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Rolling bearings — Damage and failures — Terms, characteristics and causes

Roulements — Détérioration et défaillance — Termes, caractéristiques et causes

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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ISO 15243 was prepared by Technical Committee ISO/TC 4, *Rolling bearings*.

Introduction

In practice, damage or failure of a bearing can often be the result of several mechanisms operating simultaneously. The failure can result from improper assembly or maintenance or from faulty manufacture of the bearing or its adjacent parts. In some instances, failure is due to a design compromise made in the interests of economy or from unforeseen operating conditions. It is the complex combination of design, manufacture, assembly, operation and maintenance that often causes difficulty in establishing the primary cause of failure.

In the event of extensive damage to or catastrophic failure of the bearing, the evidence is likely to be lost and it will then be impossible to identify the primary cause of failure. In all cases, knowledge of the actual operating conditions of the assembly and the maintenance history is of the utmost importance.

The classification of bearing failure established in this International Standard is based primarily upon the features visible on rolling element contact surfaces and other functional surfaces. Consideration of each feature is required for reliable determination of the cause of bearing failure. Since more than one process may cause similar effects to these surfaces, a description of appearance alone is occasionally inadequate for determining the reason for the failure. In such cases, the operating conditions must be considered.

Rolling bearings — Damage and failures — Terms, characteristics and causes

1 Scope

This International Standard defines, describes and classifies the characteristics, changes in appearance and possible causes of failure of rolling bearings occurring in service. It will assist in the understanding of the various forms of change in appearance and the failure that has occurred.

For the purposes of this International Standard the term “failure of rolling bearings” means the result of a defect or damage that prevents the bearing meeting the intended design performance.

Consideration is restricted to characteristic forms of change in appearance and failure, which have a well-defined appearance and which can be attributed to particular causes with a high degree of certainty. The features of particular interest for explaining changes and failures are described. The various forms are illustrated with photographs and diagrams, and the most frequent causes are indicated.

The failure mode designations shown in the subclause titles are recommended for general use, but similar expressions or synonyms are given within parentheses below the titles.

Examples of rolling bearing failures are given in Annex A, together with a description of the causes of failure and proposed corrective actions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5593:1997, *Rolling bearings — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5593 and the following apply.

3.1
characteristics
visual appearance resulting from service performance

NOTE Surface defects and types of geometrical change that occur during wear (appearance of wear) are partly defined in ISO 6601 and ISO 8785.

4 Classification of failure modes occurring in rolling bearings

Rolling bearing failures are classified strictly according to their primary causes. However, it is not always easy to distinguish between causes and characteristics (symptoms) or, in other words, between failure mechanisms and failure modes. The large number of articles and books written on the subject confirms this (see Bibliography).

The evolution of tribological research during recent decades has led to a remarkable increase of new knowledge describing failure mechanisms and failure modes. In this International Standard, failure modes are classified in six main groups and various sub-groups (see Figure 1).

