# BEARING HANDLING AND MAINTENANCE




# Part B

## BEARING HANDLING AND MAINTENANCE

1. BEARING HANDLING ..... B 005
2. BEARING DAMAGE AND COUNTERMEASURES (Bearing Doctor) ..... B 021




# 1. BEARING HANDLING

1.1 Precautions for Proper Handling of Bearings ..... B 006

1.2 Bearing Storage ..... B 006
1.2.1 Bearing Storage Location ..... B 006
1.2.2 How to Store Bearings ..... B 006

1.3 Mounting ..... B 006
1.3.1 Mounting of Bearings With Cylindrical Bores ..... B 006
1.3.2 Mounting of Bearings With Tapered Bores ..... B 008

1.4 Operation Inspection ..... B 008

1.5 Dismounting ..... B 011
1.5.1 Dismounting of Outer Rings ..... B 011
1.5.2 Dismounting of Bearings With Cylindrical Bores ..... B 011
1.5.3 Dismounting of Bearings With Tapered Bores ..... B 012

1.6 Inspection of Bearings ..... B 013
1.6.1 Bearing Cleaning ..... B 013
1.6.2 Inspection and Evaluation of Bearings ..... B 013

1.7 Checking the Shaft and Housing ..... B 014
1.7.1 Checking the Shaft ..... B 014
1.7.2 Checking the Housing ..... B 016

1.8 Maintenance and Inspection ..... B 017
1.8.1 Detecting and Correcting Irregularities ..... B 017
1.8.2 Diagnosis With Sound and Vibration ..... B 018

# 1. BEARING HANDLING

## 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.
Be sure to take the following precautions:

### (1) Keep Bearings and Surrounding Area Clean

Dust, dirt, and debris, even if invisible to the naked eye, have harmful effects on bearings. Prevent the entry of foreign matter by keeping the bearings and their environment as clean as possible.

### (2) Handle Carefully

Heavy shocks during handling may cause bearings to be scratched, dented, or otherwise damaged, possibly resulting in their failure. Excessively strong impacts may cause chips or cracks.

### (3) Use Proper Tools

Always use proper and well-maintained 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 hands clean when handling bearings and wear gloves if possible. Monitor for rust caused by corrosive gases or moisture.

## 1.2 Bearing Storage

To prevent rusting, each bearing is treated and packed with an anticorrosive agent, but the effectiveness of this varies greatly depending on the storage environment. Keep bearings in-box until needed and select a suitable place to store replacement bearings.

### 1.2.1 Bearing Storage Location

Bearings must be stored indoors in a cool, dry place without direct sunlight. High temperatures and high humidity must be avoided as they significantly reduce the effect of the anticorrosive. To avoid condensation, we recommend storing bearings at room temperature at 65% humidity or less.

### 1.2.2 How to Store Bearings

After considering the size and weight of the bearings to be stocked, secure enough space and proper carrying equipment to transport bearings safely. Proper storage shelves are recommended, with the lowest tray of the shelf at least 30 cm above the floor. Avoid putting bearings directly on the floor. The effectiveness of the anticorrosive varies depending on the storage environment, but it is generally effective for about one to three years. If storing the bearing for a longer time, a special storage method must be used, such as immersing the bearing in turbine oil.

## 1.3 Mounting

Bearing mounting methods strongly affect bearing accuracy, life, and performance. Bearing characteristics should first be thoroughly studied before mounting. Handling procedures for bearings should be fully investigated by design engineers and standards should be established for the following:

(1) Cleaning of bearings and related parts
(2) Confirmation of 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 grease lubrication, grease should be packed in the bearings without cleaning them first. Even when using 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 often require a tight fit. Bearings with cylindrical bores are usually mounted by pressing them onto shafts (press fit) or by first heating them to expand their diameter before they cool and shrink on a shaft (shrink fit). Bearings with tapered bores can be mounted directly on tapered shafts or on cylindrical shafts with 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 with dry ice before mounting. In this case, a rust preventive treatment must be applied to the bearing because moisture in the air will condense on the bearing surface.

### 1.3.1 Mounting of Bearings With Cylindrical Bores

#### *(1) Press Fits*

Press fitting 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 onto the shaft 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 during press mounting since the bearing may be damaged. Before mounting, applying oil to the fitted shaft surface is recommended for smooth insertion. Mounting using a hammer should only be performed for small ball bearings with minimally tight fits when a press is not available. This method should not be used for tight interference fits or for medium- or large-size bearings. Any time a hammer is used, a mounting tool must be placed on the inner ring.
When both the inner and outer rings of non-separable bearings, such as deep groove ball bearings, require a 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. A mounting tool should always be used for mounting self-aligning ball bearings since the outer ring may deflect.

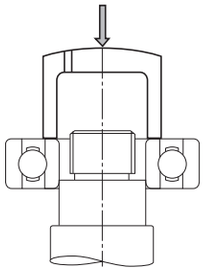


Fig. 1.1 Press Fitting Inner Ring

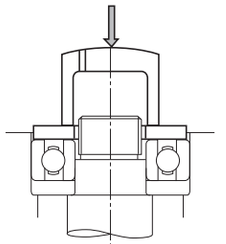


Fig. 1.2 Simultaneous Press Fitting of Inner and Outer Rings

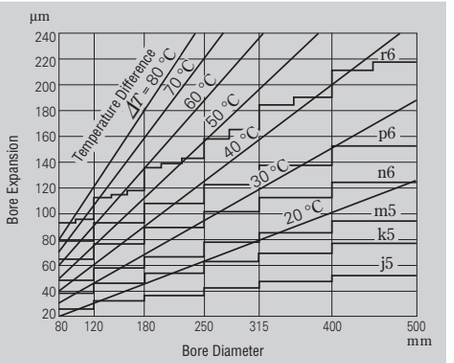



Fig. 1.3 Temperature and Thermal Expansion of Inner Ring

For separable bearings, such as cylindrical roller bearings and tapered roller bearings, the inner and outer rings may be mounted separately. Assembly of inner and outer rings previously mounted separately should be performed carefully, ensuring the correct alignment of the rings. Careless or forced assembly may cause scratches on rolling contact surfaces.

#### *(2) Shrink Fits*

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

(a) Do not heat bearings above 120˚C.
(b) Put the bearings on a wire net or suspend them in an oil tank 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 slightly during mounting.
(d) After mounting, the bearings will shrink in the axial and radial directions 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

NSK Bearing Heaters, which use electromagnetic induction to heat bearings, are widely used as an alternative to heating in oil.
In NSK Bearing Heaters, electricity (AC) in a coil produces a magnetic field that induces a current inside the bearing that generates heat without using flames or oil. Consequently, uniform heating in a short time is possible, making shrink fitting efficient and clean.
NSK induction heating equipment is useful when relatively frequent mounting and dismounting is necessary, such as with roll neck bearings for rolling mills and the cylindrical roller bearings of railway rolling stock axles. See Page B11 for more information on dismounting.

### 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 a mounting method where holes drilled in the sleeve 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 internal clearance reduction and referring to the drive-up distances 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 larger 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*, *b*, and *c* may be used as the residual clearance. For reference, points *a* and *b* are located on a horizontal line that passes through the bearing center while *c* is located at the lowest position of the bearing. 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. Allow for sufficient clearance for easy alignment of the outer ring.

## 1.4 Operation Inspection

After 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 ensure that they rotate smoothly. Check for sticking due to foreign matter or visible flaws; uneven torque caused by improper mounting or an improper mounting surface; and excessive torque caused by inadequate clearance, mounting error, or seal friction. If there are no abnormalities, powered operation may be started.

**Table 1.1 Mounting of Spherical Roller Bearings With Tapered Bores**

Units : mm

| Bearing Bore Diameter *d* | | Reduction in Radial Clearance | | Axial Drive-Up Distance | | | | Minimum Permissible Residual Clearance | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Taper 1 : 12 | | Taper 1 : 30 | | | |
| over | incl. | min. | max. | min. | max. | min. | max. | *CN* | *C3* |
| **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 bearings with C3 clearance, the maximum values listed should be used for the reduction in radial internal clearance.

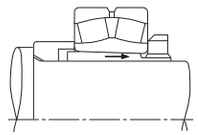


**Fig. 1.4 Mounting With Adapter**

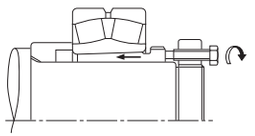


**Fig. 1.5 Mounting With Withdrawal Sleeve**

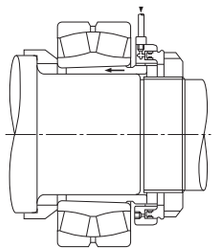


**Fig. 1.6 Mounting With Hydraulic Nut**

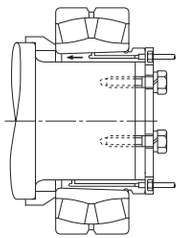


**Fig. 1.7 Mounting With Special Sleeve and Hydraulic Pressure**

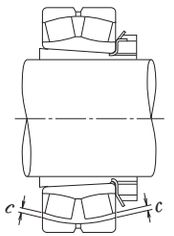



**Fig. 1.8 Clearance Measurement of a Spherical Roller Bearing**

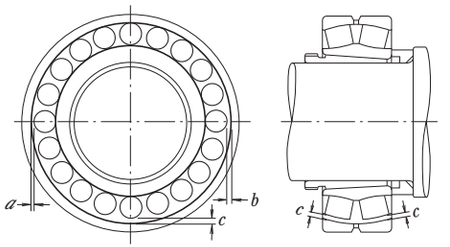



**Fig. 1.9 Measuring Clearance in Large Spherical Roller Bearing**

After a pre-operation examination, large machines that cannot be turned by hand should be started with no load. After the machine starts, immediately cut off the power and allow the machine to coast to a stop. Confirm that there are no abnormalities such as vibration, noise, contact with the rotating parts, or similar. Powered operation should be started slowly without load and observed carefully until it is determined that no abnormalities exist. Then, gradually increase the speed, load, and other conditions to their normal levels. Be sure to monitor for abnormal noise, excessive rise of bearing temperature, leakage and contamination of lubricants, etc. If any abnormality is found, stop the test immediately and inspect the machine. If possible, the bearing should be dismounted for examination.

