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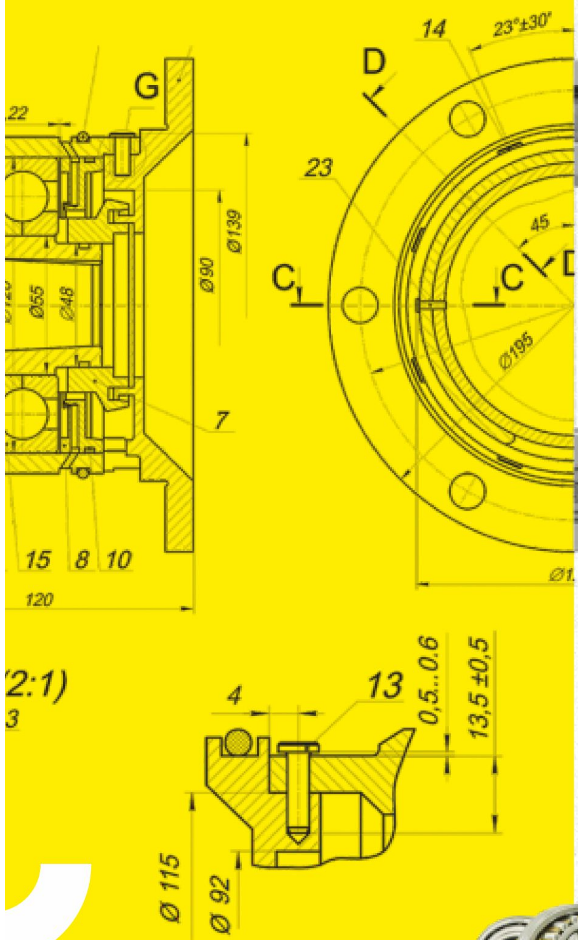

ROLLING BEARINGS

Bearing Failure

2 WHEELERS | 3 WHEELERS | 4 WHEELERS | TRACTORS | LCV, HCV | INDUSTRIES | RAILWAYS | AEROSPACE

WINNER DEMING GRAND PRIZE

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CATALOGUE/TC-106, 01/2024

This version supersedes all previously published versions. All the bearing mentioned in this catalogue are manufactured with normal tolerance class. We can, however, supply other class bearing against specific requirement.

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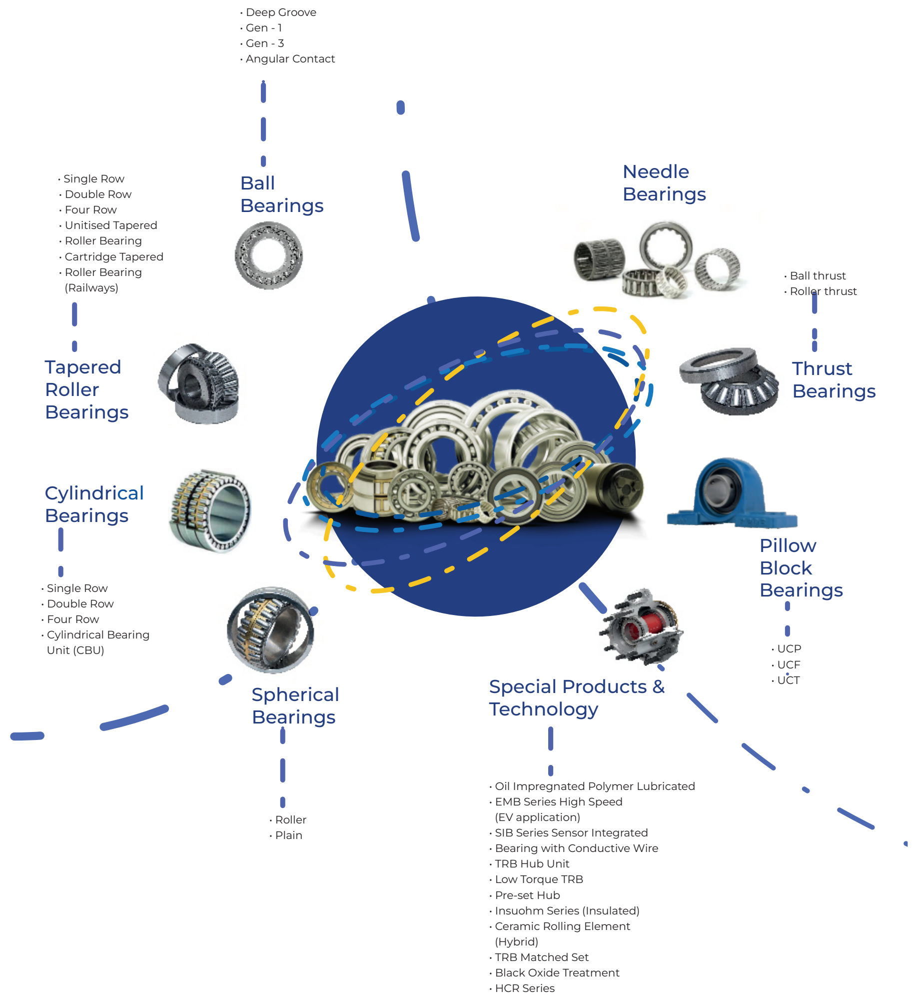
Founded in 1946, NBC is India's first bearings manufacturer and the last word in quality and durability. In 2020, the company acquired leading European manufacturer, Kinex Bearings to further boost its expertise.

