BEARING HANDLING AND MAINTENANCE
Part B

BEARING HANDLING AND MAINTENANCE

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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 or otherwise damaged, possibly resulting in their failure. Excessively strong impacts may cause brinelling, breaking, or cracking.

(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. Moreover, 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 a 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 place that is not exposed to wind or rain. In addition, an indoor environment where temperature and/or humidity is high is unsuitable for storage because such places deteriorate the anticorrosive. Be sure to store the bearings in a place where variation in environmental temperature is small.

1.2.2 How to Store Bearings

After considering the size and weight of the bearings to be stocked, secure storage 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

The method of mounting strongly affects bearing accuracy, life, and performance. Bearing characteristics should be thoroughly studied before mounting. Handling procedures for bearings should be fully investigated by design engineers and standards should be established regarding 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 bearings and allowing for mounting in a short time. 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 cylindrical roller bearings for roll necks of rolling mills and for railway journal boxes. 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. 1.8 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 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 flaws; uneven torque caused by improper mounting or flaws; excessive rise of bearing temperature, leakage and abnormal noise, etc. If any abnormality is found, stop the test immediately and inspect the machine. If possible, the bearing should be dismantled for examination.

<table>
<thead>
<tr>
<th>Bearing Bore Diameter</th>
<th>Reduction in Radial Clearance</th>
<th>Axial Drive-Up Distance</th>
<th>Minimum Permissible Residual Clearance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min.</td>
<td>max.</td>
<td>Taper 1 : 12</td>
</tr>
<tr>
<td></td>
<td>min.</td>
<td>max.</td>
<td>mm</td>
</tr>
<tr>
<td>30 40</td>
<td>0.025 0.030</td>
<td>0.40 0.45</td>
<td>—</td>
</tr>
<tr>
<td>40 50</td>
<td>0.020 0.025</td>
<td>0.45 0.50</td>
<td>—</td>
</tr>
<tr>
<td>50 60</td>
<td>0.030 0.035</td>
<td>0.45 0.55</td>
<td>—</td>
</tr>
<tr>
<td>60 80</td>
<td>0.040 0.045</td>
<td>0.60 0.70</td>
<td>—</td>
</tr>
<tr>
<td>80 100</td>
<td>0.045 0.055</td>
<td>0.70 0.85</td>
<td>1.75 2.15</td>
</tr>
<tr>
<td>100 120</td>
<td>0.050 0.060</td>
<td>0.75 0.90</td>
<td>1.9 2.25</td>
</tr>
<tr>
<td>120 140</td>
<td>0.060 0.070</td>
<td>0.90 1.10</td>
<td>2.25 2.75</td>
</tr>
<tr>
<td>140 160</td>
<td>0.065 0.080</td>
<td>1.0 1.3</td>
<td>2.5 3.25</td>
</tr>
<tr>
<td>160 180</td>
<td>0.070 0.080</td>
<td>1.1 1.4</td>
<td>2.75 3.5</td>
</tr>
<tr>
<td>180 200</td>
<td>0.080 0.100</td>
<td>1.3 1.6</td>
<td>3.25 4.0</td>
</tr>
<tr>
<td>200 225</td>
<td>0.090 0.110</td>
<td>1.4 1.7</td>
<td>3.5 4.25</td>
</tr>
<tr>
<td>225 250</td>
<td>0.100 0.120</td>
<td>1.8 1.9</td>
<td>4 4.75</td>
</tr>
<tr>
<td>250 280</td>
<td>0.110 0.140</td>
<td>2.2 2.7</td>
<td>4.25 5.5</td>
</tr>
<tr>
<td>280 315</td>
<td>0.120 0.150</td>
<td>2.4 2.7</td>
<td>4.75 6.0</td>
</tr>
<tr>
<td>315 355</td>
<td>0.140 0.170</td>
<td>2.2 2.7</td>
<td>5.5 6.75</td>
</tr>
<tr>
<td>355 400</td>
<td>0.150 0.190</td>
<td>2.4 3.0</td>
<td>6 7.5</td>
</tr>
<tr>
<td>400 450</td>
<td>0.170 0.210</td>
<td>2.7 3.3</td>
<td>6.75 8.25</td>
</tr>
<tr>
<td>450 500</td>
<td>0.190 0.240</td>
<td>3.0 3.7</td>
<td>7.5 9.25</td>
</tr>
<tr>
<td>500 560</td>
<td>0.210 0.270</td>
<td>3.4 4.3</td>
<td>8.5 11.0</td>
</tr>
<tr>
<td>560 630</td>
<td>0.230 0.300</td>
<td>3.7 4.8</td>
<td>9.25 12.0</td>
</tr>
<tr>
<td>630 710</td>
<td>0.260 0.320</td>
<td>4.2 5.3</td>
<td>10.5 13.0</td>
</tr>
<tr>
<td>710 800</td>
<td>0.280 0.370</td>
<td>4.5 5.9</td>
<td>11.5 15.0</td>
</tr>
<tr>
<td>800 900</td>
<td>0.310 0.410</td>
<td>5.0 6.6</td>
<td>12.5 16.5</td>
</tr>
<tr>
<td>900 1 000</td>
<td>0.340 0.460</td>
<td>5.5 7.4</td>
<td>14.0 18.5</td>
</tr>
<tr>
<td>1 000 1 200</td>
<td>0.370 0.500</td>
<td>5.9 8.0</td>
<td>15.0 20.0</td>
</tr>
</tbody>
</table>

