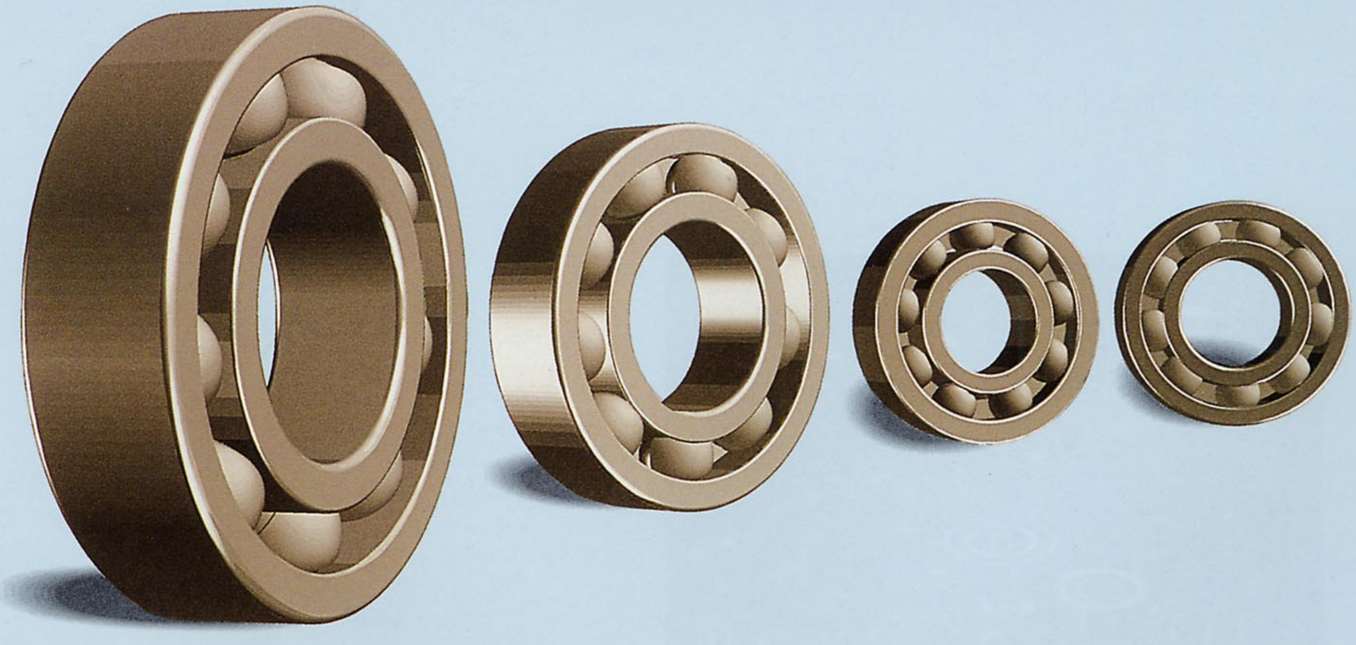
NSK

NEW BEARING DOCTOR

Diagnosis of bearing problems. Objective: Smooth & reliable operation.



On the occasion of the "New Bearing Doctor" pamphlet being published, we would like to express our sincere thanks for your continuous patronage of NSK products.

This pamphlet contains explanations about correct bearing handling, mounting, lubrication, and maintenance to prevent premature failure together with color photos of bearing failures. Please be sure to consult the NSK Rolling Bearing Catalog (CAT. No. E1101a) for more details regarding handling, maintenance, etc.

Bearings become unserviceable when they suffer premature failure which is due to a lack of attention to proper handling and/or maintenance. Premature failure is completely different from flaking (life) due to rolling fatigue. This pamphlet is useful in determining causes of and countermeasures against premature failure. It's our pleasure to offer you this pamphlet.

Index of "New Bearing Doctor"

1. Introduction

When a rolling bearing is damaged during machine operation, the entire machine or equipment may seize or malfunction. Since bearings that fail prematurely or unexpectedly cause trouble, it is important to be able to identify and predict failure beforehand, if possible, so that preventive measures can be adopted.

Generally, bearing inspection or housing inspection can identify the cause of the problem. Often the cause is attributable to poor lubrication, improper handling, selecting the wrong bearing, or not enough study of the shaft and housing. Usually the cause can be determined by considering operation of the bearing before the failure, investigating the lubrication conditions and the mounting condition, and carefully observing the damaged bearing itself.

