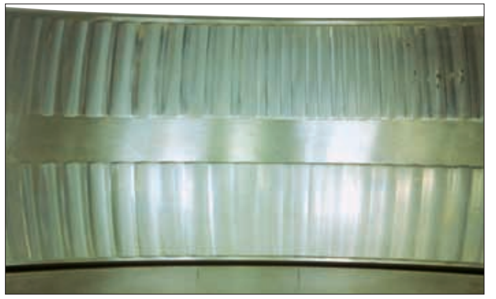


Photo 10-2
Part: Outer ring of a spherical roller bearing
Symptom: Wear having a wavy or concave-and-convex texture on loaded side of raceway surface
Cause: Entry of debris under repeated vibration while stationary

Photo 10-3
Part: Outer ring of a spherical roller bearing
Symptom: Wear occurs on loaded side of raceway surface
Cause: Low speed, heavy load and poor lubrication(No oil film)

Photo 10-4
Part: Outer ring of a spherical roller bearing (enlargement)
Symptom: Example of small flaking and wear combined on the raceway
Cause: Insufficient oil film due to poor lubrication leads to wear (primary damage) that progresses to flaking (secondary damage)

Photo 10-5
Part: Outer ring of a tapered roller bearing
Symptom: Wear occurs on outer ring raceway surface
Cause: Insufficient oil film and wear due to poor lubrication

Photo 10-6
Part: Inner ring of a double-row tapered roller bearing
Symptom: Fretting wear of raceway and stepped wear on the rib face
Cause: Fretting progression due to excessive load while stationary

Photo 10-7
Part: Tapered rollers of Photo 10-6
Symptom: Stepped wear on the roller head and face
Cause: Fretting progression due to excessive load while stationary

2.3.11 Fretting

Damage Condition	Possible Cause	Measures
Wear occurs due to repeated sliding between the two surfaces. Fretting occurs at fitting surface and also at contact area between raceway ring and rolling elements. Fretting corrosion is another term used to describe the reddish brown or black worn particles.	Poor lubrication Vibration with a small amplitude Insufficient interference	● Use a proper lubricant ● Apply a preload ● Check the interference fit ● Apply a film of lubricant to the fitting surface

Photo 11-1
Part: Inner ring of a deep groove ball bearing
Symptom: Fretting occurs on the bore surface
Cause: Vibration

Photo 11-2
Part: Inner ring of an angular contact ball bearing
Symptom: Notable fretting occurs over entire circumference of bore surface
Cause: Insufficient interference fit

Photo 11-3
Part: Outer ring of a double-row cylindrical roller bearing
Symptom: Fretting occurs on the raceway surface at roller pitch intervals

2.3.12 False Brinelling

Damage Condition	Possible Cause	Measures
Among the different types of fretting, false brinelling is the occurrence of hollow spots that resemble brinell dents, and are due to wear caused by vibration and swaying at the contact points between the rolling elements and raceway.	Oscillation and vibration of a stationary bearing during such times as transporting Oscillating motion with a small amplitude Poor lubrication	● Secure the shaft and housing during transporting ● Transport with the inner and outer rings packed separately ● Reduce the vibration by preloading ● Use a proper lubricant

Photo 12-1
Part: Inner ring of a deep groove ball bearing
Symptom: False brinelling occurs on the raceway
Cause: Vibration from an external source while stationary

Photo 12-2
Part: Outer ring of Photo 12-1
Symptom: False brinelling occurs on the raceway
Cause: Vibration from an external source while stationary

Photo 12-3
Part: Outer ring of a thrust ball bearing
Symptom: False brinelling of raceway surface at ball pitch
Cause: Repeated vibration with a small oscillating angle

Photo 12-4
Part: Rollers of a cylindrical roller bearing
Symptom: False brinelling occurs on rolling surface
Cause: Vibration from an external source while stationary

2.3.13 Seizure

Damage Condition	Possible Cause	Measures
When sudden overheating occurs during rotation, the bearing becomes discolored. Next, raceway rings, rolling elements, and cage will soften, melt and deform as damage accumulates.	Poor lubrication Excessive load (Excessive preload) Excessive rotational speed Excessively small internal clearance Entry of water and debris Poor precision of shaft and housing, excessive shaft bending	● Study the lubricant and lubrication method ● Reinvestigate the suitability of the bearing type selected ● Study the preload, bearing clearance, and fitting ● Improve the sealing mechanism ● Check the precision of the shaft and housing ● Improve the mounting method