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.
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 locator 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

<table>
<thead>
<tr>
<th>Irregularities</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loud Metallic Sound (*)</td>
<td>Abnormal load</td>
<td>Improve the fit, internal clearance, preload, and/or position of housing shoulder.</td>
</tr>
<tr>
<td></td>
<td>Incorrect mounting</td>
<td>Improve the machining accuracy and alignment of the shaft and housing, improve the accuracy of the mounting, or change the mounting method.</td>
</tr>
<tr>
<td></td>
<td>Insufficient or improper lubricant</td>
<td>Replenish the lubricant or select another lubricant.</td>
</tr>
<tr>
<td></td>
<td>Contact of rotating parts</td>
<td>Modify the seal ( labyrinth, etc.).</td>
</tr>
<tr>
<td>Rhythmic Sound</td>
<td>Flaws, corrosion, or scratches on raceways</td>
<td>Clean or replace the bearing, improve the seals, and use clean lubricant.</td>
</tr>
<tr>
<td></td>
<td>Brinelling</td>
<td>Replace the bearing and use care when handling bearings.</td>
</tr>
<tr>
<td></td>
<td>Flaking on raceway</td>
<td>Replace the bearing.</td>
</tr>
<tr>
<td>Irregular Sound</td>
<td>Excessive clearance</td>
<td>Improve the fit, clearance and preload.</td>
</tr>
<tr>
<td></td>
<td>Entry of foreign particles</td>
<td>Clean or replace the bearing, improve the seals, and use clean lubricant.</td>
</tr>
<tr>
<td></td>
<td>Flaws or flaking on balls</td>
<td>Replace the bearing.</td>
</tr>
<tr>
<td>Abnormal Temperature Rise</td>
<td>Excessive lubricant</td>
<td>Reduce the amount of lubricant and/or select a stiffer grease.</td>
</tr>
<tr>
<td></td>
<td>Insufficient or improper lubricant</td>
<td>Replenish lubricant or select another appropriate lubricant.</td>
</tr>
<tr>
<td></td>
<td>Abnormal load</td>
<td>Improve the fit, internal clearance, preload, and/or position of housing shoulder.</td>
</tr>
<tr>
<td></td>
<td>Incorrect mounting</td>
<td>Improve the machining accuracy and alignment of the shaft and housing, improve the accuracy of the mounting, or change the mounting method.</td>
</tr>
<tr>
<td></td>
<td>Creep on fitted surface, excessive seal friction</td>
<td>Replace the bearing, change the seal type, and correct the shaft and housing to consider the fit.</td>
</tr>
<tr>
<td>Vibration (Runout)</td>
<td>Brinelling</td>
<td>Replace the bearing and use care when handling bearings.</td>
</tr>
<tr>
<td></td>
<td>Flaking</td>
<td>Replace the bearing.</td>
</tr>
<tr>
<td></td>
<td>Incorrect mounting</td>
<td>Correct the squarness between the shaft and housing shoulder or side of space.</td>
</tr>
<tr>
<td></td>
<td>Entry of foreign particles</td>
<td>Clean or replace the bearing, improve the seals.</td>
</tr>
<tr>
<td>Leakage or Discoloration of Lubricant</td>
<td>Too much lubricant. entry of foreign matter or abrasion chips</td>
<td>Replace the bearing or lubricant, reduce the amount of lubricant, select a stiffer grease, and clean the housing and adjacent parts.</td>
</tr>
</tbody>
</table>

Note (*) 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.
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 and allows 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 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. As shown in Fig. 1.16, this is followed by hammaruing on the sleeve using a suitable 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 to mount several bearings of these types on a shaft.

1.5.4 Dismounting of Bearings With Tapered Bores
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1.5.5 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. 1.16, this is followed by hammering on the sleeve using a suitable 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 to mount several bearings of these types on a shaft.

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1.5.7 Dismounting of Bearings With Tapered Bores
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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 the rinsing oil. Always keep the rinsing oil clean.

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) Any 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 bearing is evident.
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.