Sometimes bearings are damaged and fail both quickly and unexpectedly. Such premature failure is different from fatigue failure which is due to flaking. Bearing life can be separated and categorized into two types: premature failure and normal rolling contact fatigue.

2. Bearing Handling

2.1 Precautions for Handling

Since rolling bearings are high precision machine parts, they must be handled carefully. Even if high quality bearings are used, their expected life and performance cannot be attained if they are used improperly. The main precautions to be observed are as follows:

(1) Keep the Bearings and Surrounding Area Clean: Dust and dirt, even if invisible to the naked eye, have harmful effects on bearings. It is necessary to prevent the entry of dust and dirt by keeping the bearings and their environment as clean as possible.

(2) Careful Handling: Heavy shocks during handling may scratch or cause other damage to the bearing possibly resulting in bearing failure. Strong impacts may cause brinelling, breaking, or cracking.

(3) Use Proper Tools: Always use the proper tool when handling bearings and avoid general purpose tools.

(4) Prevent Corrosion: Since perspiration on the hands and various other contaminants may cause corrosion, keep your hands clean when handling bearings. Wear gloves if possible.

2.2 Mounting

It is advisable to study the bearing mounting thoroughly since the quality of the bearing mounting influences the bearing's running accuracy, life, and performance. It is recommended that the mounting method include the following steps.

(1) Clean the bearing and surrounding parts.
(2) Check the dimensions and finish conditions of related parts.
(3) Follow mounting procedure.
(4) Check if the bearing is mounted correctly.
(5) Supply with correct kind and quantity of lubricant.

Since most bearings rotate with the shaft, the bearing mounting method is generally an interference (tight) fit for the inner ring and shaft while giving a clearance (loose) fit for the outer ring and housing.

2.3 Check the Operation

After mounting the bearing, it is important to carry out an operating test to confirm that the bearing is mounted properly. Table 2.1 indicates operating test methods. If irregularities are detected, immediately suspend the test and consult Table 2.2 which lists appropriate countermeasures to specific bearing problems.

Table 2.1 Methods to check operation

Machine size	Operating procedure	Bearing condition checks
Small machine	Manual operation. Turn the bearing by hand. If no problems are detected, then proceed to operate the machine.	Stick-slip (Debris, cracks, dents). Uneven rotating torque (Faulty mounting). Excessive torque (Error in mounting or insufficient radial internal clearance).
	Power operation. Initially start at a low speed and without a load. Gradually increase speed and load to reach rating.	Check for irregular noise. Check for bearing temperature rise. Lubricant leakage. Discoloration.
Large machine	Idle operation. Turn ON power and allow machine to rotate slowly. Turn OFF the power and allow the bearing to coast to a stop. If no irregularities are detected by the test, then proceed to the loaded rotation testing.	Vibration. Noise, etc.
	Power operation. Follow the same power operation testing as used for small machine testing.	Follow the same checkpoints as the small machine test.

Table 2.2 Causes and countermeasures for operating irregularities

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

3. Bearing Maintenance

It is necessary to periodically inspect and maintain the bearing and its operating conditions in order to maximize the bearing life. In general, the following method is adopted.

(1) Inspection under operating conditions

To determine the bearing replacement periods and replenishment intervals for lubricant, investigate the lubricant properties and consider factors such as operating temperature, vibration, and bearing noise. (Refer to Section 4 for more details.)

(2) Inspection of the bearing

Be sure to investigate the bearing thoroughly during times of periodic machine inspection and part replacement. Check the raceway condition. Determine if damage exists. Confirm if the bearing can be reused or should be replaced. (Refer to Section 5 for more details.)

4. Bearing Performance Factors

Key bearing performance factors during operation are bearing noise, vibration, temperature, and lubricant state. Please refer to Table 2.2 if any operation irregularities are detected.

4.1 Bearing Noise

During operation, sound detection instruments (stethoscope, NSK Bearing Monitor, etc.) can be used to investigate the volume and characteristics of the bearing rotation noise. It is possible to distinguish bearing damage such as small flaking by means of its unusual yet characteristic noise.

4.2 Bearing Vibration

Bearing irregularities can be analyzed by measuring the vibrations of an operating machine. A frequency spectrum analyzer is used to measure the magnitude of vibration and the distribution of the frequencies. Test results enable the determination of the likely cause of the bearing irregularity. The measured data varies depending on the operating conditions of the bearing and the location of the vibration pick-up. Therefore, the method requires the determination of evaluation standards for each measured machine.