Although bearing temperature can generally be estimated by the temperature of the outside surface of the housing, it is better to directly measure the temperature of the outer ring through oil holes. The bearing temperature should rise gradually to a steady state within one to two hours after operation starts. If the wrong bearing or mounting is used, bearing temperature may increase rapidly and become abnormally high. The cause of this abnormal temperature may be excessive lubricant, insufficient bearing clearance, incorrect mounting, or excessive friction of the seals.

In high-speed operation, an incorrect selection of bearing type or lubricating method may also cause abnormal temperature rise.

The sound of a bearing may be checked with a noise locater or vibration monitoring equipment. Abnormal conditions may be 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. Details and countermeasures for various irregularities are listed in Table 1.2.

**Table 1. 2 Causes of and Countermeasures for Operating Irregularities**

| Irregularities | | Possible Causes | Countermeasures |
|---|---|---|---|
| Noise | Loud Metallic Sound (1) | Abnormal load | Improve the fit, internal clearance, preload, and/or position of housing shoulder. |
| | | Incorrect mounting | Improve the machining accuracy and alignment of the shaft and housing, improve the accuracy of the mounting, or change the mounting method |
| | | Insufficient or improper lubricant | Replenish the lubricant or select another lubricant. |
| | | Contact of rotating parts | Modify the seal (labyrinth, etc.). |
| | Rhythmic Sound | Flaws, corrosion, or scratches on raceways | Clean or replace 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. |
| | | Entry of foreign particles | Clean or replace the bearing, improve the seals, and use clean lubricant. |
| | | Flaws or flaking on balls | Replace the bearing. |
| Abnormal Temperature Rise | | Excessive lubricant | Reduce the amount of lubricant and/or select a stiffer grease. |
| | | Insufficient or improper lubricant | Replenish lubricant or select another appropriate lubricant. |
| | | Abnormal load | Improve the fit, internal clearance, preload, and/or position of housing shoulder. |
| | | Incorrect mounting | Improve the machining accuracy and alignment of the shaft and housing, improve the accuracy of the mounting, or change the mounting method. |
| | | Creep on fitted surface, excessive seal friction | Replace the bearing, change the seal type, and correct the shaft and housing to consider the fit. |
| Vibration (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. |
| | | Entry of foreign particles | Clean or replace the bearing, improve the seals. |
| Leakage or Discoloration of Lubricant | | Too much lubricant, entry of foreign matter or abrasion chips | Replace the bearing or lubricant, reduce the amount of lubricant, select a stiffer grease, and clean the housing and adjacent parts. |

**Note** (1) Intermittent squealing or high-pitched noise may be heard in medium- to large-sized cylindrical roller bearings or ball bearings operating under grease lubrication in low-temperature environments. Under such low-temperature conditions, bearing temperature will not rise, and fatigue life and grease performance are not affected. Although intermittent squealing or high-pitched noises may occur under these conditions, the bearing is fully functional and can continue to be used. If greater noise reduction or quieter operation 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 is removed only for inspection, it should be dismounted as carefully as when it was mounted. If the bearing has a tight fit, 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 plan and while 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 into a housing with push-out holes, first place bolts in the push-out holes at several locations along the 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. For 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 that the outer ring may be pressed out with a dismounting tool or by tapping.

### 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, 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.

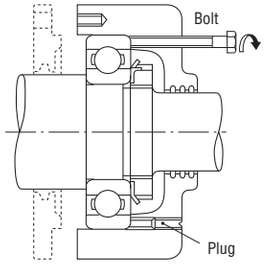



**Fig. 1.10 Removal of Outer Ring With Dismounting Bolts**

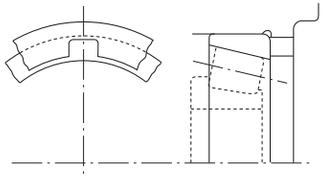


**Fig. 1.11 Removal Notches**

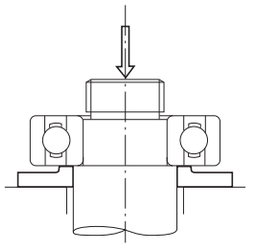


**Fig. 1.12 Removal of Inner Ring Using a Press**

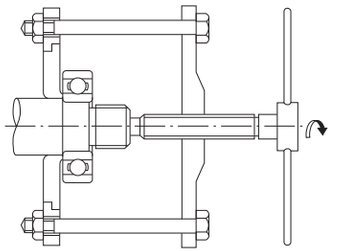


**Fig. 1.13 Removal of Inner Ring Using a Withdrawal Tool (1)**

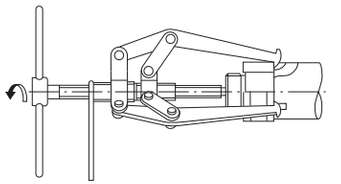


**Fig. 1.14 Removal of Inner Ring Using a Withdrawal Tool (2)**

In both cases, the claws of the tools must substantially engage the face of the inner ring; therefore, consider the size of the shaft shoulder during design or cut grooves in the shoulder to accommodate the withdrawal tools (Fig. 1.14).
The oil-injection method is usually used for the dismounting of large bearings. Oil pressure is applied through holes in the shaft, allowing for easy dismounting. For 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-type cylindrical roller bearings. The inner rings are expanded by brief local heating, and then removed (Fig. 1.15). Induction heating is also used when mounting several of these bearings 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. As shown in Fig. 1.18, this is followed by hammering on the sleeve using a suitable tool. 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 remove the sleeve by tightening the bolts as shown in Fig. 1.17.
Large bearings may be removed 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 removal method using a hydraulic nut.

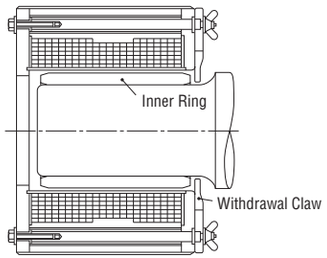



Fig. 1.15 Removal of Inner Ring Using an Induction Heater

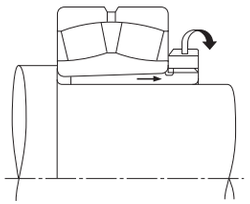


Fig. 1.16 Removal of Withdrawal Sleeve Using a Withdrawal Nut (1)

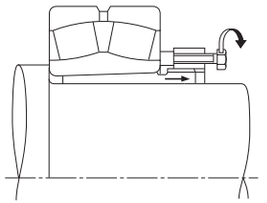


Fig. 1.17 Removal of Withdrawal Sleeve Using a Withdrawal Nut (2)

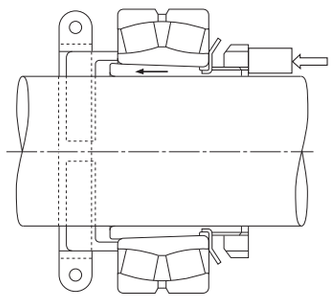


Fig. 1.18 Removal of Adapter With a Stop and Axial Pressure

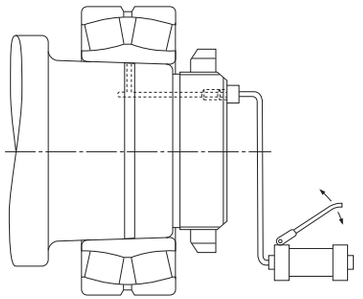


Fig. 1.19 Removal Using an Oil Injection Hydraulic Pump

## 1.6 Inspection of Bearings

### 1.6.1 Bearing Cleaning

When bearings are inspected, first record the appearance of the bearings and check the amount and condition of the residual lubricant. After the lubricant has been sampled, 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 have a metal net to submerge the bearings in 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. Lubricant and other deposits should be removed in the oil bath during an initial rough cleaning with a soft brush or similar. After the bearing is relatively clean, give it a finishing rinse. The finishing rinse should be performed carefully by rotating the bearing while keeping it immersed in rinsing oil. Always keep the rinsing oil clean.

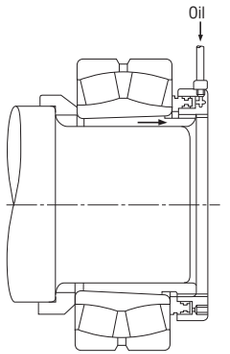



Fig. 1.20 Removal Using a Hydraulic Nut

### 1.6.2 Inspection and Evaluation of Bearings

After being thoroughly cleaned, examine the condition of bearing raceways and external surfaces, the amount of cage wear, the increase in internal clearance, and degradation of tolerances. Carefully check these points and examine for possible damage or other abnormalities to determine if the bearing can be reused.
For 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 bearing in the machine, operating conditions, and the time until the next inspection. However, if any of the following are true, reuse is not possible and replacement is necessary:

(a) Cracks exist in the inner or outer rings, rolling elements, or cage.
(b) Flaking is present on the raceway or rolling elements.
(c) There is significant smearing of the raceway surfaces, ribs, or rolling elements.
(d) The cage is significantly worn or rivets are loose.
(e) Rust or scoring is present on the raceway surfaces or rolling elements.
(f) Significant impact or brinell traces exist on the raceway surfaces or rolling elements.
(g) There is significant evidence of creep on the bore or periphery of the outer ring.
(h) Discoloration by heat is evident.
(i) Significant damage to the seals or shields of grease-sealed bearings has occurred.