(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 wear.
- 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.
- If there is stepped wear: After measuring the shaft, determine if correction is possible.

(c) Anticorrosive agent

After completing the check, apply an anticorrosive agent.

If there is rust: Remove rust with an oil stone and/or sandpaper to smooth the surface.

If there are scratches or dents: Round the edge 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.

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.
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):
  Reconstitute the correct housing size before reuse.
  • If there is stepped wear:
    Use an inside micrometer for measurement.
    • If there is a step:
      Remove rust with an oil stone and/or sandpaper to smooth the surface.
      • If there is rust:
        Round edges 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:
  Reconstitute the correct housing size before reuse.
  • If there is rust:
    Use an inside micrometer for measurement.
    • If there is rust:
      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 and the reliability, productivity, and operating costs of the equipment containing the bearings are all improved. 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).

---

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

<table>
<thead>
<tr>
<th>Sound Type</th>
<th>Vibration</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Race noise</strong></td>
<td>Free vibration of raceway ring</td>
<td>Continuous noise; basic unavoidable noise that all bearings generate</td>
</tr>
<tr>
<td><strong>Rollerball click noise</strong></td>
<td>Free vibration of raceway ring, free vibration of cage</td>
<td>Regular noise at a certain interval: found in large bearings and horizontal shafts, radial loads and low rpm</td>
</tr>
<tr>
<td><strong>Squeal noise</strong></td>
<td>Free vibration of raceway ring</td>
<td>Intermittent or continuous; generally found in large cylindrical roller bearings and under radial load, grease lubrication, and particular speeds</td>
</tr>
<tr>
<td><strong>Cage nod</strong></td>
<td>Free vibration of cage</td>
<td>Regular noise at a set interval; generated by all bearing types</td>
</tr>
<tr>
<td><strong>Cage sound</strong></td>
<td>Vibration of cage</td>
<td>Intermittent or continuous; lubrication with certain greases</td>
</tr>
<tr>
<td><strong>Tapping sound</strong></td>
<td>Free vibration of cage</td>
<td>Set interval; slightly irregular under radial load and during initial stage</td>
</tr>
<tr>
<td><strong>Rumbling</strong></td>
<td>Vibration from passage of rolling element</td>
<td>Continuous; found in all bearing types under radial load</td>
</tr>
<tr>
<td><strong>Chatter noise</strong></td>
<td>Vibration due to waviness</td>
<td>Inner ring: Continuous noise; Outer ring: Continuous noise</td>
</tr>
<tr>
<td><strong>Flaw noise</strong></td>
<td>Vibration due to flaw</td>
<td>Inner ring: Continuous noise; Outer ring: Regular noise at a set interval</td>
</tr>
<tr>
<td><strong>Contamination noise</strong></td>
<td>Vibration due to contamination</td>
<td>Irregular</td>
</tr>
<tr>
<td><strong>Seal noise</strong></td>
<td>Free vibration of a seal</td>
<td>Contact seal</td>
</tr>
<tr>
<td><strong>Lubricant noise</strong></td>
<td>—</td>
<td>Irregular</td>
</tr>
<tr>
<td><strong>Rumbling</strong></td>
<td>Runout</td>
<td>Continuous</td>
</tr>
</tbody>
</table>

---

**Generated Frequency (Frequency Analysis)**

- **Radial (Angular) Direction**: Axial Direction
- **FFT of Original Wave**: FFT After Envelope
  - Source: Countermeasures
  - Improve rigidity around bearings, provide appropriate radial clearance, use high-quality bearings
  - Reduce radial clearance, apply preload, use high-viscosity oil
  - Self-induced vibration caused by sliding friction at rolling surface
  - Reduces radial clearance, apply preload, change grease, replace with bearings with countermeasures
  - Self-induced vibration caused by friction at cage guide surface
  - Change grease brand, replace with cage with countermeasures
  - Collision of cage and rolling elements
  - Reduce radial clearance, apply preload, use low-viscosity lubricant
  - Displacement of inner ring due to rolling element passage
  - Reduces radial clearance, apply preload
  - Inner ring raceway waviness, irregularity of shaft exterior
  - Use high-quality bearings, improve shaft accuracy
  - Outer ring raceway waviness, irregularity of housing bore
  - Use high-quality bearings, improve housing accuracy
  - Rolling element waviness
  - Use high-quality bearings
  - Nicks, dents, rust, flaking on inner ring raceway
  - Replace bearing and take care when handling
  - Nicks, dents, rust, flaking on inner ring raceway
  - Replace bearing and take care when handling
  - Nicks, dents, rust, flaking on rolling elements
  - Replace bearing and take care when handling
  - Entry of dirt and debris
  - Wash the bearing, improve sealing