It is useful to be able to detect irregularities from the bearing vibration pattern during operation. Please refer to the NSK pamphlet Pr. No. 410 (Bearing Monitor) for more information about such a device.

4.3 Bearing Temperature

Generally, the bearing temperature can be estimated from the temperature of the housing outside surface, but a preferable way is to obtain direct measurements from the bearing outer ring by a probe going through an oil hole.

Usually, the bearing temperature gradually increases after the start of operation until reaching a steady state condition about 1 or 2 hours later. The bearing steady state temperature depends on load, rotational speed and heat transfer properties of the machine. Insufficient lubrication or improper mounting might cause the bearing temperature to rise rapidly. In such a case, suspend the machine operation and adopt an appropriate countermeasure.

4.4 Effects of Lubrication

The two main purposes of lubrication are to minimize friction and reduce wear inside bearings that might otherwise fail prematurely. Lubrication provides the following advantages:

(1) Reduction of Friction and Wear

Direct metallic contact between the bearing rings, rolling elements and cage, which are the basic components of a bearing, is prevented by an oil film which reduces the friction and wear in the contact areas.

(2) Extension of Fatigue Life

The rolling fatigue life of bearings depends greatly upon the viscosity and film thickness between the rolling contact surfaces. A heavy film thickness prolongs the fatigue life, but it is shortened if the viscosity of the oil is too low so that the film thickness is insufficient.

(3) Dissipation of Frictional Heat and Cooling

Circulation lubrication may be used to carry away either frictional heat or heat transferred from the outside to prevent the bearing from overheating and the oil from deteriorating.

(4) Sealing and Rust Prevention

Adequate lubrication also helps to prevent foreign material from entering the bearings and guards against corrosion or rusting.

4.5 Selection of Lubrication

Bearing lubrication methods are divided into two main categories: grease lubrication and oil lubrication. A lubrication method is adopted that matches the application conditions and application purpose in order to attain best performance from the bearing. Table 4.1 shows a comparison between grease and oil lubrication.

Table 4.1 Comparison between grease and oil lubrication

Item	Grease lubrication	Oil lubrication
Housing structure and seal method	Simple	May be complex. Careful maintenance required.
Speed	Limiting speed is 65%~80% of that with oil lubrication	High limiting speed
Cooling effect	Poor	Heat transfer is possible using forced oil circulation
Fluidity	Poor	Good
Lubricant replacement	Sometimes difficult	Easy
Removal of foreign material	Removal of particles from grease is impossible	Easy
External contamination due to leakage	Surroundings seldom contaminated by leakage	Often leaks if proper countermeasures are not taken. Not suitable if external contamination must be avoided.

(1) Grease lubrication

Grease is a lubricant that is made from base oil, thickener, and additives. When selecting a grease, it is necessary to select a grease that is suitable to the bearing application conditions. There are large differences in performance even between different brands of the same type of grease. Therefore special attention must be given to grease selection. Table 4.2 gives examples of applications and grease consistency.

(2) Oil lubrication

There are several different oil lubrication methods: Oil bath, Drip feed, Splash, Circulating, Jet, Oil mist, and Oil air. Oil lubrication methods are more suitable for higher speed and higher temperature applications than are grease lubrication methods. Oil lubrication is especially effective in the case where it is necessary to dissipate heat to the exterior.

Be sure to select a lubricating oil that has suitable viscosity at the bearing operating temperature. Generally, an oil with a low viscosity is used for high speed application while an oil with high viscosity is used for applications with heavy loads. For normal application conditions, Table 4.3 lists the suitable viscosity range for the operating temperature.

For reference when making a selection, Fig. 4.1 shows the relationship between temperature and viscosity for the lubricating oil. Table 4.4 gives examples of how to select the lubrication oil for different bearing application conditions.