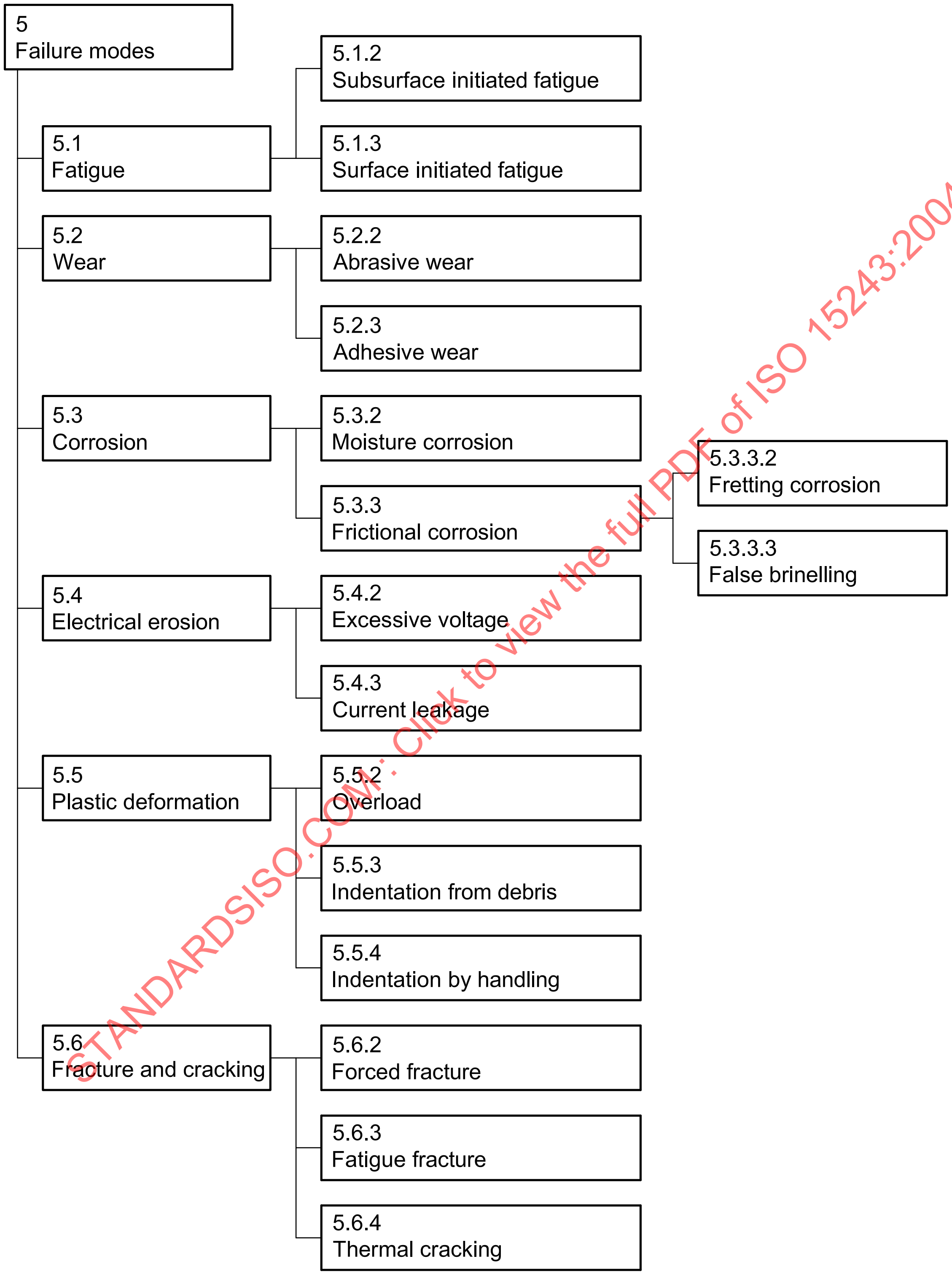


Figure 1 — Classification of failure modes

5 Failure modes

5.1 Fatigue

5.1.1 General definition

The change in the structure, which is caused by the repeated stresses developed in the contacts between the rolling elements and the raceways, is described as fatigue. Fatigue is manifested visibly as a flaking of particles from the surface.

5.1.2 Subsurface initiated fatigue

Under the influence of loads in rolling contacts, described by the Hertzian Theory, structural changes will occur and microcracks will be initiated at a certain depth under the surface, i.e. subsurface. The initiation of the microcracks is often caused by inclusions in the bearing steel (see Figure 2). The microcracks, which are observed at the edge of the white etched areas (butterflies), will normally propagate to the rolling contact surface producing flaking, spalling (pitting) and then peeling (see Figure 3).

NOTE The bearing life calculation in accordance with ISO 281 and ISO 281/Amd. 2 is based on subsurface initiated fatigue.

5.1.3 Surface initiated fatigue

Fatigue initiated from the surface is, among other things, caused by surface distress.

Surface distress is the damage to the rolling contact metal surface asperities under a reduced lubrication regime and a certain percentage of sliding motion, causing the formation of

- asperity microcracks, see Figure 4;
- asperity microspalls, see Figure 5;
- microspalled areas (grey stained), see Figure 6.

Indentations in the raceways caused either by contaminant particles or by handling can also lead to surface initiated fatigue (see 5.5.3 and 5.5.4). Surface initiated fatigue caused by indentation arising from plastic deformation is shown in A.2.6.1 and A.2.6.3.