---

**Sound waveform of a normal bearing**

**Sound waveform of a scratched bearing**

---

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. 1.26**

**Fig. 1.27**

---

**Notes:**

- m = Positive integer (1, 2, 3, ...)
- N = Number of rolling elements
- fn = Natural frequency of ring in radial bending mode (Hz)
- fb = Natural frequency of the mode of angular vibration in mass of outer ring-spring system (Hz)
- br = Rotation frequency of inner ring (Hz)
- f = Orbital revolution frequency of rolling elements (Hz)
- am = Number of rotations
- ai = Inner ring raceway waviness, irregularity of shaft exterior
- aii = Outer ring raceway waviness, irregularity of housing bore
- aiii = Rolling element waviness
- aiv = Nicks, dents, rust, flaking on inner ring raceway
- av = Nicks, dents, rust, flaking on inner ring raceway
- aw = Nicks, dents, rust, flaking on rolling elements
- ax = Entry of dirt and debris
- b = Change the seal, change the grease
- c = Lubricant or lubricant bubbles crushed between rolling elements and races
- d = Change the grease
- e = Irregular inner ring cross-section
- f = Ball vibration in bearing, rolling elements non-equidistant
- g =非 - Linear vibration due to rigid vibration by ball variation
- h = Use high-quality bearings
2. BEARING DAMAGE AND COUNTERMEASURES (Bearing Doctor)

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

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2.3.17 Mounting Flaws ..................................................... B 050
2.3.18 Discoloration ......................................................... B 051

Appendix Bearing Diagnostic Chart ..................................... B 052
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 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.

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 wear 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).
2.3 Bearing Damage and Countermeasures

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 B46 may be useful as a quick reference guide.

### 2.3.1 Flaking (Spalling)

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Small pieces of bearing material split off from the smooth surface of the raceway or rolling elements due to rolling fatigue and create regions with a rough and coarse texture. | • Excessive load  
• Poor mounting (misalignment)  
• Moment load  
• Entry of foreign debris or water  
• Poor lubrication, improper lubricant  
• Unsuitable bearing clearance  
• Improper precision of shaft or housing, unevenness in housing rigidity, large shaft bending  
• Rust, corrosion pits, smearing, dents (Brinelling) | ➢ Reconfirm the bearing application and check load conditions  
➢ Improve the mounting method  
➢ Improve the sealing mechanism, prevent rusting during idle periods  
➢ Use a lubricant with the proper viscosity, improve the lubrication method  
➢ Check the precision of the shaft and housing  
➢ 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 1-1
  - Symptom: Flaking of ball surface
  - Cause: Dents due to shock load while stationary
**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

**Photo 1-11**  
Part: Outer ring of a spherical roller bearing  
Symptom: Discoloration and flaking 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 of outside surface  
Cause: Progression of fatigue in outer ring material (Prolonged grinding on outer ring outside surface)

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

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

**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 1. Combined Flaking Damage

<table>
<thead>
<tr>
<th>Photo 1-15</th>
<th>Part:</th>
<th>Outer ring of a cylindrical roller bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom:</td>
<td>Rust, flaking, and crack on raceway surface</td>
<td></td>
</tr>
<tr>
<td>Cause:</td>
<td>Rust at the pitch interval led to flaking during operation. Further operation resulted in cracking.</td>
<td></td>
</tr>
</tbody>
</table>

Example 2. Combined Flaking Damage

<table>
<thead>
<tr>
<th>Photo 1-16</th>
<th>Part:</th>
<th>Outer ring of a spherical roller bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom:</td>
<td>Flaking, cracking, and wear combined on the outer ring raceway</td>
<td></td>
</tr>
<tr>
<td>Cause:</td>
<td>Wear in two places due to poor lubrication. Primary damage progressed to flaking in one spot (secondary damage) that later became a crack (tertiary damage).</td>
<td></td>
</tr>
</tbody>
</table>

2.3.2 Peeling

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>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. Small particles fall off and extensive minor flaking occurs.</td>
<td>Unsuitable lubricant</td>
<td>Select a different lubricant</td>
</tr>
<tr>
<td></td>
<td>Entry of debris into lubricant</td>
<td>Improve the sealed mechanism</td>
</tr>
<tr>
<td></td>
<td>Rough surface due to poor lubrication</td>
<td>Improve the surface finish of the mating parts</td>
</tr>
<tr>
<td></td>
<td>Surface roughness of mating parts</td>
<td></td>
</tr>
</tbody>
</table>

Example 1. Combined Flaking Damage

<table>
<thead>
<tr>
<th>Photo 2-1</th>
<th>Part:</th>
<th>Inner ring of a spherical roller bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom:</td>
<td>Round peeling on the center of the raceway surface</td>
<td></td>
</tr>
<tr>
<td>Cause:</td>
<td>Poor lubrication</td>
<td></td>
</tr>
</tbody>
</table>