Table 4.3 Required viscosity by bearing type

Bearing type	Viscosity at operating temperature
Ball bearings, Cylindrical roller bearings	13 mm²/s or more
Tapered roller bearings, Spherical roller bearings	20 mm²/s or more
Spherical thrust roller bearings	32 mm²/s or more

Remarks: 1 mm²/s = 1 cSt (Centi-Stokes)

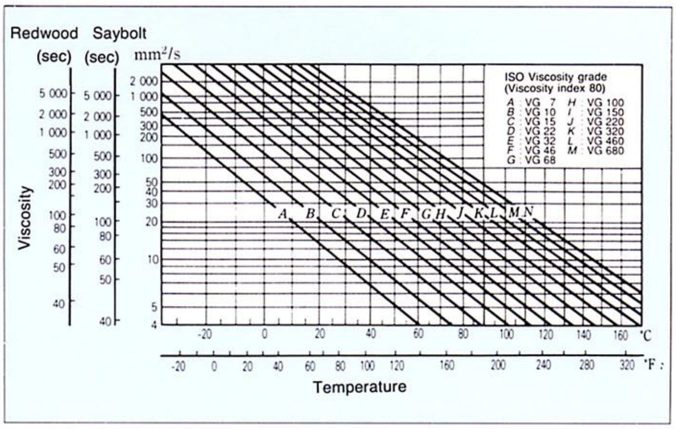


Fig. 4.1 Relation between oil viscosity and temperature

Table 4.2 Examples of applications and grease consistency

Consistency number	#0	#1	#2	#3	#4
Consistency (1/10 mm)	355~385	310~340	265~295	220~250	175~205
Application	Central grease supply	Central grease supply, Low temperature	General grease	General grease, High temperature	High temperature
	Where fretting occurs easily	Where fretting occurs easily	Sealed ball bearings	Sealed ball bearings	Where grease is used as a seal

Table 4.4 Selection of lubricating oils for different bearing applications

Operating temperature	Speed	Light or normal load	Heavy or shock load
−30~0°C	Below limiting speed	ISO VG 15, 22, 32 (Refrigerator oil)	—
0~50°C	Below 50% of limiting speed	ISO VG 32, 46, 68 (Bearing oil, Turbine oil)	ISO VG 46, 68, 100 (Bearing oil, Turbine oil)
	Between 50% and 100% of limiting speed	ISO VG 15, 22, 32 (Bearing oil, Turbine oil)	ISO VG 22, 32, 46 (Bearing oil, Turbine oil)
	Above limiting speed	ISO VG 10, 15, 22 (Bearing oil)	—
50~80°C	Below 50% of limiting speed	ISO VG 100, 150, 220 (Bearing oil)	ISO VG 150, 220, 320 (Bearing oil)
	Between 50% and 100% of limiting speed	ISO VG 46, 68, 100 (Bearing oil, Turbine oil)	ISO VG 68, 100, 150 (Bearing oil, Turbine oil)
	Above limiting speed	ISO VG 32, 46, 68 (Bearing oil, Turbine oil)	—
80~110°C	Below 50% of limiting speed	ISO VG 320, 460 (Bearing oil)	ISO VG 460, 680 (Bearing oil, Gear oil)
	Between 50% and 100% of limiting speed	ISO VG 150, 220 (Bearing oil)	ISO VG 220, 320 (Bearing oil)
	Above limiting speed	ISO VG 68, 100 (Bearing oil, Turbine oil)	—

Notes: 1. As for the limiting speed, use the value listed under oil lubrication in the Bearing Dimension Tables of "NSK Rolling Bearings" (No. E140).
2. Refer to refrigerator oil (JIS K2211), Bearing oil (JIS K2239), Turbine oil (JIS K2213), Gear oil (JIS K2219).
3. Temperature ranges are shown in the left column in the table above. For operating temperatures that are on the high temperature side, a high viscosity lubrication oil is recommended.

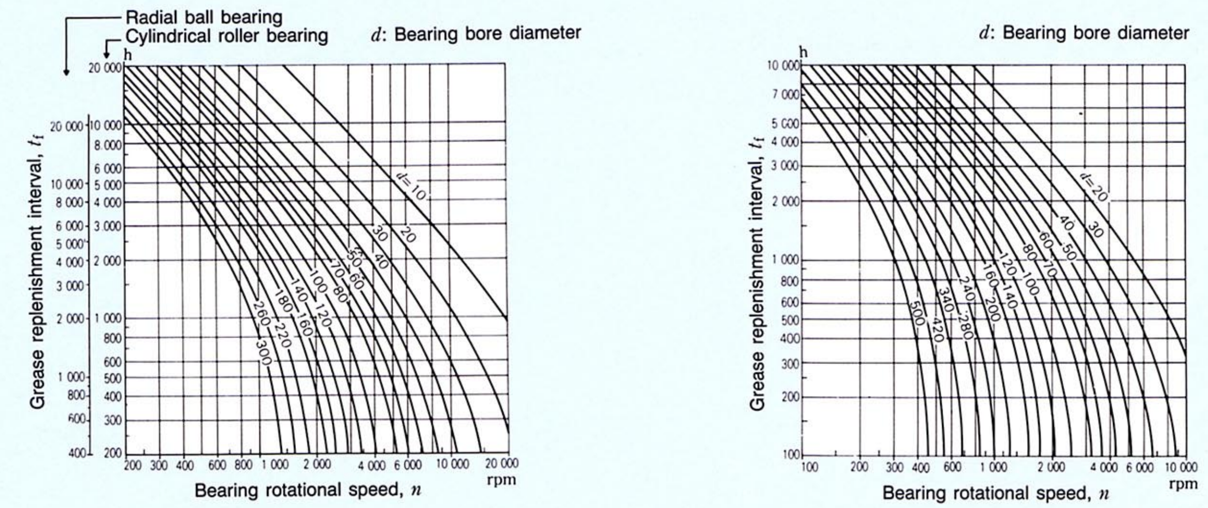
4.6 Replenishment and Replacement of Lubricant