## 1.7 Checking the Shaft and Housing

### 1.7.1 Checking the Shaft

***(a) Cylindrical Shaft***

(1) Dimensional check of shaft
Use an outside micrometer to 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.

(2) Check of shaft outside surface
Check the surface of shaft where the bearing will be mounted for scratches, dents, rust, or stepped wear.
- If there are scratches or dents:
  Round the edge with an oil stone and/or sandpaper to smooth the surface.
- If there is rust:
  Remove rust with an oil stone and/or sandpaper to smooth the surface.
- If there is stepped wear:
  After measuring the shaft, determine if correction is possible.

(3) Anticorrosive agent
After completing the check, apply an anticorrosive agent.

***(b) Tapered Shaft***

(1) Check of shaft shape
Measure the shape of the shaft where the bearing will be mounted to confirm that it is correct. The measurement positions are shown in Fig. 1.22.
Use a taper gauge (sine bar system) for measurement (Fig. 1.22).

(2) Check of shaft outside surface
Check the shaft surface where the bearing will be mounted for scratches, dents, rust, or stepped wearing.

- If there are scratches or dents:
  Round edge with an oil stone and/or sandpaper to smooth the surface.
- If there is rust:
  Remove rust with an oil stone and/or sandpaper to smooth the surface.
  Inspect the shape of the tapered section with a taper gauge. Apply a thin coat of bluing over the entire surface of taper gauge bore face, and insert the gauge slowly after matching it to the center of the tapered shaft. Move the gauge back and forth and pull it out slowly. Note the surface of the tapered shaft covered with blue dye.
  If the blue area is over 80%, the shaft may be reused. When using a sine-bar taper gauge, follow the instructions given by the manufacturer.
- If there is stepped wear:
  After measuring the shaft, determine if correction is possible.

(3) Anticorrosive agent
After completing the check, apply an anticorrosive agent.

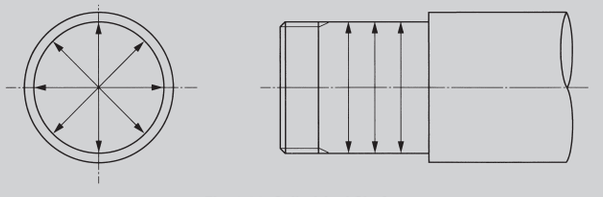


Fig. 1.21 Cylindrical Shaft

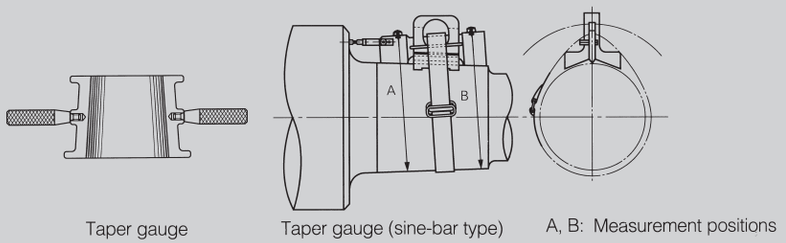



Fig. 1.22 Tapered Shaft

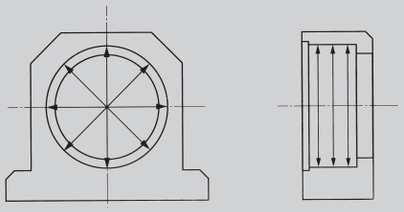
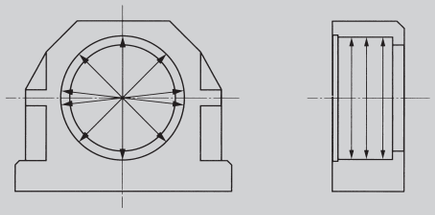


Fig. 1.23 Integrated Housing



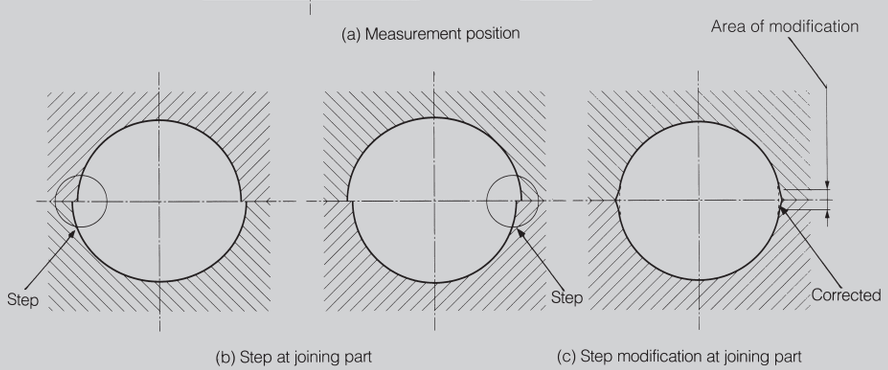




Fig. 1.24 Split Housing

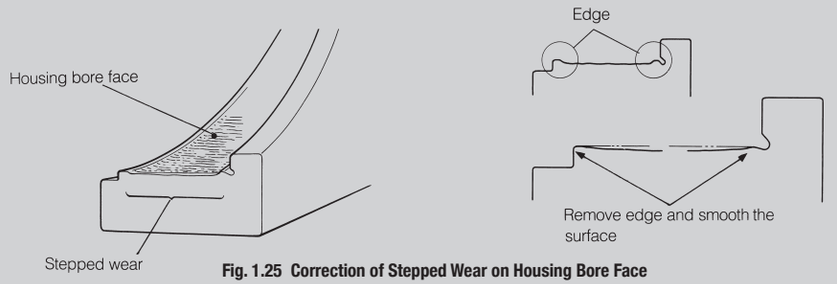



Fig. 1.25 Correction of Stepped Wear on Housing Bore Face

### 1.7.2 Checking the Housing

***(a) Integrated Housing***

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

(2) Check of housing bore face
Check the surface of the housing bore where the bearing will be mounted for scratches, dents, rust, or stepped wear.
- If there are scratches or dents:
  Round edges with an oil stone and/or sandpaper to smooth the surface.
- If there is rust:
  Remove rust with an oil stone and/or sandpaper to smooth the surface.
- If there is stepped wear (Fig. 1.25):
  After measuring the housing bore, decide if correction and reuse is possible. If the measured value of the housing bore is within its tolerance, use an oil stone and/or sandpaper to remove any sections with stepped wear and smooth the surface before reuse. If stepped wear is severe, either plate or apply thermal spraying to reconstitute the correct housing size before reuse.

(3) Anticorrosive agent
After completing the check, apply an anticorrosive agent.

***(b) Split Housing***

(1) Check of housing bore size
When using a split housing, correctly assemble the housing without the bearing and measure bore dimensions at the place where the bearing will be mounted to confirm that the dimensions are correct .
The measurement position is shown in Fig. 1.24 (a).
Use an inside micrometer for measurement.

(2) Check of housing bore face
Check the surface of the housing bore where the bearing will be mounted for scratches, dents, rust, or stepped wear.
- If there are scratches or dents:
  Round edges with an oil stone and/or sandpaper to smooth the surface.
- If there is rust:
  Remove rust with an oil stone and/or sandpaper to smooth the surface.
- If there is stepped wear (Fig. 1.25):
  After measuring the housing bore, decide if correction is possible.
  If the measured value of the housing bore is within its tolerance, use an oil stone and/or sandpaper to remove any sections with stepped wear and smooth the surface before reuse.
- If the stepped wear is severe:
  Either plate or apply thermal spraying to reconstitute the correct housing size before reuse.
- If there is a step:
  Steps may occur where the split halves of the housing join. If a step is found, correct it as shown in Fig. 1.24 (c).

(3) Anticorrosive agent
After completing the check, apply an anticorrosive agent.

## 1.8 Maintenance and Inspection

### 1.8.1 Detecting and Correcting Irregularities

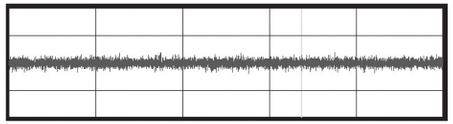
In order to maintain the original performance of a bearing for as long as possible, proper maintenance and inspection must be performed. If proper procedures are used, many bearing problems can be avoided, allowing for improvements in the reliability, productivity, and operating costs of equipment containing bearings. Periodic maintenance should be performed following specified procedures. 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 proper corrective actions should be taken after referring to Table 1.2. If necessary, the bearing should be dismounted and examined in detail. Refer to Section 1.6 Inspection of Bearings for dismounting and inspection procedures.

### 1.8.2 Diagnosis with Sound and Vibration

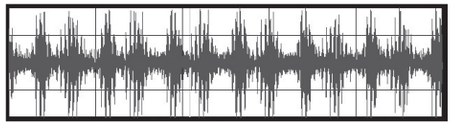
#### *Classification of sounds and vibrations*

Sounds and vibration accompany the rotation of rolling bearings. The tone and amplitude of such sounds and vibration vary depending on the type of bearing, mounting conditions, operational conditions, etc. The sounds 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. However, boundaries between groups are not definite. Even if some types of sounds or vibrations are inherent in the bearings, the volume might be related to the manufacturing process. Conversely, some types of sounds or vibrations, even if caused by manufacturing, cannot be eliminated under normal conditions.