Example 2. Combined Flaking Damage

<table>
<thead>
<tr>
<th>Photo 2-2</th>
<th>Part:</th>
<th>Enlargement of pattern in Photo 2-1</th>
</tr>
</thead>
</table>

Photo 2-3

<table>
<thead>
<tr>
<th>Photo 2-3</th>
<th>Part:</th>
<th>Convex rollers from Photo 2-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom:</td>
<td>Round peeling on the center of the rolling surfaces</td>
<td></td>
</tr>
<tr>
<td>Cause:</td>
<td>Poor lubrication</td>
<td></td>
</tr>
</tbody>
</table>

Photo 2-4

<table>
<thead>
<tr>
<th>Photo 2-4</th>
<th>Part:</th>
<th>Outer ring of a spherical roller bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom:</td>
<td>Peeling near the shoulder of the raceway over the entire circumference</td>
<td></td>
</tr>
<tr>
<td>Cause:</td>
<td>Poor lubrication</td>
<td></td>
</tr>
</tbody>
</table>
### 2.3.3 Scoring

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countereasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>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 appears on the roller end, while scoring on the rib surface appears on the contacting roller end.</td>
<td>• Excessive load, excessive preload • Poor lubrication • Particles caught in the surface • Inclination of inner and outer rings • Shaft bending • Poor precision of the shaft and housing</td>
<td>• Check the size of the load • Adjust the preload • Improve the lubricant and the lubrication method • Check the precision of the shaft and housing</td>
</tr>
<tr>
<td>Photo 3-1</td>
<td>Part: Inner ring of a spherical roller bearing</td>
<td>Symptom: Scoring on large rib face of inner ring</td>
</tr>
<tr>
<td></td>
<td>Cause: Roller slippage due to sudden acceleration and deceleration</td>
<td>Cause: Worn particles mixed with lubricant and breakdown of oil film due to excessive load</td>
</tr>
<tr>
<td>Photo 3-2</td>
<td>Part: Convex rollers of Photo 3-1</td>
<td>Symptom: Scoring on roller end face</td>
</tr>
<tr>
<td></td>
<td>Cause: Roller slippage due to sudden acceleration and decelerition</td>
<td>Cause: Poor lubrication and excessive axial load</td>
</tr>
<tr>
<td>Photo 3-3</td>
<td>Part: Inner ring of a tapered roller thrust bearing</td>
<td>Symptom: scoring on the face of inner ring rib</td>
</tr>
<tr>
<td></td>
<td>Cause: Worn particles mixed with lubricant and breakdown of oil film due to excessive load</td>
<td>Cause: Poor lubrication and excessive axial load</td>
</tr>
<tr>
<td>Photo 3-4</td>
<td>Part: Rollers of a double-row cylindrical roller bearing</td>
<td>Symptom: Scoring on the roller end face</td>
</tr>
<tr>
<td></td>
<td>Cause: Poor lubrication and excessive axial load</td>
<td>Cause: Debris caught in the surface and excessive axial load</td>
</tr>
<tr>
<td>Photo 3-5</td>
<td>Part: Inner ring of a spherical thrust roller bearing</td>
<td>Symptom: Scoring on the rib face of inner ring</td>
</tr>
<tr>
<td></td>
<td>Cause: Debris caught in the surface and excessive axial load</td>
<td>Cause: Debris caught in the surface and excessive axial load</td>
</tr>
<tr>
<td>Photo 3-6</td>
<td>Part: Convex rollers of Photo 3-5</td>
<td>Symptom: Scoring on the roller end face</td>
</tr>
<tr>
<td></td>
<td>Cause: Debris caught in surface and excessive axial load</td>
<td>Cause: Debris caught in surface and excessive axial load</td>
</tr>
<tr>
<td>Photo 3-7</td>
<td>Part: Cage of a deep groove ball bearing</td>
<td>Symptom: Scoring on the pressed-steel cage pockets</td>
</tr>
<tr>
<td></td>
<td>Cause: Entry of debris</td>
<td>Cause: Entry of debris</td>
</tr>
<tr>
<td>Photo 3-8</td>
<td>Part: Outer ring of a double-row cylindrical roller bearing</td>
<td>Symptom: Notable scoring on the face of an outer ring rib</td>
</tr>
<tr>
<td></td>
<td>Cause: Excessive axial load</td>
<td>Cause: Excessive axial load</td>
</tr>
</tbody>
</table>
### 2.3.4 Smearing