(1) Grease replenishment intervals

As time passes, grease deteriorates and the lubricating ability is degraded. Be sure to replenish the grease at the correct interval. The grease replenishment interval depends on factors like the bearing type, dimensions, and rotation speed. Fig. 4.2 shows approximate grease replenishment intervals as a function of operating time and rotational speed. As a general rule, the grease replenishment interval should be halved for each 15°C bearing temperature rise above 70°C.

(2) Lubrication oil replacement interval

The oil replacement intervals depend on the operating conditions and the oil quantity. In general, for an operating temperature under 50°C, and in clean environments, the replacement interval is 1 year. If the oil temperature is above 100°C, then the oil should be changed at least once every three months.



(1) Radial ball bearing and cylindrical roller bearing

(2) Tapered roller bearing and spherical roller bearing

Fig. 4.2 Grease replenishment intervals

5. Bearing Inspection

When inspecting a bearing during periodic inspection of equipment, operating inspections, or replacement of adjacent parts, determine the condition of the bearing and if its continued service is advisable.

A record should be kept of the inspection and external appearance of dismounted bearings. After taking a grease sample and measuring the quantity of residual grease, the bearing should be cleaned. Also, determine whether abnormalities and damage exist in the cage, fitting surfaces, rolling element surfaces, and raceway surfaces. Refer to Section 6 regarding the observation of running traces on the raceway surface.

When evaluating whether a bearing can be reused or not, the following points need to be considered: degree of bearing damage, machine performance, critical nature of the application, operating conditions, inspection interval. If the inspection reveals bearing damage or abnormalities, then try to confirm the cause and determine a countermeasure by referring to Section 7 and then carry out the countermeasure.

If your inspection discovers any of the following kinds of damage, which would prevent the bearing from being reused, then the bearing must be replaced with a new one.

(1) Cracks or chipping in the cage, rolling elements, or raceway ring.
(2) Flaking in the rolling elements or raceway ring.
(3) Notable scoring on the rolling elements, rib face (collar), or raceway surface.
(4) Notable wear on the cage or loose rivets.
(5) Flaws or rust on the rolling elements or raceway surface.
(6) Notable dents on the rolling elements or raceway surface.
(7) Notable creep of the outer ring outside surface or inner ring bore.
(8) Discoloration due to heating.
(9) Serious damage on shield or seal of grease packed bearings.

6. Running Traces and Applied Loads

As the bearing rotates, the raceways of the inner ring and outer ring make contact with the rolling elements. This results in a wear path on both the rolling elements and raceways. Running traces are useful, since they indicate the loading conditions, and should be carefully observed when the bearing is disassembled.

If the running traces are clearly defined, it is possible to determine whether the bearing is carrying a radial load, axial load or moment load. Also, the roundness condition of the bearing can be determined. Check whether unexpected bearing loads or large mounting errors occurred. Also, determine the probable cause of the bearing damage.

Fig. 6.1 shows the running traces generated in deep groove bearings under various load conditions. Fig. 6. 1 (a) shows the most common running trace generated when the inner ring rotates under a radial load only. Figs. 6.1 (e) through (h) show several different running traces that result in a shortened life due to their adverse effect on the bearings.