Photo 13-1
Part: Inner ring of a spherical roller bearing
Symptom: Raceway is discolored and melted. Worn particles from the cage were rolled and attached to the raceway
Cause: Insufficient lubrication

Photo 13-2
Part: Convex rollers of Photo 13-1
Symptom: Discoloration and melting of roller rolling surface, adhesion of worn particles from cage
Cause: Insufficient lubrication

Photo 13-3
Part: Inner ring of an angular contact ball bearing
Symptom: Raceway discoloration, melting occurs at ball pitch intervals
Cause: Excessive preload

Photo 13-4
Part: Outer ring in Photo 13-3
Symptom: Raceway discoloration, melting occurs at ball pitch intervals
Cause: Excessive preload

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Photo 13-5
Part: Balls and cage of Photo 13-3
Symptom: Cage is damaged by melting, balls become discolored and melted
Cause: Excessive preload

Photo 13-6
Part: Rollers of a large tapered roller bearing
Symptom: Seizure occur at large end face of roller
Cause: Poor lubrication and excessive axial load

Photo 13-7
Part: Cylindrical roller bearing
Symptom: Seizure occurs on ring raceway surface and roller
Cause: Excessively small internal clearance causes heat generation by sliding of the inner ring and rollers under high speed and light load

2.3.14 Creep

Damage Condition	Possible Cause	Measures
Creep is the phenomenon in bearings where relative slipping occurs at the fitting surfaces and thereby creates a clearance at the fitting surface. Creep causes a shiny appearance, occasionally with scoring or wear.	Insufficient interference or loose fit Insufficient sleeve tightening	● Check the interference, and prevent rotation ● Correct the sleeve tightening ● Study the shaft and housing precision ● Preload in the axial direction ● Tighten the raceway ring side face ● Apply adhesive to the fitting surface ● Apply a film of lubricant to the fitting surafce

Photo 14-1
Part: Inner ring of a spherical roller bearing
Symptom: Creep accompanied by scoring of bore surface
Cause: Insufficient interference

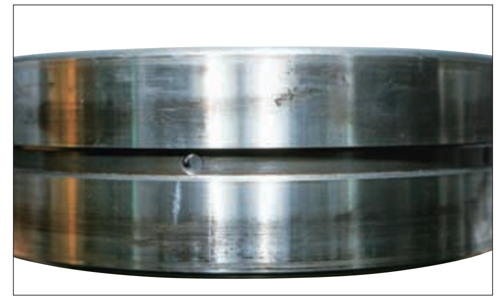


Photo 14-2
Part: Outer ring of a spherical roller bearing
Symptom: Creep occurs over entire circumference of outside surface
Cause: Loose fit between outer ring and housing

2.3.15 Electrical Corrosion

Damage Condition	Possible Cause	Measures
When electric current passes through a bearing, arcing and burning occur through the thin oil film at points of contact between the race and rolling elements. The points of contact are melted locally to form "fluting" or groove-like corrugations which are seen by the naked eye. The magnification of these grooves will reveal crater-like depressions which indicate melting by arcing.	Electrical potential difference between inner and outer rings Electrical potential difference of a high frequency that is generated by instruments or substrates when used near a bearing.	● Design electric circuits which prevent current flow through the bearings ● Insulation of the bearing

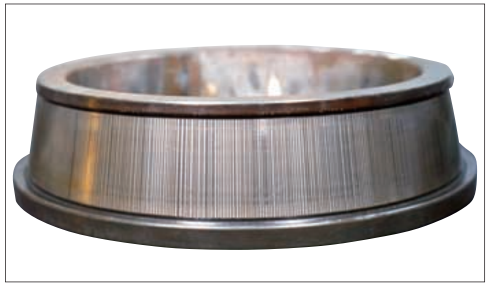


Photo 15-1
Part: Inner ring of a tapered roller bearing
Symptom: Striped pattern of corrosion occurs on the raceway surface

Photo 15-2
Part: Tapered rollers in Photo 15-1
Symptom: Striped pattern of corrosion occurs on the rolling surface

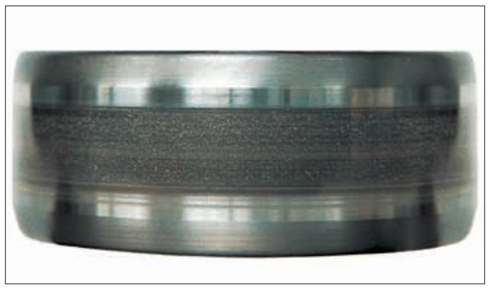
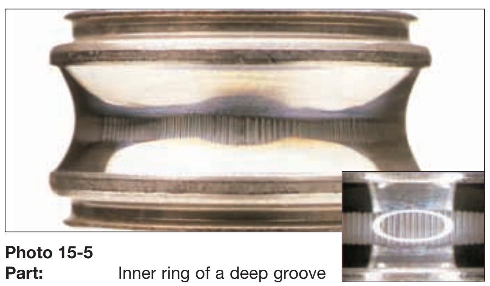