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

| Photo 4-1                                                                 | Inner ring of a cylindrical roller bearing                                       | Outer ring of Photo 4-1                                                      |
| Part:                                                                                   | Symptom: Smearing circumferentially on raceway surface                        | Part: Outer ring of Photo 4-1                                                 |
| Cause:                                                                                   | Cause: Roller slippage due to excessive grease filling                        | Cause: Poor lubrication                                                       |

| Photo 4-5                                                                 | Inner ring of a spherical roller bearing                                        | Outer ring of Photo 4-6                                                      |
| Part:                                                                                   | Symptom: Partial smearing circumferentially on raceway surface                | Part: Outer ring of Photo 4-5                                                 |
| Cause:                                                                                   | Cause: Poor lubrication                                                        | Cause: Poor lubrication                                                       |

| Photo 4-6                                                                 | Convex rollers of Photo 4-5                                                   | Rollers of a large cylindrical roller bearing                                 |
| Part:                                                                                   | Symptom: Smearing at the center of the rolling surface                        | Part: Smearing on rolling surface                                              |
| Cause:                                                                                   | Cause: Poor lubrication                                                        | Cause: Light load and poor lubrication                                         |

| Photo 4-7                                                                 | Partial smearing circumferentially on raceway surface                          |                                                                 |
| Part:                                                                                   | Symptom: Smearing at the center of the rolling surface                        |                                                                 |
| Cause:                                                                                   | Cause: Poor lubrication                                                        |                                                                 |

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

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Small pieces broken off due to excessive load or shock load act locally on a part of the roller corner or rib of a raceway ring. | • Shock during mounting  
• Excessive load  
• Poor handling, such as dropping | ➢ Improve the mounting method  
(shrink fit, use of proper tools)  
➢ Reconsider load conditions  
➢ Provide enough backup and support for the bearing rib |

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

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

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

- **Photo 5-4**: Outer ring of a solid type needle roller bearing  
  Part: Outer ring of a solid type needle roller bearing  
  Symptom: Fracture 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 rib)

### 2.3.6 Cracks

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Fissures in the raceway ring and rolling elements. Continued use in 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 load conditions  
➢ Improve the mounting method  
➢ Use an appropriate shaft shape |

- **Photo 6-1**: Outer ring of a double-row cylindrical roller bearing  
  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**: Roller of a tapered roller thrust bearing  
  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**: Outer ring of a double-row cylindrical roller bearing  
  Part: Outer ring of a double-row cylindrical roller bearing  
  Symptom: Cracks propagated 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**: Roller of a tapered roller thrust bearing  
  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
2.3.7 Cage Damage

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Various damage 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)  
• Poor handling  
• Large moment load  
• Shock and large vibration  
• Excessive rotation speed, sudden acceleration/deceleration  
• Poor lubrication  
• Temperature rise | • Check the mounting method  
• Check the temperature, rotation, and load conditions  
• Reduce vibration  
• Select a different cage type  
• Select a different lubrication method or lubricant |

---

Photo 6-4
Part: Outer ring of a double-row cylindrical roller bearing (outer ring rotation)
Symptom: Cracks on outer side 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 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 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: Flaking origin directly beneath the raceway surface

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

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

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

---

Damage Possible Causes Countermeasures
Various damage 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)  
• Poor handling  
• Large moment load  
• Shock and large vibration  
• Excessive rotation speed, sudden acceleration/deceleration  
• Poor lubrication  
• Temperature rise | • Check the mounting method  
• Check the temperature, rotation, and load conditions  
• Reduce vibration  
• Select a different cage type  
• Select a different lubrication method or lubricant |
### 2.3.8 Denting

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 mounting (Brinell dents).

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris such as metallic particles caught in the surface</td>
<td>• Debris such as metallic particles caught in the surface</td>
<td></td>
</tr>
<tr>
<td>Excessive load</td>
<td>• Excessive load</td>
<td></td>
</tr>
<tr>
<td>Shock during transport or mounting</td>
<td>• Shock during transport or mounting</td>
<td></td>
</tr>
</tbody>
</table>

- Wash the housing
- Improve the sealing mechanism
- Filter the lubrication oil
- Improve the mounting and handling methods

**Possible Causes**

- Debris such as metallic particles caught in the surface
- Excessive load
- Shock during transport or mounting

**Countermeasures**

- Wash the housing
- Improve the sealing mechanism
- Filter the lubrication oil
- Improve the mounting and handling methods

---

**Photo 7-5**
- Part: Cage of an angular contact ball bearing
- Symptom: Deformation and wear of a machined high-tension-brass cage
- 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 load 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

---

**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 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 over the rolling surface
- Cause: Debris caught in the surface
### 2.3.9 Pitting

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>The surface of the rolling element or raceway has small holes and a dull luster.</td>
<td>• Debris caught in the lubricant  • Exposure to moisture in the atmosphere  • Poor lubrication</td>
<td> Improve the sealing mechanism   Filter the lubrication oil thoroughly   Use another appropriate lubricant</td>
</tr>
</tbody>
</table>