By recording the sounds and vibrations of a rotating machine and analyzing them, the cause may be inferred. As shown by the figures on the next page, a mechanically normal bearing shows a stable waveform. However, a bearing with damage such as a scratch 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 the inner ring raceway surface is damaged
Bore diameter: 100 mm
Recording and analysis method: Envelope analysis of sounds recorded by microphone for a test machine
Number of rotations: 50 min$^{-1}$

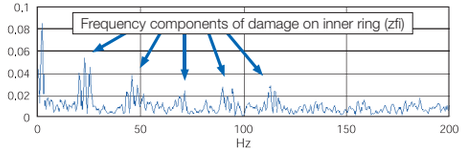



Fig. 1.27

**Table 1.3 Classification of Sounds and Vibrations in a Rolling Bearing**

| | Sound Type | | Vibration | | Features |
|---|---|---|---|---|---|
| Structural | Race noise | | Free vibration of raceway ring | | Continuous noise: basic unavoidable noise that all bearings generate |
| | Roller/ball click noise | | Free vibration of raceway ring, free vibration of cage | | Regular noise at a certain interval: found in large bearings and horizontal shafts, radial loads and low rpm |
| | Squeal noise | | Free vibration of raceway ring | | Intermittent or continuous: generally found in large cylindrical roller bearings and under radial load, grease lubrication, and particular speeds |
| | Cage noise | "CK" sound | Free vibration of cage | | Regular noise at a set interval: generated by all bearing types |
| | | "CG" sound | Vibration of cage | | Intermittent or continuous: lubrication with certain greases |
| | | Tapping sound | Free vibration of cage | | Set interval: slightly irregular under radial load and during initial stage |
| | Rumbling | | Vibration from passage of rolling element | | Continuous: found in all bearing types under radial load |
| Manufacturing | Chatter noise | | Vibration due to waviness | Inner ring | Continuous noise |
| | | | | Outer ring | Continuous noise |
| | | | | Rolling element | Continuous with rollers, occasional with balls |
| Handling | Flaw noise | | Vibration due to flaw | Inner ring | Regular noise at a set interval |
| | | | | Outer ring | |
| | | | | Rolling element | |
| | Contamination noise | | Vibration due to contamination | | Irregular |
| Other | Seal noise | | Free vibration of a seal | | Contact seal |
| | Lubricant noise | | — | | Irregular |
| | Rumbling | | Runout | $f_r$ | Continuous |
| | | | | $f_c$ | Continuous |
| | | | | $f_r - 2f_c$ | Continuous |

| Generated Frequency (Frequency Analysis) | | | Source | Countermeasures |
|---|---|---|---|---|
| FFT of Original Wave | | FFT After Envelope (Basic No.) | | |
| Radial (Angular) Direction | Axial Direction | | | |
| $f_{RiN}$, $f_{MI}$ | $f_{AiN}$, $f_{AM}$ | — | Selective resonance from waviness (rolling friction) | Improve rigidity around bearings, provide appropriate radial clearance, use high-viscosity lubricant and high-quality bearings. |
| $f_{RiN}$, $f_{MI}$ Natural frequency of cage | $f_{AiN}$, $f_{AM}$ | $Zf_c$ | Collision of rolling elements with inner ring or cage | Reduce radial clearance, apply preload, use high-viscosity oil |
| ($\approx f_{R2N}$, $f_{R3N}$) | — | ? | Self-induced vibration caused by sliding friction at rolling surface | Reduce radial clearance, apply preload, change grease, replace with bearings with countermeasures |
| Natural frequency of cage | | $f_c$ | Collision of cage with rolling elements or rings | Apply preload, use high-viscosity lubricant, reduce mounting error |
| Natural frequency of cage | | ? | Self-induced vibration caused by friction at cage guide surface | Change grease brand, replace with cage with countermeasures |
| Natural frequency of cage | | $Zf_c$ | Collision of cage and rolling element caused by grease resistance | Reduce radial clearance, apply preload, use low-viscosity lubricant |
| $Zf_c$ | — | — | Displacement of inner ring due to rolling element passage | Reduce radial clearance, apply preload |
| $nZf_i \pm f_r$ ($nZ \pm 1$ peaks) | $nZf_i$ ($nZ$ peaks) | — | Inner ring raceway waviness, irregularity of shaft exterior | Use high-quality bearings, improve shaft accuracy |
| $nZf_c$ ($nZ \pm 1$ peaks) | $nZf_c$ ($nZ$ peaks) | — | Outer ring raceway waviness, irregular housing bore | Use high-quality bearings, improve housing bore accuracy |
| $2nf_b \pm f_c$ ($2n$ peaks) | $2nf_b$ ($2n$ peaks) | — | Rolling element waviness | Use high-quality bearings |
| $f_{RiN}$, $f_{MI}$ | $f_{AiN}$, $f_{AM}$ | $Zf_i$ | Nicks, dents, rust, flaking on inner ring raceway | Replace bearing and take care when handling |
| | | $Zf_c$ | Nicks, dents, rust, flaking on inner ring raceway | Replace bearing and take care when handling |
| | | $2f_b$ | Nicks, dents, rust, flaking on rolling elements | Replace bearing and take care when handling |
| $f_{RiN}$, $f_{MI}$ | $f_{AiN}$, $f_{AM}$ | Irregular | Entry of dirt and debris | Wash the bearing, improve sealing |
| Natural frequency of seal | | ($f_r$) | Self-induced vibration due to friction at seal contact area | Change the seal, change the grease |
| ? | ? | Irregular | Lubricant or lubricant bubbles crushed between rolling elements and raceways | Change the grease |
| $f_r$ | — | — | Irregular inner ring cross-section | Use high-quality bearings |
| $f_c$ | — | — | Ball variation in bearing, rolling elements non-equidistant | Use high-quality bearings |
| $f_r - 2f_c$ | — | — | Non-linear vibration due to rigid variation by ball variation | Use high-quality bearings |

$n$: Positive integer (1, 2, 3...)
$Z$: Number of rolling elements
$f_{RiN}$: Natural frequency of ring in radial bending mode (Hz)
$f_{MI}$: Natural frequency in the mode of angular vibration in inertia of outer ring-spring system (Hz)
$f_i$: 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 an 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 COUNTERMEASURES (Bearing Doctor)

2.1 Bearing Damage ..... B 022

2.2 Running Traces and Applied Loads ..... B 022

2.3 Bearing Damage and Countermeasures ..... B 024
- 2.3.1 Flaking (Spalling) ..... B 025
- 2.3.2 Peeling ..... B 027
- 2.3.3 Scoring ..... B 028
- 2.3.4 Smearing ..... B 029
- 2.3.5 Chips ..... B 030
- 2.3.6 Cracks ..... B 031
- 2.3.7 Cage Damage ..... B 032
- 2.3.8 Dents ..... B 033
- 2.3.9 Pitting ..... B 034
- 2.3.10 Wear ..... B 035
- 2.3.11 Fretting ..... B 036
- 2.3.12 False Brinelling ..... B 037
- 2.3.13 Seizure ..... B 038
- 2.3.14 Creep ..... B 039
- 2.3.15 Electrical Erosion ..... B 040
- 2.3.16 Rust and Corrosion ..... B 041
- 2.3.17 Mounting Flaws ..... B 042
- 2.3.18 Discoloration ..... B 043

Appendix Bearing Diagnostic Chart ..... B 044

# 2. BEARING DAMAGE AND COUNTERMEASURES (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 can be caused by improper mounting, improper handling, improper or insufficient lubrication, entry of foreign matter, or abnormal heat generation.
For instance, the causes of rib scoring may include insufficient lubrication, use of improper lubricant, a 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 before the failure are known, including the application, 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 contact the rolling elements. This results in a dull trace on both the rolling elements and raceways. Running traces are useful because they indicate load conditions; they should be carefully checked when the bearing is disassembled.
If running traces are clearly defined, it is possible to determine whether the bearing was carrying a radial load, axial load, or moment load. Furthermore, the roundness of the bearing can be determined. Check whether unexpected bearing loads or large mounting errors occurred, and determine the probable cause of the bearing damage.

Fig. 2.2 shows 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 reflect a shortened life due to adverse effects on the bearings.
Similarly, Fig. 2.2 shows different roller bearing running traces. Fig. 2.2 (i) shows an outer ring running trace when a radial load is properly applied to a cylindrical roller bearing with a load on a rotating inner ring. Fig. 2.2 (j) shows a running trace resulting from 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. Fig. 2.2 (k) shows the running trace on the outer ring under radial load for double-row tapered roller bearings where a single load is applied to the rotating inner ring 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, the application of a radial load causes running traces to appear on the outer ring as shown in Fig. 2.2 (m).