Photo 15-3
Part: Inner ring of a cylindrical roller bearing
Symptom: Belt pattern of electrical corrosion accompanied by pits on the raceway surface

Photo 15-4
Part: Balls of a groove ball bearing
Symptom: Electrical corrosion has a dark color that covers the entire ball surface



Enlargement

Photo 15-5
Part: Inner ring of a deep groove ball bearing
Symptom: Fluting occurs on the raceway surface (High frequency)

Photo 15-6
Part: Outer ring of a deep groove ball bearing
Symptom: Fluting occurs on the raceway surface (High frequency)

2.3.16 Rust and Corrosion

Damage Condition	Possible Cause	Measures
Bearing rust and corrosion are pits on the surface of rings and rolling elements and may occur at the rolling element pitch on the rings or over the entire bearing surfaces.	Entry of corrosive gas or water Improper lubricant Formation of water droplets due to condensation of moisture High temperature and high humidity while stationary Poor rust preventive treatment during transporting Improper storage conditions Improper handling	● Improve the sealing mechanism ● Study the lubrication method ● Anti-rust treatment for periods of non-running ● Improve the storage methods ● Improve the handling method

Photo 16-1
Part: Outer ring of a cylindrical roller bearing
Symptom: Rust on the rib face and raceway surface
Cause: Poor lubrication due to water entry

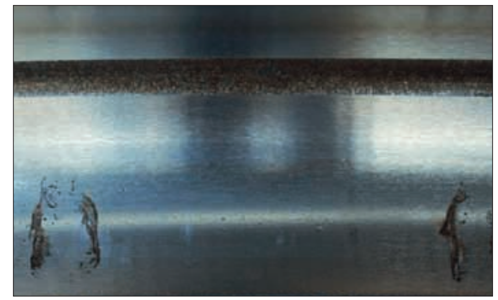


Photo 16-2
Part: Outer ring of a slewing ring
Symptom: Rust on raceway surface at ball pitch
Cause: Moisture condensation during stationary periods

Photo 16-3
Part: Inner ring of a spherical roller bearing
Symptom: Rust on raceway surface at roller pitch
Cause: Entry of water into lubricant

Photo 16-4
Part: Rollers of a spherical roller bearing
Symptom: Pit-shaped rust on rolling contact surface. Corroded portions.
Cause: Moisture condensation during storage

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2.3.17 Mounting Flaws

Damage Condition	Possible Cause	Measures
Straight line scratches on surface of raceways or rolling elements caused during mounting or dismounting of bearing.	Inclination of inner and outer rings during mounting or dismounting. Shock load during mounting or dismounting.	● Use appropriate jig and tool ● Avoid a shock load by use of a press machine ● Center the relative mating parts during mounting

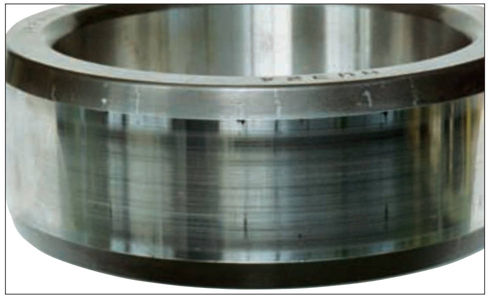

Photo 17-1
Part: Inner ring of a cylindrical roller bearing
Symptom: Axial scratches on raceway surface
Cause: Inclination of inner and outer rings during mounting

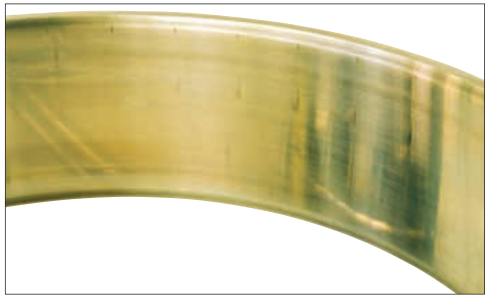

Photo 17-2
Part: Outer ring of a double-row cylindrical roller bearing
Symptom: Axial scratches at roller pitch intervals on raceway surface
Cause: Inclination of inner and outer rings during mounting