---

#### Photos

- **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

- **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)

### 2.3.10 Wear

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface deterioration due to sliding friction at the surface of the raceway, rolling elements, roller end faces, rib face, cage pockets, etc.</td>
<td>• Entry of debris  • Progression from rust and electrical corrosion  • Poor lubrication  • Sliding due to irregular motion of rolling elements</td>
<td> Improve the sealing mechanism   Clean the housing   Filter the lubrication oil thoroughly   Check the lubricant and lubrication method   Prevent misalignment</td>
</tr>
</tbody>
</table>

---

#### Photos

- **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)
2.3.11 Fretting

A type of wear due to repeated sliding between two surfaces. Fretting occurs at the fitting surface and at the contact area between the raceway ring and rolling elements. Fretting corrosion is another term used to describe reddish brown or black worn particles.

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Poor lubrication</td>
<td>- Use a proper lubricant</td>
</tr>
<tr>
<td></td>
<td>- Vibration with a small amplitude</td>
<td>- Apply a preload</td>
</tr>
<tr>
<td></td>
<td>- Insufficient interference</td>
<td>- Check the interference fit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Apply a film of lubricant to the fitting surface</td>
</tr>
</tbody>
</table>

- Poor lubrication
- Vibration with a small amplitude
- Insufficient interference

Countermeasures:
- Use a proper lubricant
- Apply a preload
- Check the interference fit
- Apply a film of lubricant to the fitting surface
### 2.3.12 False Brinelling

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| 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.  
- Oscillating motion with a small amplitude  
- Poor lubrication | ➢ Secure the shaft and housing during transport  
➢ Transport with the inner and outer rings packed separately  
➢ Reduce vibration by preloading  
➢ Use another appropriate lubricant |

#### Cause:
- Vibration from an external source while stationary

#### Symptom:
- False brinelling on the raceway

#### Part:
- Inner ring of a deep groove ball bearing  
- Outer ring of a spherical roller bearing  
- Convex rollers of Photo 13-1

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

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

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

#### Photo 12-4: Rollers of a cylindrical roller bearing  
#### Part: Rollers of Photo 12-4  
#### Symptom: Raceway discoloration, melting at ball pitch intervals  
#### Cause: Excessive preload

### 2.3.13 Seizure

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| When sudden overheating occurs during rotation, the bearing becomes discolored. If operation continues, the 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 | ➢ Review the lubricant and lubrication method  
➢ Re-investigate the suitability of the bearing type selected  
➢ Review the preload, bearing clearance, and fitting  
➢ Improve the sealing mechanism  
➢ Check the precision of the shaft and housing  
➢ Improve the mounting method |

#### Cause:
- Excessive preload

#### Symptom:
- Raceway discoloration, melting at ball pitch intervals

#### Part:
- Inner ring of a cylindrical roller bearing  
- Convex rollers of Photo 13-1  
- Outer ring in Photo 13-3

#### Photo 13-1: Inner ring of a spherical roller bearing  
#### Part: Inner ring of Photo 13-1  
#### Symptom: Discoloration and melting of raceway  
#### Cause: Insufficient lubrication

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

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

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

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep</td>
<td>Insufficient interference or loose fit</td>
<td>Check interference and prevent rotation</td>
</tr>
<tr>
<td></td>
<td>Insufficient sleeve tightening</td>
<td>Correct the sleeve tightening</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Review precision of the shaft and housing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply axial preload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tighten the raceway ring side face</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply adhesive to the fitting surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply a film of lubricant to the fitting surface</td>
</tr>
</tbody>
</table>

A phenomenon in bearings where relative slippage occurs at the fitting surfaces. Creep causes a shiny appearance, occasionally with scoring or wear.

---

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

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

**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

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| When electric current passes through a bearing, arcing and burning occur throughout 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 can be seen by the naked eye. Magnification of these grooves reveals crater-like depressions that indicate melting by arcing. | • Electric potential difference between inner and outer rings  
• High-frequency electric potential difference generated by instruments or substrates used near a bearing. | ➤ Design electric circuits that prevent current flow through the bearings  
➤ Insulate the bearing |

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 15-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner ring of a tapered roller bearing</td>
<td>Striped pattern of erosion on the raceway surface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 15-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapered rollers in Photo 15-1</td>
<td>Striped pattern of erosion on the rolling surface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 15-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner ring of a cylindrical roller bearing</td>
<td>Pits on the surface of rings and rolling elements. These may occur at the rolling element pitch on the rings or over entire bearing surfaces.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 15-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balls of a deep groove ball bearing</td>
<td>A dark color covering the entire ball surface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 15-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner ring of a deep groove ball bearing</td>
<td>Fluting on the raceway surface (high frequency)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 15-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer ring of a deep groove ball bearing</td>
<td>Fluting on the raceway surface</td>
</tr>
</tbody>
</table>