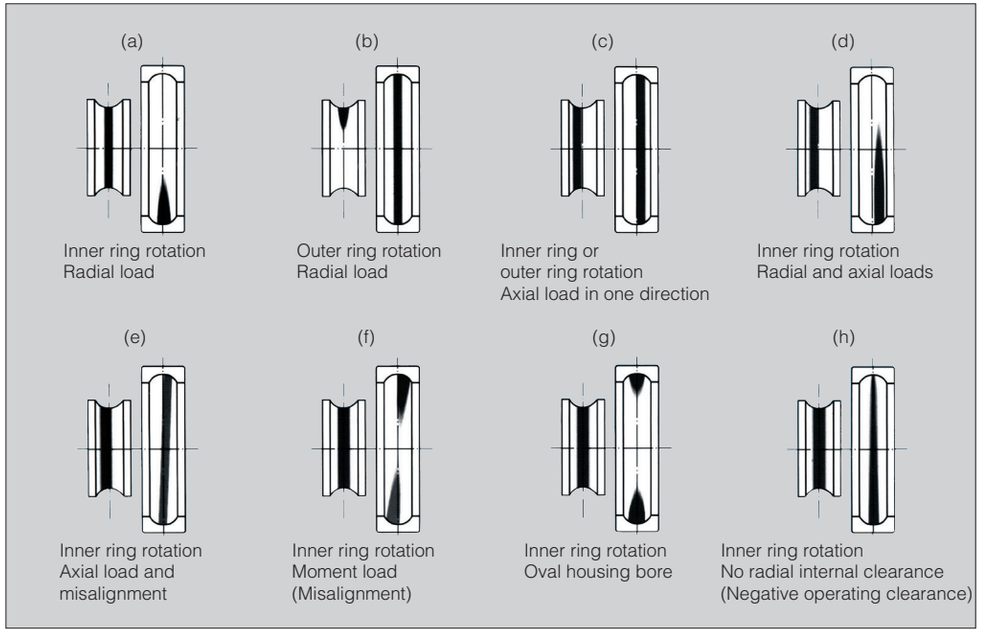



**Fig. 2.2 Typical Running Traces of Deep Groove Ball Bearings**

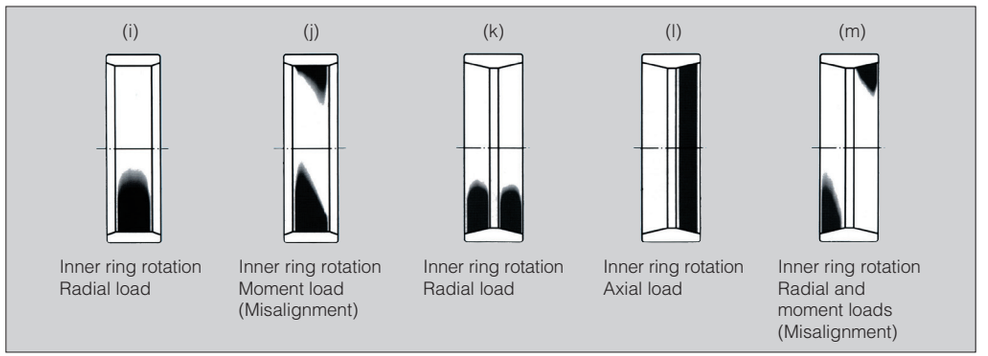



**Fig. 2.2 Typical Running Traces of Roller Bearings**

## 2.3 Bearing Damage and Countermeasures

A bearing that is properly selected and handled can be expected to last until the end of its service life. Damage that occurs at the end of a bearing's life is called flaking or spalling.
However, flaking and other kinds of damage can occur prematurely for avoidable reasons including poor handling, insufficient or improper lubrication, the entry of contaminants, mounting errors, shaft bending/deflection, a lack of consideration for the housing or surroundings, or a combination of these issues.
Recurrence of premature failures can be prevented by knowing details about the bearing surroundings, the state and structure of the equipment containing the bearing, and operating conditions before and after an incident.
Sections 2.3.1 through 2.3.18 show various types of bearing damage and countermeasures. Please consult these sections when trying to determine the cause of bearing damage. The bearing diagnostic chart in the Appendix on Page B44 may be useful as a quick reference guide.

### 2.3.1 Flaking (Spalling)

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| As the bearing rotates under load, pieces of the raceways of the inner/outer rings and the rolling surfaces of the rolling elements break off in a scale-like pattern due to rolling fatigue. | • Excessive load<br>• Poor mounting (misalignment)<br>• Moment load<br>• Entry of foreign matter or moisture<br>• Poor lubrication, improper lubricant<br>• Unsuitable bearing clearance<br>• Poor accuracy of the shaft/housing, uneven housing rigidity, large shaft deflection<br>• Progressive damage from rust, corrosion pits, smearing, dents (Brinelling) | ➢ Reconfirm the bearing application and check load conditions<br>➢ Improve the mounting method<br>➢ Improve the sealing mechanism, prevent rust during idle periods<br>➢ Use a lubricant with the proper viscosity, improve the lubrication method<br>➢ Check accuracy of shaft and housing<br>➢ Check the bearing internal clearance |

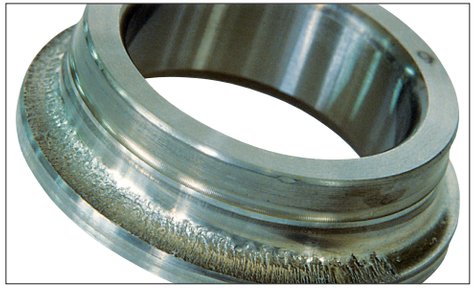


**Photo 1-1**
**Part:** Inner ring of an angular contact ball bearing
**Symptom:** Flaking around half of the circumference of the raceway surface
**Cause:** Poor lubrication due to entry of cutting coolant into bearing

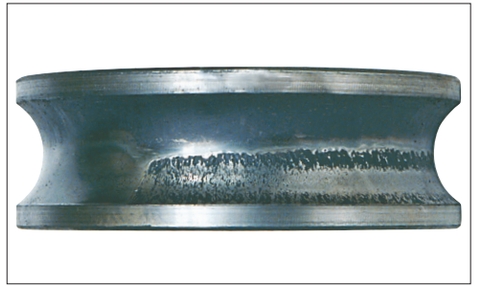


**Photo 1-2**
**Part:** Inner ring of an angular contact ball bearing
**Symptom:** Flaking diagonally along raceway
**Cause:** Poor alignment between shaft and housing during mounting



**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

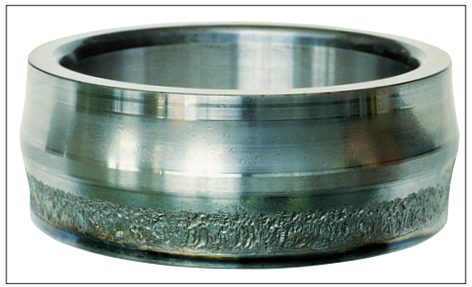


**Photo 1-5**
**Part:** Inner ring of a spherical roller bearing
**Symptom:** Flaking of only one raceway over its entire circumference
**Cause:** Excessive axial load

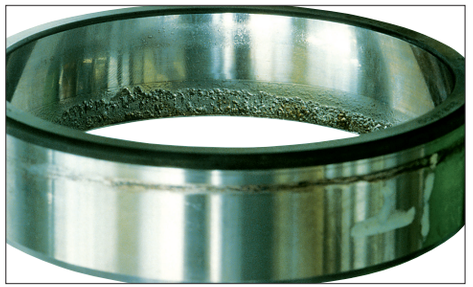


**Photo 1-6**
**Part:** Outer ring of Photo 1-5
**Symptom:** Flaking of only one raceway over its entire circumference
**Cause:** Excessive axial load



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



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

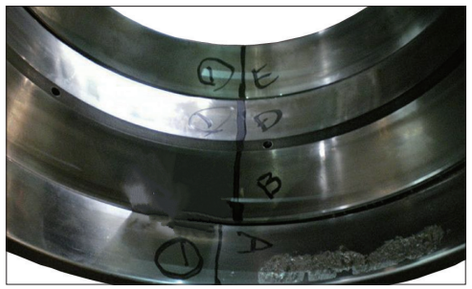


**Photo 1-9**
**Part:** Outer ring of a four-row tapered roller bearing
**Symptom:** Flaking of raceway (loading area)
**Cause:** Excessive moment load



**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 misalignment



## 2.3.2 Peeling

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Dull or cloudy spots appear on the bearing surface along with light wear. Tiny cracks are generated from these dull spots downward to a depth of 5 to 10 µm. Peeling (micro-flaking) occurs over a wide area. | • Unsuitable lubricant<br>• Entry of debris into lubricant<br>• Rough surface due to poor lubrication<br>• Surface roughness of mating parts | ➢ Select a different lubricant<br>➢ Improve the sealing mechanism<br>➢ Improve the surface finish of the mating parts |





**Photo 2-1**
**Part:** Inner ring of a spherical roller bearing
**Symptom:** Circular peeling on the center of the raceway surface
**Cause:** Poor lubrication

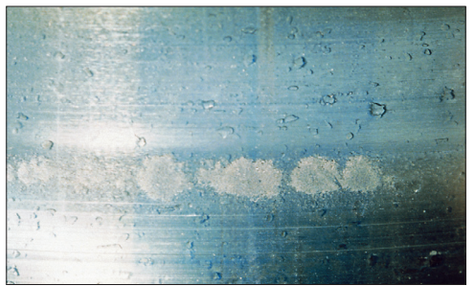


**Photo 2-2**
**Part:** Enlargement of pattern in Photo 2-1



**Photo 2-3**
**Part:** Convex rollers from Photo 2-1
**Symptom:** Circular peeling on the center of the rolling surfaces
**Cause:** Poor lubrication