75 years since its beginning, NBC remains India's leading bearings manufacturer andexporter. NBC is also the world's only bearings manufacturer to receive the prestigious Deming Grand Prize for Total Quality Management.

- 1946 India's first bearing manufacturer
- 250+ million bearings manufactured/ annum
- 3100+ variants of bearings offered
- 5 manufacturing locations
- Leading exporter
- Happy customers in 30+ countries
- R&D and Innovation Centre
- 2800+People
- Automotive
- Industrial
- Railway
- Aerospace

Products from NBC

Since the challenges faced by industry are many, NBC offers a diverse range of exceptional bearings. NBC bearings are available in sizes from 04 mm bore to 2000 mm outer diameter.



* Products with special features like high temperature application, special heat treatment, coated roller/races and cage options are also available across product range.

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Ball Bearings, Angular Contact and Duplex Bearings

When a bearing carries heavy axial load, abutments must be deeper i.e. it should not extend beyond the inner ring outside diameter or below the outer ring bore. A deep abutment can cause difficulties when a bearing is removed from its seating and, therefore, it is advantageous to provide grooves or holes on such an abutment so that a suitable extraction tool can be used.

Roller Bearings

Bearings not carrying axial loads

The maximum abutment depth is more important for these bearings than for ball bearings. The maximum inner abutment diameter and minimum outer ring abutment diameter are recommended accordingly. Broadly these coincide with the diameter of the inner and outer ring raceways respectively.

Bearings carrying axial load

Abutments for these bearings should extend beyond the raceways to avoid shear stresses in the lips. Every possible care is necessary to ensure that the abutments are flat and square with the axis of rotation.

Thrust Bearings

Abutments for Thrust bearings should extend beyond the pitch circle diameter of the balls to prevent the washers moving under load.

For standard Thrust bearings with one small bore washer and one large bore washer, the approximate pitch circle diameter

$$= \frac{\text{Small bore diameter} + \text{Large outside diameter}}{2}$$

In case of bearings with two bore washers, use the pitch circle diameter for the same basic bearing size with one large bore washer and one small bore washer.

14 Bearing Failure

14.1 Bearing Failure

Rolling bearing consists of Inner ring, outer ring, rolling elements and cage/retainer to hold the rolling elements (ball/roller) at their respective position. Application of rolling bearing can be seen almost everywhere e.g. aerospace, railways, automotive and industrial segment.

In general, if rolling bearings are used properly they will continue to run till their predicted fatigue life. In the rolling bearing, failure can happen due to a number of reasons. Most common are:

- Fatigue failure
- Lubrication problem
- Contamination

But the type of failure varies depending upon the industry and application.

Proper investigation of the root cause of a bearing failure is necessary to make suitable recommendations for eliminating the cause of failure. However, sometimes it becomes difficult or even impossible to ascertain the exact root cause of a bearing failure when bearing subjected to advance stage or catastrophic mode failure. In such cases, finding out primary cause may become a tricky task as the evidence is likely to be lost. If all the variables and conditions are known at the time of failure occurrence or prior to the time of failure including the application and operating conditions then, by understanding the traces of failure and defining its probable causes, the possibility of similar type of failure in the future can be avoided. Moreover, two or more failure patterns can occur simultaneously and reduce the bearing life exponentially. Proper examination of contact traces, seating of bearing and running path pattern on the raceways for given application can help us in conducting proper root cause analysis of a bearing failure. Failure in bearing can take place due to human error and fatigue failure.