### 2.3.16 Rust and Corrosion

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Pits on the surface of rings and rolling elements. These may occur at the rolling element pitch on the rings or over entire bearing surfaces. | • Entry of corrosive gas or water  
• Improper lubricant  
• Formation of water droplets due to condensation  
• High temperature and high humidity while stationary  
• Poor rust preventive treatment during transport  
• Improper storage conditions  
• Improper handling | ➤ Improve the sealing mechanism  
➤ Review the lubrication method  
➤ Apply an anti-rust treatment during idle periods  
➤ Improve storage methods  
➤ Improve handling |

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 16-1</th>
</tr>
</thead>
</table>
| Outer ring of a cylindrical roller bearing | Rust on the rib face and raceway surface  
Poor lubrication due to water entry |

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 16-2</th>
</tr>
</thead>
</table>
| Outer ring of a slewing ring | Rust on raceway surface at ball pitch  
Condensation during stationary periods |

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 16-3</th>
</tr>
</thead>
</table>
| Inner ring of a spherical roller bearing | Rust on raceway surface at roller pitch  
Entry of water into lubricant |

<table>
<thead>
<tr>
<th>Part:</th>
<th>Photo 16-4</th>
</tr>
</thead>
</table>
| Rollers of a spherical roller bearing | Ph-phased rust on rolling contact surface, corroded portions  
Condensation during storage |
### 2.3.17 Mounting Flaws

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Straight-line scratches on surface of raceways or rolling elements caused during mounting. | • Inclination of inner and outer rings during mounting or dismounting  
• Shock load during mounting or dismounting | ➢ Use appropriate jigs and tools  
➢ Avoid shock load by using 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

<table>
<thead>
<tr>
<th>Damage</th>
<th>Possible Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Changed coloring of cage, rolling elements, or raceway ring due to reactions 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:** Blush 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:** Blush or purplish discoloration on raceway surface
- **Cause:** Heat generation due to poor lubrication
## Appendix: Bearing Diagnostic Chart

<table>
<thead>
<tr>
<th>Damage</th>
<th>Location (Phenomenon)</th>
<th>Handling</th>
<th>Surroundings</th>
<th>Lubrication</th>
<th>Load</th>
<th>Speed</th>
<th>Cause</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3.1 Flaking (Spalling)</td>
<td>Raceway, rolling surface</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>2.3.2 Peeling</td>
<td>Raceway, rolling surface</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bearing outside surface (rolling contact)</td>
<td>○*</td>
<td>○</td>
<td>○</td>
<td></td>
<td>○</td>
<td></td>
<td>Mating part</td>
</tr>
<tr>
<td>2.3.3 Scoring</td>
<td>Roller end face surface, rib surface</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cage guide surface, pocket surface</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.4 Smearing</td>
<td>Raceway, rolling surface</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>2.3.5 Fracture</td>
<td>Raceway collar, rollers</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>2.3.6 Cracks</td>
<td>Raceway rings, rolling elements</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rib surface, roller end face, cage guide surface (thermal crack)</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3.7 Cage damage</td>
<td>Deformation, fracture</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wear</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>2.3.8 Denting</td>
<td>Raceway, rolling surface (many small dents)</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raceway (debris on the rolling element pitch)</td>
<td>○</td>
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<tr>
<td>2.3.9 Pitting</td>
<td>Raceway, rolling surface</td>
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<tr>
<td>2.3.10 Wear</td>
<td>Raceway, rolling surface, rib surface, roller end face</td>
<td>○</td>
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<td>○</td>
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<tr>
<td>2.3.11 Fretting</td>
<td>Raceway, rolling surface</td>
<td>○</td>
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<td></td>
<td>Bearing outside &amp; bore, side surface (contact with housing and shaft)</td>
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<tr>
<td>2.3.12 False Brinelling</td>
<td>Raceway, rolling surface</td>
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<tr>
<td>2.3.13 Seizure</td>
<td>Raceway ring, rolling element, cage</td>
<td>○</td>
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<tr>
<td>2.3.14 Creep</td>
<td>Fitting surface</td>
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<td>Clearance fit</td>
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<td>2.3.15 Electrical erosion</td>
<td>Raceway, rolling surface</td>
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<td>○</td>
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<td></td>
<td>Electricity passing through the rolling element</td>
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<tr>
<td>2.3.16 Rust and corrosion</td>
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<td>2.3.17 Mounting flaws</td>
<td>Raceway, rolling surface</td>
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<td>2.3.18 Discoloration</td>
<td>Raceway ring, rolling element, cage</td>
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**Remark**: This chart is not comprehensive; it lists only the more commonly occurring damages, causes, and locations.