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

## 2.3.3 Scoring

| Damage | Possible Causes | Countereasures |
|---|---|---|
| A kind of surface damage caused by localized bonding (adhesive wear) between sliding surfaces.<br>Linear scratches occur around the circumference of the raceway and rolling surfaces.<br>Cycloidal-shaped damage also appears on roller end faces and ribs in contact with the end face. | • Excessive load, excessive preload<br>• Poor lubrication<br>• Contact with embedded contaminants<br>• Inclination of inner and outer rings<br>• Shaft bending<br>• Poor accuracy of shaft and housing | ➢ Check the size of the load<br>➢ Adjust the preload<br>➢ Improve the lubricant and the lubrication method<br>➢ Check the accuracy 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 slippage due to sudden acceleration and deceleration



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

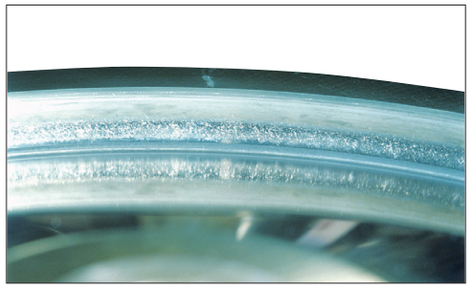


**Photo 3-3**
**Part:** Inner ring of a tapered roller thrust bearing
**Symptom:** Scoring on the face of inner ring rib
**Cause:** Worn particles mixed with lubricant and breakdown of oil film due to excessive load

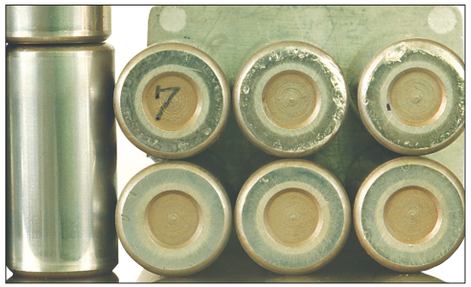


**Photo 3-4**
**Part:** Rollers of a double-row cylindrical roller bearing
**Symptom:** Scoring on the roller end face
**Cause:** Poor lubrication and excessive axial load



## 2.3.4 Smearing

| Damage | Possible Causes | Countereasures |
|---|---|---|
| Surface damage that occurs from many small seizures between bearing components caused by oil film rupture and/or sliding.<br>Surface roughening occurs along with melting. | • High speed and light load<br>• Sudden acceleration/deceleration<br>• Improper lubricant<br>• Entry of water | ➢ Improve the preload<br>➢ Improve the bearing clearance<br>➢ Use a lubricant with good oil film formation<br>➢ Improve the lubrication method<br>➢ Improve the sealing mechanism |



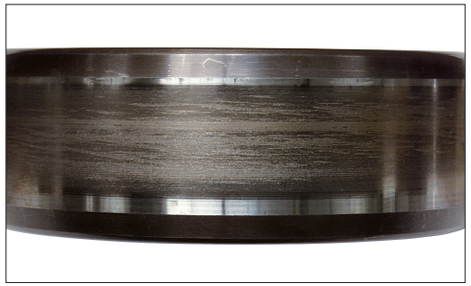


**Photo 4-1**
**Part:** Inner ring of a cylindrical roller bearing
**Symptom:** Smearing circumferentially on raceway surface
**Cause:** Roller slippage due to excessive grease fill

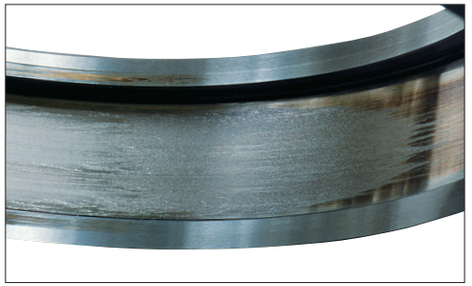


**Photo 4-2**
**Part:** Outer ring of Photo 4-1
**Symptom:** Smearing circumferentially on raceway surface
**Cause:** Roller slippage due to excessive grease fill

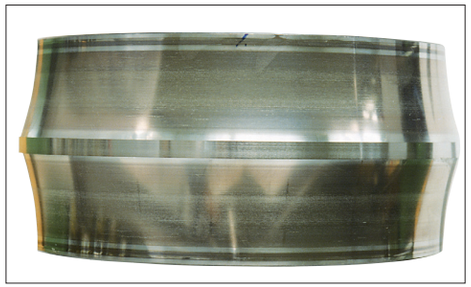


**Photo 4-3**
**Part:** Inner ring of a spherical roller bearing
**Symptom:** Smearing circumferentially on raceway surface
**Cause:** Poor lubrication

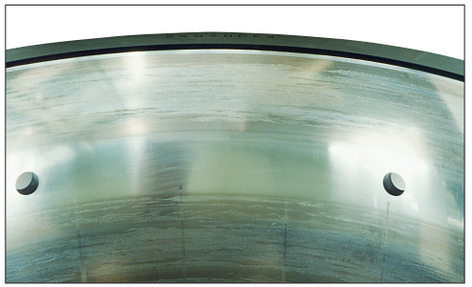


**Photo 4-4**
**Part:** Outer ring of Photo 4-3
**Symptom:** Smearing circumferentially on raceway surface
**Cause:** Poor lubrication

## 2.3.5 Chips

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Small pieces of material break off from part of a roller or ring rib corner due to impact or excessive loads applied locally. | • Impacts/shocks during mounting<br>• Excessive load<br>• Poor handling, such as dropping the bearing | ➢ Improve the mounting method (shrink fit, use of proper tools)<br>➢ Reconsider load conditions<br>➢ Provide enough backup and support for the bearing rib |



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

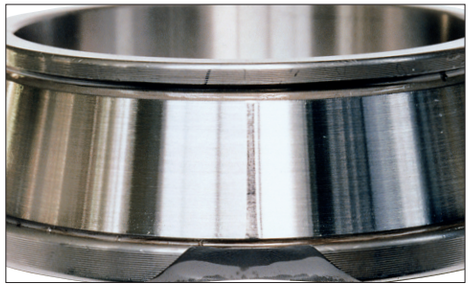


**Photo 5-2**
**Part:** Inner ring of a tapered roller bearing
**Symptom:** Chipping of large rib
**Cause:** Large shock during mounting

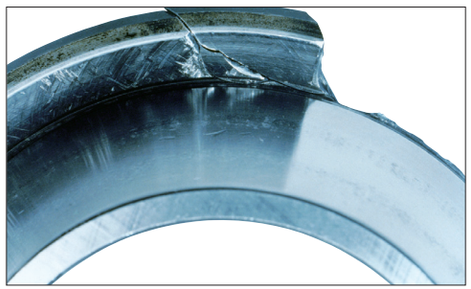


**Photo 5-3**
**Part:** Inner ring of a spherical thrust roller bearing
**Symptom:** Chipping of large rib
**Cause:** Repeated load



**Photo 5-4**
**Part:** Outer ring of a solid type needle roller bearing
**Symptom:** Chipping of outer ring rib
**Cause:** Roller inclination due to excessive load (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 | Possible Causes | Countermeasures |
|---|---|---|
| Fissures in the raceway rings or rolling elements.<br>Continued use may cause fissures to develop into larger cracks or fractures. | • Excessive interference<br>• Excessive load, shock load<br>• Progressive damage from flaking<br>• Heat generation and fretting caused by contact between mounting parts and raceway ring<br>• Heat generation due to creep<br>• Poor taper angle of tapered shaft<br>• Poor cylindricality of shaft<br>• Interference with bearing chamfer due to a large shaft corner radius | ➢ Correct the interference<br>➢ Check load conditions<br>➢ Improve the mounting method<br>➢ Use an appropriate shaft shape |

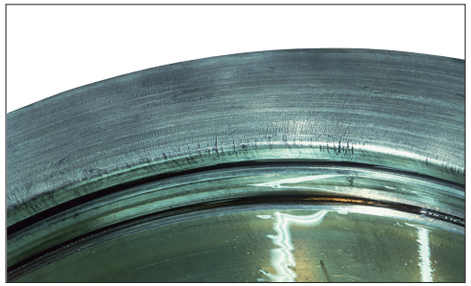


**Photo 6-1**
**Part:** Outer ring of a double-row cylindrical roller bearing
**Symptom:** Thermal cracks on the outer ring side face
**Cause:** Abnormal heat generation due to contact sliding between the mating part and face of outer ring



**Photo 6-2**
**Part:** Roller of a tapered roller thrust bearing
**Symptom:** Thermal cracks 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 load

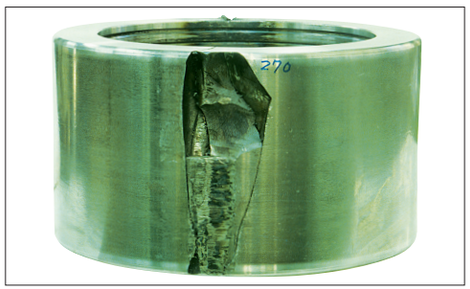


**Photo 6-4**
**Part:** Outer ring of a double-row cylindrical roller bearing (outer ring rotation)
**Symptom:** Cracks on outside surface
**Cause:** Flat wear and heat generation due to non-rotation of the outer ring

## 2.3.7 Cage Damage

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Any damage to the cage, including cage deformation, fracture, and wear; fracture of cage pillar; deformation of side face; and wear of pocket surface or guide surface. | • Poor mounting (bearing misalignment)<br>• Poor handling<br>• Large moment load<br>• Shock and large vibration<br>• Excessive rotation speed, sudden acceleration/deceleration<br>• Poor lubrication<br>• Temperature rise | ➢ Check the mounting method<br>➢ Check the temperature, rotation, and load conditions<br>➢ Reduce vibration<br>➢ Select a different cage type<br>➢ Select a different lubrication method or 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