In contrast to fatigue life, bearings premature failure due to human error include:

1. Improper mounting/handling practice
2. Wrong bearing selection
3. Inappropriate operating condition
4. Insufficient lubrication
5. Solid or liquid contamination
6. Wrong lubrication selection
7. Material fault/inclusion
8. Deviation/abnormality in manufacturing process

14.2 Classification of Failure Modes in Rolling Bearing

While performing bearing failure analysis, it is first and foremost important to understand the basic classification of different types of failures modes and what causes them. Rolling bearing failures are classified strictly according to their primary causes which constitutes of wear, indentation, surface distress, corrosion and electric current damage. Each of the different causes of bearing failure produces its own characteristic damage. Such damages are known as primary damage which gives rise to secondary or advance mode of failure which constitutes of flaking, cracks and cage damage. This will result in scrapping of the bearing due to excessive internal clearance, noise, vibration etc. A failed bearing can frequently display a combination of primary & secondary damages. The classification of bearing failure is based on ISO 15243: 2004. The failure modes are divided into 6 main modes and sub-modes based on the appearances and features that are visible on the bearing components surfaces.

(Note: Bearing manufacturers can classify bearing failures in their own way and use different terminology)

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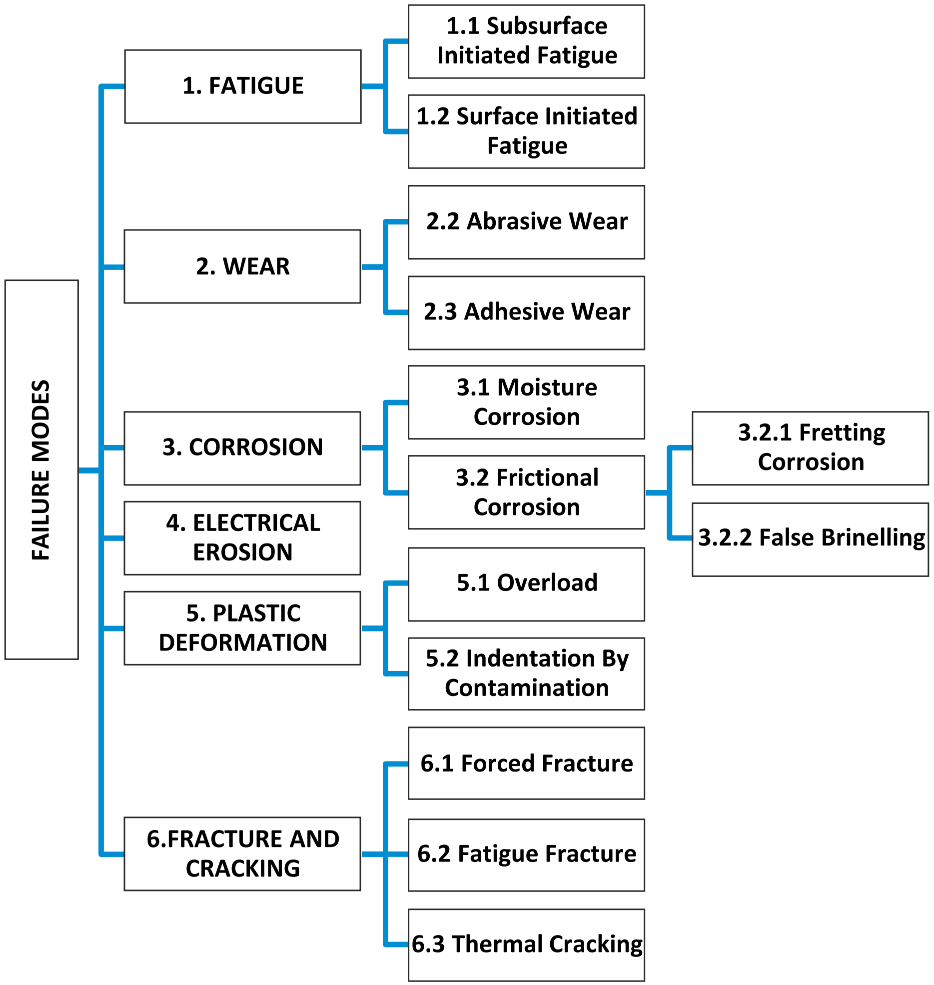
Failure modes classification as per ISO 15243:2004
(Rolling Bearing Damage and Failures)