Similarly, Fig. 6.2 shows different roller bearing running traces: Fig. 6.2 (i) shows the outer ring running trace when a radial load is properly applied to a cylindrical roller bearing which has a load on a rotating inner ring. Fig. 6.2 (j) shows the running trace in the case of shaft bending or relative inclination between the inner and outer rings. This misalignment leads to the generation of slightly shaded (dull) bands in the width direction. Traces are diagonal at the beginning and end of the loading zone. For double-row tapered roller bearings where a single load is applied to the rotating inner ring, Fig. 6.2 (k) shows the running trace on the outer ring under radial load while Fig. 6.2 (l) shows the running trace on the outer ring under axial load. When misalignment exists between the inner and the outer rings, then the application of a radial load causes running traces to appear on the outer ring as shown in Fig. 6.2 (m).

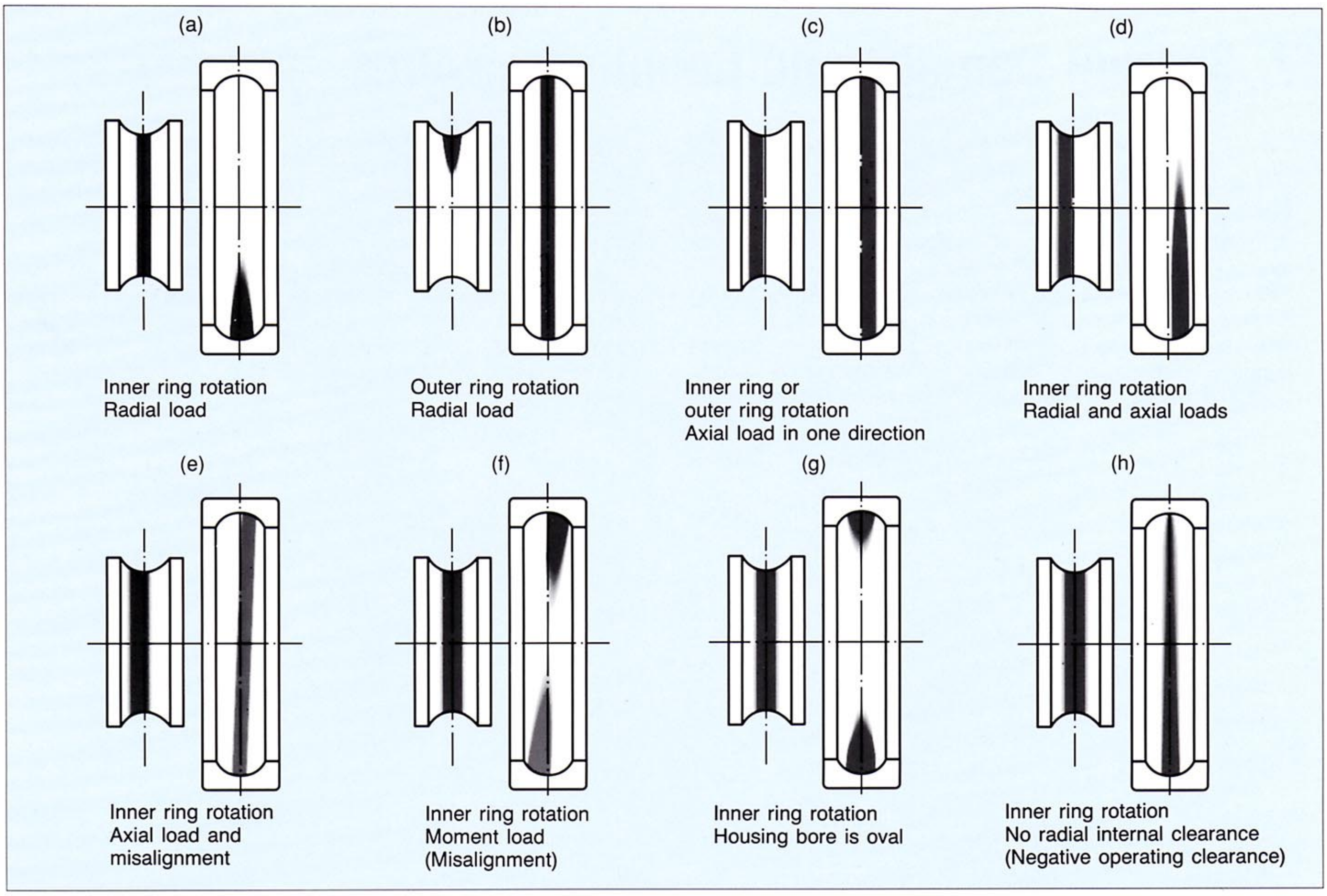


Fig. 6.1 Typical running traces of deep groove ball bearings