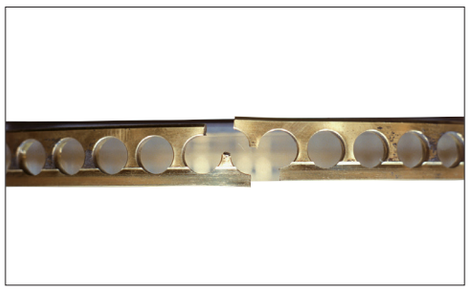


**Photo 7-3**
**Part:** Cage of an angular contact ball bearing
**Symptom:** Fracture of machined high-tension-brass cage

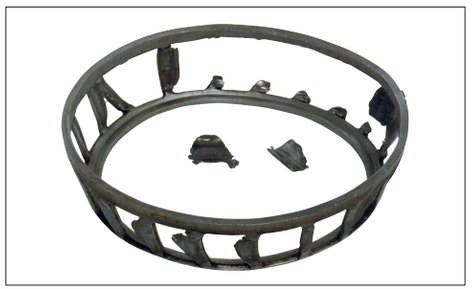


**Photo 7-4**
**Part:** Cage of a tapered roller bearing
**Symptom:** Pillar fractures of pressed-steel cage



## 2.3.8 Dents

| Damage | Possible Causes | Countermasures |
|---|---|---|
| Fine particles or foreign matter trapped in the bearing create indentations on the raceway/rolling contact surfaces.<br>Impacts or shocks during mounting may also cause dents at the rolling element pitch interval (Brinell dents). | • Contact with embedded contaminants<br>• Excessive load<br>• Shock during transport or mounting | ➢ Clean the housing<br>➢ Improve the sealing mechanism<br>➢ Filter the lubrication oil<br>➢ Improve mounting and handling methods |





**Photo 8-1**
**Part:** Inner ring of a double-row tapered roller bearing
**Symptom:** Frosted raceway surface
**Cause:** Contact with embedded contaminants

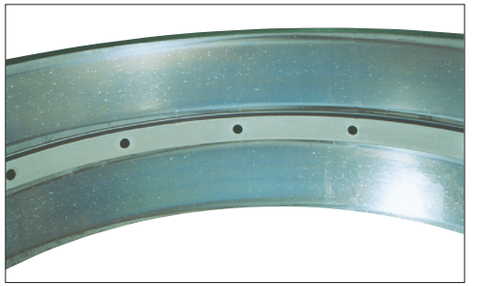


**Photo 8-2**
**Part:** Outer ring of a double-row tapered roller bearing
**Symptom:** Indentations on raceway surface
**Cause:** Contact with embedded contaminants

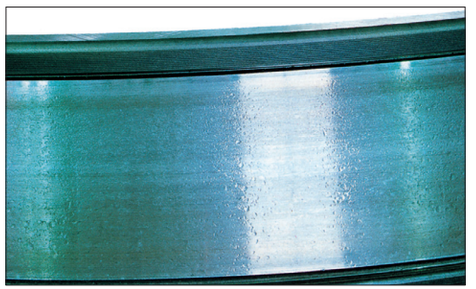


**Photo 8-3**
**Part:** Inner ring of a tapered roller bearing
**Symptom:** Small and large indentations over entire raceway surface
**Cause:** Contact with embedded contaminants



**Photo 8-4**
**Part:** Tapered rollers of Photo 8-3
**Symptom:** Small and large indentations over the rolling surface
**Cause:** Contact with embedded contaminants

## 2.3.9 Pitting

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| The surface of the rolling element or raceway has small holes and a dull luster. | • Contact with embedded contaminants<br>• Exposure to moisture in the atmosphere<br>• Poor lubrication | ➢ Improve the sealing mechanism<br>➢ Filter the lubrication oil thoroughly<br>➢ Use another appropriate lubricant |



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



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

## 2.3.10 Wear

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Surface deterioration due to sliding friction at the surface of the raceway, rolling elements, roller end faces, rib face, cage pockets, etc. | • Contamination<br>• Progressive damage from rust or electrical erosion<br>• Poor lubrication<br>• Sliding due to irregular motion of rolling elements | ➢ Improve the sealing mechanism<br>➢ Clean the housing<br>➢ Filter the lubrication oil thoroughly<br>➢ Check the lubricant and lubrication method<br>➢ Prevent misalignment |



**Photo 10-1**
**Part:** Inner ring of a cylindrical roller bearing
**Symptom:** Pits and wave-shaped wear on raceway surface
**Cause:** Electrical erosion

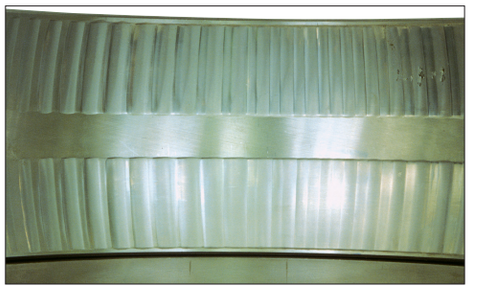


**Photo 10-2**
**Part:** Outer ring of a spherical roller bearing
**Symptom:** Wear with a wavy or concave-and-convex texture on loaded side of raceway surface
**Cause:** Entry of debris under repeated vibration while stationary

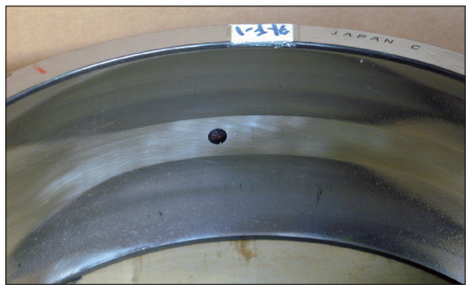


**Photo 10-3**
**Part:** Outer ring of a spherical roller bearing
**Symptom:** Wear on loaded side of raceway surface
**Cause:** Low speed, heavy load, and poor lubrication (no oil film)



**Photo 10-4**
**Part:** Outer ring of a spherical roller bearing (enlargement)
**Symptom:** Combined flaking and wear on the raceway
**Cause:** Insufficient oil film due to poor lubrication led to wear (primary damage) that progressed to flaking (secondary damage)

## 2.3.11 Fretting

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| A type of wear caused by repeated and relative micro-slips between two surfaces.<br>It occurs at the contact area between the ring and rolling elements and at fitting surfaces. It is sometimes called fretting corrosion due to the reddish brown or black wear particles produced. | • Poor lubrication<br>• Oscillating motion or vibration with a small amplitude<br>• Insufficient interference | ➢ Use a proper lubricant<br>➢ Apply a preload<br>➢ Check the interference fit<br>➢ Apply lubricant to the fitting surface |



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



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

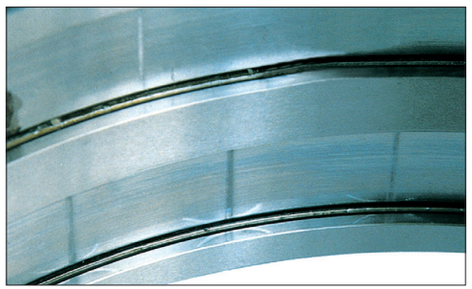


**Photo 11-3**
**Part:** Outer ring of a double-row cylindrical roller bearing
**Symptom:** Fretting on the raceway surface at roller pitch intervals

## 2.3.12 False Brinelling

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Hollow spots that resemble Brinell dents that 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 transport, etc.<br>• Oscillating motion with a small amplitude<br>• Poor lubrication | ➢ Secure the shaft and housing during transport<br>➢ Transport with the inner and outer rings packed separately<br>➢ Reduce vibration by preloading<br>➢ Use appropriate lubricant |





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

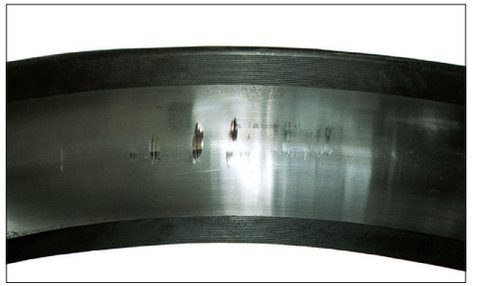


**Photo 12-2**
**Part:** Outer ring of Photo 12-1
**Symptom:** False brinelling on the raceway
**Cause:** Vibration from an external source while stationary



**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 on rolling surface
**Cause:** Vibration from an external source while stationary

## 2.3.13 Seizure

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| During rotation, the rings, rolling elements, and cage heat up rapidly. If heat becomes excessive, parts may become discolored before softening, deforming, and melting, causing eventual seizing. | • Poor lubrication<br>• Excessive load (excessive preload)<br>• Excessive rotational speed<br>• Excessively small internal clearance<br>• Entry of moisture or foreign matter<br>• Poor accuracy of shaft and housing, excessive shaft bending | ➢ Review the lubricant and lubrication method<br>➢ Re-investigate the suitability of the bearing type selected<br>➢ Review the preload, bearing clearance, and fitting<br>➢ Improve the sealing mechanism<br>➢ Check the accuracy of the shaft and housing<br>➢ Improve the mounting method |



**Photo 13-1**
**Part:** Inner ring of a spherical roller bearing
**Symptom:** Discoloration and melting of raceway. Worn particles from the cage rolled off 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

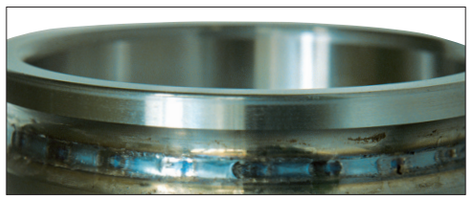


**Photo 13-3**
**Part:** Inner ring of an angular contact ball bearing
**Symptom:** Raceway discoloration, melting at ball pitch intervals
**Cause:** Excessive preload