1. Fatigue

Fatigue is visible as flaking of particles from the surface. During service bearing surface undergoes repetitive loading from rolling elements. Due to repteated stress there is change in the microstructure between the rolling elements and the raceways. This results into material removal from bearing components surface(s).This is called bearing fatigue failure or flaking.

Flaking occurs when small chips of bearing material gets tear off from the smooth surface of the raceway or rolling elements due to rolling fatigue, thereby creating regions having rough and coarse texture.Flaking may be caused at initial stage of bearing life by

- over-load during operation
- excessive load due to improper handling,
- poor shaft or housing accuracy,
- installation error,
- ingress of foreign objects
- rusting, etc.

If the flaking is noticed at its initial stage then it is possible to identify its cause and the appropriate action can be taken to prevent its recurrence. When flaking propogates further, it makes its presence known in the form of noise and vibrations which indicates it is time to change the bearing.

Fatiuge failures are:

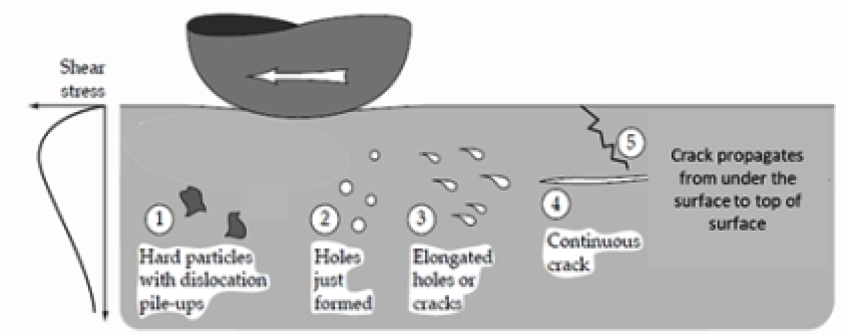
- Subsurface initiated
- Surface initiated

Subsurface Initiated fatigue

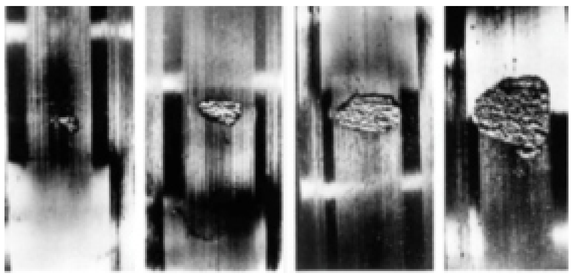
During operation, there are repeated cyclic stress in the rotating part and constant stresses in the stationary part. Under load zone the rolling elements are compressed due to maximum load and as they move out of load zone they expand due to minimum load.

Depending upon the operating condition (i.e load, operating clearance and temperature) and number of stress cycles over a period of time, there is a build-up of residual stresses that will cause micro cracks to be initiated at a certain depth under the surface i.e. subsurface. These cracks will propagate from under the component surface to top of the surface.

Illustration of a process of subsurface crack formation.



In another case, presence of higher nonmetallic inclusion in bearing material may lead to sub-surface initiated fatigue. During operation, beneath the bearing surface which undergoes repetitive loading condition these nonmetallic inclusion acts like stress riser and create micro cracks which finally may lead flaking. Initially fatigue is visible as flaking which propagates to spalling (pitting) and then peeling as shown in figure below- progression of subsurface fatigue.