Photo 17-3
Part: Rollers of a cylindrical roller bearing
Symptom: Axial scratches on rolling surface
Cause: Inclination of inner and outer rings during mounting

2.3.18 Discoloration

Damage Condition	Possible Cause	Measures
Discoloration of cage, rolling elements, and raceway ring occurs due to a reaction with lubricant and high temperature.	Poor lubrication Oil stain due to a reaction with lubricant High temperature	● Improve the lubrication method

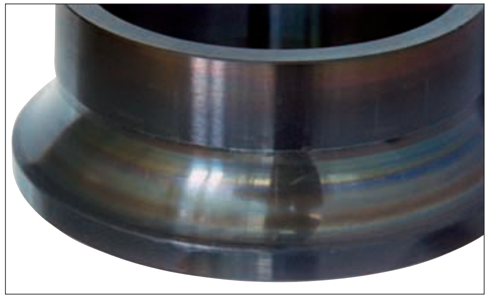

Photo 18-1
Part: Inner ring of an angular contact ball bearing
Symptom: Bluish or purplish discoloration on raceway surface
Cause: Heat generation due to poor lubrication

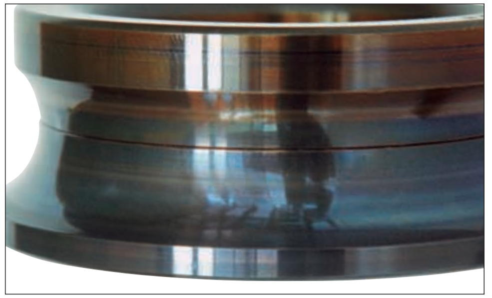

Photo 18-2
Part: Inner ring of a 4-point contact ball bearing
Symptom: Bluish or purplish discoloration on raceway surface
Cause: Heat generation due to poor lubrication

Appendix Bearing Diagnostic Chart

		Cause													
		Handling		Bearing surrounding			Lubri-cation		Load			Speed			
Damage name	Location (Phenomenon)	Stock·Shipping	Mounting	Shaft Housing	Sealed device Water·Debris	Temperature	Lubricant	Lubrication method	Excessive load Impact load	Moment	Ultra small load	High speed, High acceleration & deceleration	Shaking·Vibration Stationary	Bearing Selection	Remarks
2.3.1 Flaking	Raceway, Rolling surface		○	○	○		○	○	○	○				○	
2.3.2 Peeling	Raceway, Rolling surface				○		○	○			○	○			
	Bearing outside surface (Rolling contact)			○*	○		○	○							*Mating rolling part
2.3.3 Scoring	Roller end face surface, Rib surface		○	○	○		○	○	○	○		○			
	Cage guide surface, Pocket surface		○		○		○	○							
2.3.4 Smearing	Raceway, Rolling surface				○		○	○			○	○			
2.3.5 Fracture	Raceway collar, Rollers	○	○	○					○	○					
2.3.6 Cracks	Raceway rings, Rolling elements		○	○		○			○	○					
	Rib surface, Roller end face, Cage guide surface (Thermal crack)			○				○	○	○					
2.3.7 Cage damage	(Deformation), (Fracture)		○	○					○	○					
	(Wear)		○		○		○	○	○	○		○			
2.3.8 Denting	Raceway, Rolling surface, (Innumerable small dents)				○			○							
	Raceway (Debris on the rolling element pitch)	○	○						○				○		
2.3.9 Pitting	Raceway, Rolling surface				○		○	○							
2.3.10 Wear	Raceway, Rolling surface, Rib surface, Roller end face		○		○		○	○							
2.3.11 Fretting	Raceway, Rolling surface	○	○	○			○	○	○			○	○		
	Bearing outside & bore, side surface (Contact with housing and shaft)		○	○					○						
2.3.12 False brinelling	Raceway, Rolling surface	○					○	○					○		
2.3.13 Seizure	Raceway ring, Rolling element, Cage		○	○	○		○	○	○	○		○		○	
2.3.14 Creep	Fitting surface		○	○		○	○*	○*	○			○			*Clearance fit
2.3.15 Electrical corrosion	Raceway, Rolling surface		○*	○*											*Electricity passing through the rolling element
2.3.16 Rust and corrosion	Raceway ring, Rolling element, Cage	○	○		○	○	○	○							
2.3.17 Mounting flaws	Raceway, Rolling surface		○	○											
2.3.18 Discoloration	Raceway ring, Rolling element, Cage					○	○	○							

Remark This chart is not comprehensive. It lists only the more commonly occurring damages, causes, and locations.

Note