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



## 2.3.14 Creep

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| A phenomenon in bearings where relative slippage occurs at the fitting surfaces. Creep causes a shiny appearance, occasionally with scoring or wear. | • Insufficient interference or loose fit<br>• Insufficient sleeve tightening | ➢ Check interference and prevent rotation<br>➢ Correct the sleeve tightening<br>➢ Review precision of the shaft and housing<br>➢ Apply axial preload<br>➢ Tighten the raceway ring side face<br>➢ Apply adhesive to the fitting surface<br>➢ Apply lubricant to the fitting surface |



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

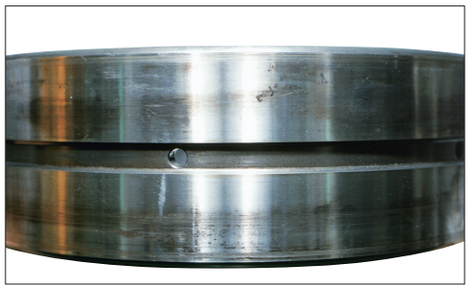


**Photo 14-2**
**Part:** Outer ring of a spherical roller bearing
**Symptom:** Creep over entire circumference of outside surface
**Cause:** Loose fit between outer ring and housing

## 2.3.15 Electrical Erosion

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Electrical erosion (sometimes called electric corrosion) occurs when an electric current flows through the oil film in the contact area between the raceways and rolling elements, causing sparking/arcing that melts the surfaces locally and makes them uneven. Visible dull areas are made up of small depressions called craters or pits. These may develop into an uneven axial pattern of ridge-like marks (fluting) with circumferential grooving. | • Electric potential difference between inner and outer rings<br>• High-frequency electric potential difference generated by instruments or substrates used near a bearing. | ➢ Design electric circuits that prevent current flow through the bearings<br>➢ Insulate the bearing |

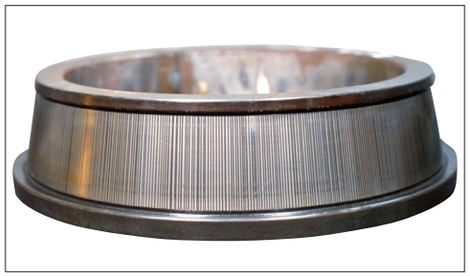


**Photo 15-1**
**Part:** Inner ring of a tapered roller bearing
**Symptom:** Striped pattern of erosion on the raceway surface



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

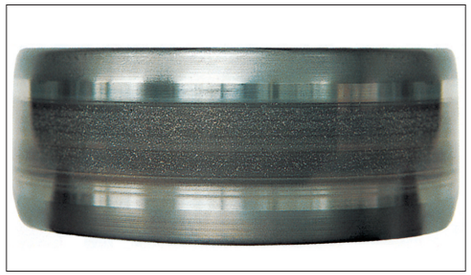
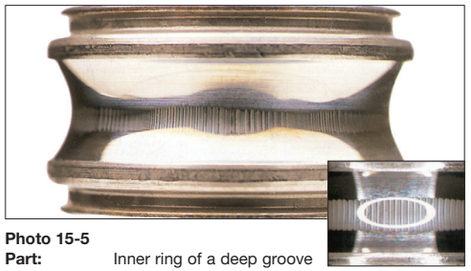


**Photo 15-3**
**Part:** Inner ring of a cylindrical roller bearing
**Symptom:** Belt pattern of electrical erosion accompanied by pits on the raceway surface



**Photo 15-4**
**Part:** Balls of a deep groove ball bearing
**Symptom:** A dark color covering the entire ball surface



Enlargement

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



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



## 2.3.16 Rust and Corrosion

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Rust or corrosion can occur in pit-shaped or scatter-like patterns on the rings or rolling elements. It may also appear along the rolling element pitch or across entire bearing surfaces. | • Entry of corrosive gas or water<br>• Improper lubricant<br>• Formation of water droplets due to condensation<br>• High temperature and high humidity while stationary<br>• Poor rust preventive treatment during transport<br>• Improper storage conditions<br>• Improper handling | ➢ Improve the sealing mechanism<br>➢ Review the lubrication method<br>➢ Apply an anti-rust treatment during idle periods<br>➢ Improve storage methods<br>➢ Improve handling |



**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

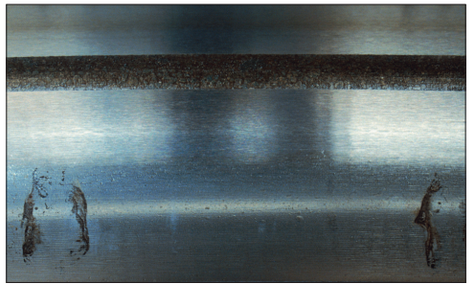


**Photo 16-2**
**Part:** Outer ring of a slewing ring
**Symptom:** Rust on raceway surface at ball pitch
**Cause:** Condensation during stationary periods



**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:** Condensation during storage

## 2.3.17 Mounting Flaws

| Damage | Possible Causes | Countermeasures |
|---|---|---|
| Linear scratches on raceways and rolling surfaces caused by improper mounting, dismounting, or handling. | • Inclination of inner and outer rings during mounting or dismounting<br>• Shock load during mounting or dismounting | ➢ Use appropriate jigs and tools<br>➢ Avoid shock load by using a press machine<br>➢ Center the relative mating parts during mounting |

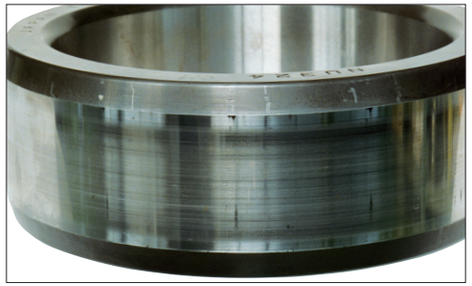


**Photo 17-1**
**Part:** Inner ring of a cylindrical roller bearing
**Symptom:** Axial scratches on raceway surface
**Cause:** Inclination of inner and outer rings during mounting

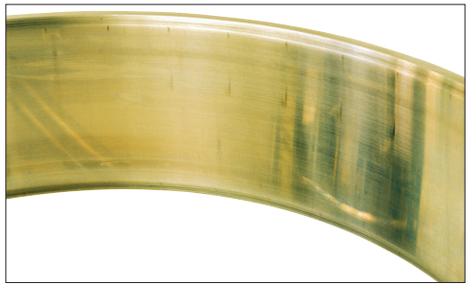


**Photo 17-2**
**Part:** Outer ring of a double-row cylindrical roller bearing
**Symptom:** Axial scratches at roller pitch intervals on raceway surface
**Cause:** Inclination of inner and outer rings during mounting



**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 | Possible Causes | Countermeasures |
|---|---|---|
| Changed coloring of cage, rolling elements, or raceway ring due to reactions with lubricant and high temperature. | • Poor lubrication<br>• Oil stain due to a reaction with lubricant<br>• High temperature | ➢ Improve the lubrication method |

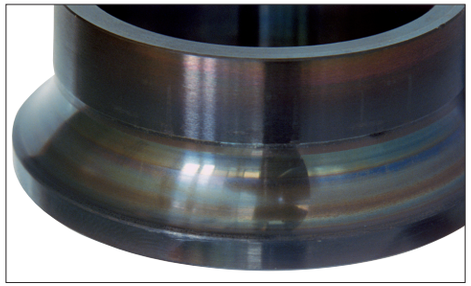


**Photo 18-1**
**Part:** Inner ring of an angular contact ball bearing
**Symptom:** Bluish or purplish discoloration on raceway surface
**Cause:** Heat generation due to poor lubrication

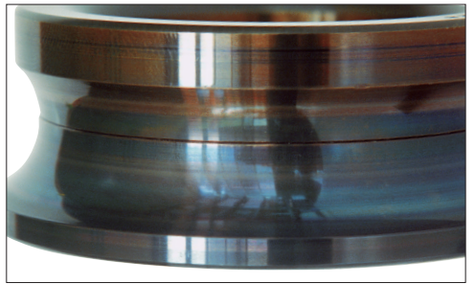


**Photo 18-2**
**Part:** Inner ring of a four-point contact ball bearing
**Symptom:** Bluish or purplish discoloration on raceway surface
**Cause:** Heat generation due to poor lubrication

# Appendix: Bearing Diagnostic Chart

| Damage | Location (Phenomenon) | Cause | | | | | | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Handling | | Bearing Surroundings | | | Lubrication | | Load | | | Speed | | | |
| | | Storage, Transport | Mounting | Shaft, Housing | Seal, Water, Contaminants | Temperature | Lubricant | Lubrication Method | Excessive Load, Shock Load | Moment Load | Ultra-Small Load | High Speed, High Acceleration/Deceleration | Shaking,Vibration, Stationary | Bearing Selection | |
| 2.3.1 Flaking (Spalling) | Raceway, rolling surface | | ○ | ○ | ○ | | ○ | ○ | ○ | ○ | | | | ○ | |
| 2.3.2 Peeling | Raceway, rolling surface | | | | ○ | | ○ | ○ | | | ○ | ○ | | | |
| | Bearing outside surface (rolling contact) | | | ○* | ○ | | ○ | ○ | | | | | | | *Mating 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 Chips | 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 Dents | Raceway, rolling surface, (many 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 erosion | 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 common damage, causes, and locations.