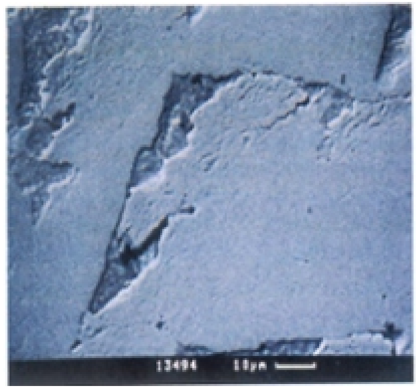
Stage 1 Stage 2 Stage 3 Stage 4

Surface Initiated fatigue

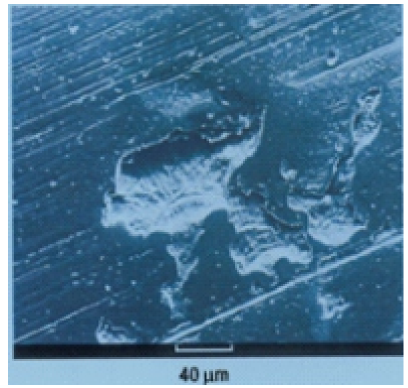
Fatigue initiated from the surface is mainly caused due to surface distress. Surface distress is the damage to the rolling contact surface roughness under the reduced lubrication or wrong lubricant selection.It may also occur when lubrication is contaminated with foreign particles due to poor sealing of bearing which may result into high stress concentration on bearing surfaces. This in turn will give metal to metal contact, together with a certain percentage of sliding motion causing the formation of

- Surface microcracks
- Surface microspalls

Micro-cracks can start in the asperties, followed by micro spalls, finally leading to micro flaking



Micro Cracks



Micro Spalling

Causes	Countermeasures
• Insufficient lubrication • Inadequate lubrication • Contamination • Improper mounting	• Lubricant quantity and filling method should be proper to avoid metal to metal contact • Lubricant properties should satisfy bearing operating conditions ex. EP additive grease can be used in extreme pressure conditions. • Lubricant should be free from any dust or contamination • Follow standard mounting practices.

Localized flaking on the Inner ring of DRAC due to improper lubrication.

Localized flaking on the bearing raceway corresponding to rolling element pitch, due to faulty assembly of the bearing (misalignment or less clearance) in application.

Localized flaking on cup of taper roller bearing caused due to impact loading

Flaking in the load zone on the outer ring of taper roller bearing caused by excessive loading

Axially displaced flaking pattern of uniform width and in opposite direction of Inner & outer raceway due to high axial load in application.

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2. Wear

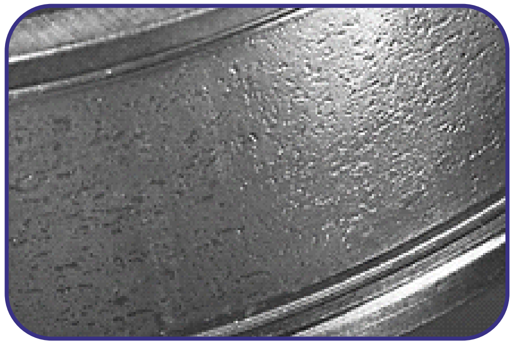
Wear is the progressive removal of the material resulting from interaction of the asperities of two sliding or rolling/sliding contacting surfaces during application. There are two basic mechanism of wear in rolling element bearings:

- Abrasive wear
- Adhesive wear.

2.1 Abrasive wear (particle wear; three body wear)

Abrasive wear is the result of inadequate lubrication or fine foreign particles entry in the bearing.

Sand, fine metal particles from grinding/machining and fine metal/carbides from gears will wear or lap the rolling elements and races. The surfaces become dull to a degree, which varies according to the coarseness and nature of the abrasive particles. These particles increase in numbers as the material is worn away from the running surfaces and the cage. Finally, wear progresses with time which ultimately results in flaking and thus failure of the bearing.

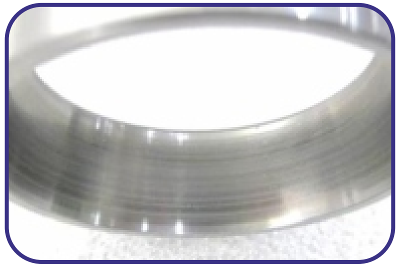


Abrasive wear on the inner ring raceways of a double-row cylindrical roller bearing with central rib

In tapered bearings, the roller head surface and cone flange/rib face will have more wear comparatively to the raceways due to both sliding and rolling contact at flange surface. This wear will result in increased end play or internal clearance which will result in misalignment in the bearing and thus reduces fatigue life. Abrasive wear can also affect other parts of the machine where bearings are used.

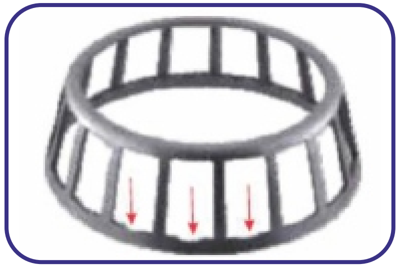
Excessive wear of rollers head either due to excessive preloading or heavy contamination

Causes	Countermeasures
• Sealing ineffective • Contaminated lubricant due to worn out particles from bearing/adjacent components. • Improper cleaning before and during mounting operation.	• Check/ improve the sealing effectiveness. • Always use fresh/clean lubricant. Change oil at specified intervals of mileage covered. • Unpack the bearing at the time of mounting only. Use clean tools and keep the area cleaned where bearing is mounted.



Grooving on cup raceway and rollers outer diameter surface of Taper roller bearing due to fine size hard contaminants

Excessive wear of cage pocket as a result of flaking on single ball



Heavy wear on retainer pockets of taper roller bearing due to over rolling of hard contaminants between rollers head surface and retainer pockets

Wear caused by inadequate lubricant

Causes	Countermeasures
• Lubricant has gradually been used up /lost its .	• Check that the lubricant reaches the bearing/ frequent lubrication.

Inner ring of taper roller bearing plastically deformed and discolored due to lack of lubrication or loss of lubricating properties in high temperature application

2.2 Adhesive wear (smearing, skidding, galling)

Adhesive wear is a transfer of material from one surface to another with frictional heating and sometimes, tempering or re-hardening of the surface. This produces localized stress concentrations with the potential for cracking or flaking of the contact areas.

Smearing (skidding) - Occurrence of surface roughness due to inadequate lubrication between the surfaces which results in sliding/slipping of rolling elements and transfer of material between

Creep- When there is a small clearance between the bearing ring and its seating surface the rolling motion of the ring against its seating with a minute difference in the rotational speeds is termed as Creep.

When creep occurs, the asperities in the ring /seating surface contact region are over rolled, which can cause the surface of the ring to take a shiny appearance.

Mirror like/shiny appearance on bore & OD surface due to creeping caused by micro-motion

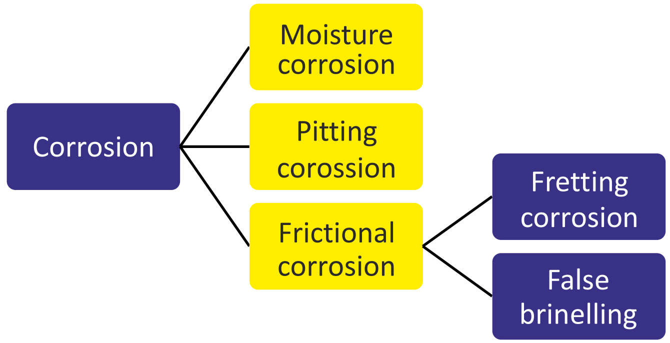
Seizing marks on Inner & outer ring - Rotary motion between rings and shaft/housing with loose fits under circumferential /static load or insufficient axial support of rings can cause cold welding at the fitting surfaces (inner ring bore, outer ring outside diameter) and axial mating surfaces or shiny appearance of contact areas where surface roughness is good. Wear of fitting surface and face perhaps causes reduction in preload or clearance enlargement.

Seizing marks on inner ring bore surface due to loose fits

3. Corrosion

It is the gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment.

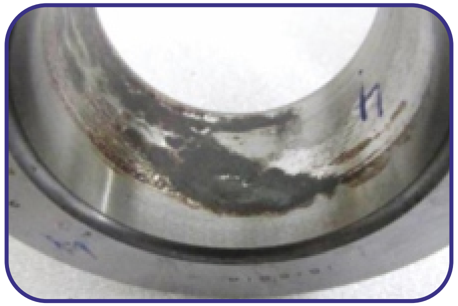
In case bearing is handled or stored improperly which resulted into removal of rust preventive oil film or when water enter through defective or inadequate seals or sometimes from condensation under certain conditions, black oxide commonly called “water etch” will form at respective rolling positions.



3.1 Moisture corrosion (oxidation, rust)

When steel, used for rolling bearing components comes in contact with moisture e.g. water or acid, oxidation of surfaces takes place. Subsequently the formation of corrosion pits occurs & finally leads to flaking of the surface and could initiate cracking. It is most often caused by condensate collecting in the bearing housing due to temperature changes. Rust will form if water or corrosive agents reach the inside of the bearing.

Causes	Countermeasures
• Improper lubricant used • Damaged, worn or inadequate sealing can lead to entry of water, moisture or corrosive substance in the bearing • High temperature & high humidity environment while stationary • Poor packaging or storing conditions • Bearing handling with bare hands	• Study of lubrication suitability as per the application • Improve sealing mechanism • Anti-rust treatment for periods of non-running • Follow best practices for storage and handling • Improve handling methods i.e. usage of gloves



Moisture corrosion on Inner race bore of Taper Roller Bearing

Moisture corrosion on outer ring of Spherical Roller Bearing

Contact corrosion on cone raceway of Taper Roller Bearing at roller pitch distance

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3.2 Pitting Corrosion

Pitting corrosion is a localized form of corrosion by which cavities or "holes" are produced in the material. Pitting is considered to be more dangerous than uniform corrosion damage because it is more difficult to detect, predict and design against. Corrosion products often cover the pits.

- Factors influencing pitting: Cl- content, pH value, temperature, presence of oxidizing agent


Pitting corrosion on balls of deep groove ball bearing

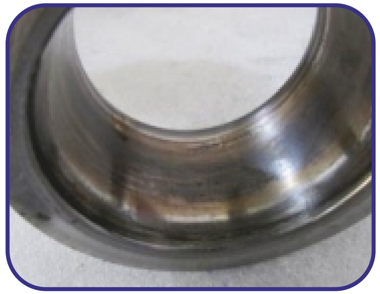
3.3 Frictional Corrosion

Frictional corrosion is a chemical reaction caused by relative micro movements between mating surfaces under certain frictional conditions. These micro-movements lead to oxidation of the surface and the material becomes visible as powdery rust and/or loss of material from one or both mating surfaces.

3.3.1 Fretting Corrosion

Fretting corrosion occurs when there is relative movement between bearing ring and shaft or housing, on account of the fit being too loose. The relative movement may also cause small particles of material to become detach from the surface. These particles oxidize quickly when exposed to the oxygen in the atmosphere; powdery rust develops (iron oxide). The bearing surface becomes shinny or a discolored blackish red.

Causes	Countermeasures
• Vibrations with small amplitude • Insufficient interference • Poor lubrication • Form disturbance of fitting surfaces • Shaft deflection or housing deformation	• Maintain desired preload in the bearing • Improve fits • Use of proper lubricant/ lubricant film at fitting surfaces • Shaft or housing rigidness to bending



Fretting corrosion on cone bore of Taper Roller Bearing due to micro movement between cone and shaft

3.3.2 False Brinelling

When bearing is stationary, lubrication film between the rolling elements and the raceways is very thin; gives metal to metal contact and the vibration produce small relative movements of rolling elements and rings. As a result of these relative movements, small particles break away from the surfaces and thus would lead to the formation of depressions on the raceways with a combination of corrosion & wear depending on the intensity of the vibrations, the lubrication conditions and load.

In the case of stationary bearings, the depression appears at rolling pitch and can often be discolored reddish or shinny. For the case of bearings in running condition (while rotation) false brinelling caused by vibration are visible in the form of closely spaced flutes.

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Causes	Countermeasures
• Oscillation or vibration while bearing is stationary e.g. while transportation • Oscillations with small amplitude • Poor lubrication	• Secure shaft & housing while transportation • Radially preload the bearing or provide a vibration damping base • Use oil or high consistency grease when bearings are used for oscillation motion • Use of proper lubricant

Brinelling mark on cup raceway due to vibrations

False brinelling marks along with roller dents near large face of Taper Roller Bearing due to vibrations

False brinelling and contact corrosion marks on cup raceway of Taper Roller Bearing due to water/moisture entry and vibrations

4. Electric Erosion

Electrical erosion is the removal of material from the contact surfaces caused by the passage of electric current. When electric current passes through a bearing, arcing and burning occur through the thin oil film at points of contact between the races and rolling elements. The material is heated to temperatures ranging from tempering to melting levels. This leads to the appearance of discolored areas, varying in size, where the material has been tempered, re-hardened or melted. Small craters also form where the metal has melted.

Craters formed by current leakage resulting in fluting

Fluting on inner ring raceway with dark colored balls

5. Plastic Deformation

Permanent deformation occurs whenever the yield strength of the material is exceeded. This can occur in two different ways:

- On a macro scale, where the contact load between a rolling element and the raceway causes yielding over a substantial portion of the contact footprint.
- On micro scale, where a foreign object is over-rolled between a rolling element and the raceway and yielding occurs only a small part of contact point.

5.1 True Brinelling

Overloading of a stationary bearing by static load or shock load leads to plastic deformation at the rolling element/raceway contacts. Overloading can occur by excessive preloading or due to incorrect handling during mounting.

Ball bearings are subjected to indentations if the pressure is applied to the wrong race such that it passes through the balls during the mounting or dismounting operations or if it is subjected to abnormal loading in stationary condition.

Causes	Countermeasures
• Excessive load/ mounting pressure • Shock during transport or due to improper mounting/careless handling • Mounting pressure applied to wrong race	• Improvement in mounting and handling practices. • Apply mounting pressure to the ring with interference fit.

True brinelling mark on inner race shoulder of Ball Bearing due to improper mounting/dismounting

5.2 Indentation

5.2.1 Indentation from foreign particles

When foreign particles get trapped and over-rolled between the rolling surfaces, indentations are formed on raceways and rolling elements. The size and shape of the indentation depends on the nature of the particles. It can be caused by –

i. Soft particles e.g. fibers or wood

ii. Hardened steel particles e.g. from gears or bearing itself.

iii. Hard mineral particles e.g. grinding wheels

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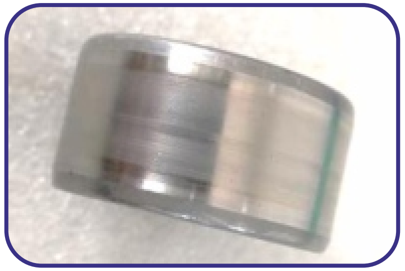
Causes	Countermeasures
• Ingress of solid foreign particles into the bearing • Trapping of flaked particles	• Lubrication oil change at defined service interval • Improve sealing • Cleanliness to be maintained while bearing mounting operation • Check for the involved & other bearings/components for flaking/damage

Wear and indentation on cup raceway soft foreign particle contamination



Wear and indentation on inner ring raceway of Cylindrical Roller Bearing due to soft foreign particle contamination

Wear and indentation on inner ring raceway of Double Row Spherical Roller Bearing due to soft foreign particle contamination

6. Fracture

Crack initiates and propagates when the ultimate tensile strength of the material is locally exceeded. Fracture is the result of a crack propagating to the point of complete separation of the component.

6.1 Forced fracture

Forced fracture is due to stress concentration in excess of the material tensile strength and is caused by local over-stressing, e.g. from impact, or by over-stressing due to an excessive interference fit.

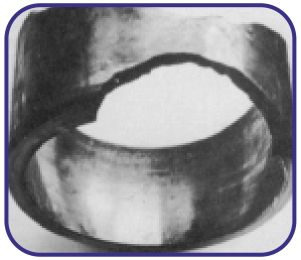
Forced fracture of Outer ring caused by a direct impact blow

Forced fracture due to excessive interference fit

6.2 Fatigue fracture

Frequent exceeding of the fatigue strength limit under bending, tension or torsion conditions results in fatigue cracking. A crack is initiated at a stress raiser and propagates in steps over a part of the component cross section, ultimately resulting in a forced fracture.

Fatigue fracture is sometimes caused by insufficient support of the bearing ring in the housing or on the shaft

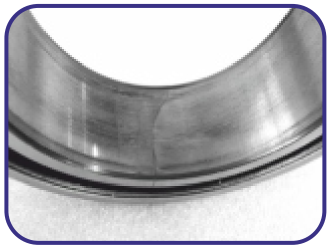


Fatigue fracture of Outer ring caused by insufficient support in the housing

Fatigue fracture of an outer ring from snap ring groove in Double Row Angular Contact Ball Bearing caused by axial loading

6.3 Thermal cracking (heat cracking)

Thermal cracking is caused by high frictional heating due to sliding motion. Crack usually propagates at right angle to the direction of sliding. Hardened steel components are sensitive to thermal cracking due to re-hardening of the surfaces in combination with the development of high residual tensile stress.



Thermal cracking on cone bore of taper roller bearing

Technical Data Rolling Bearing

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