NOTE ISO 281/Amd. 2 includes surface related calculation parameters that are known to have an influence on the bearing life, such as material, lubrication, environment, contaminant particles and bearing load.

Figure 2 — Subsurface microcrack with the "butterfly phenomenon" (white etched area) (Scale 500:1)

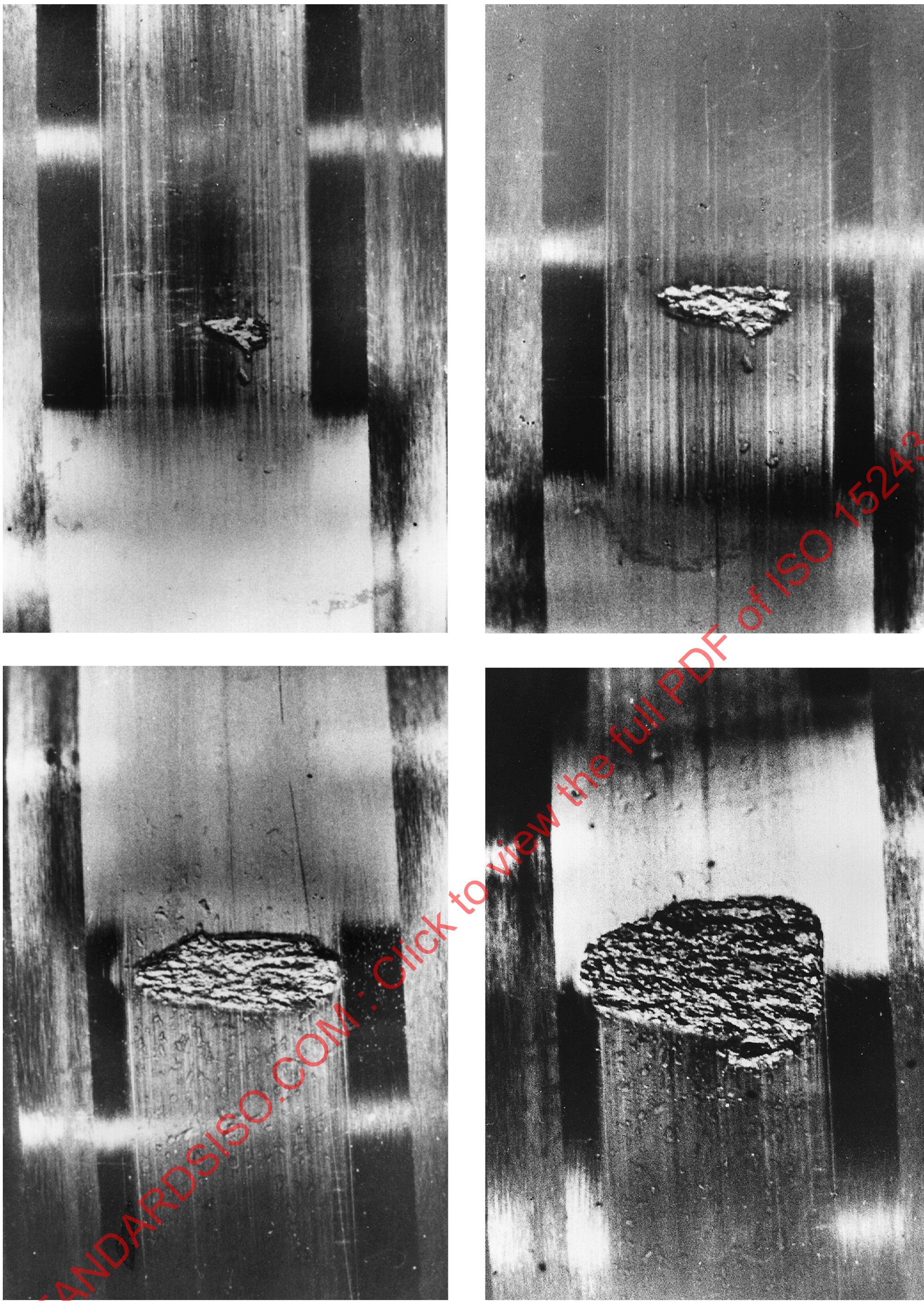


Figure 3 — Progression of subsurface fatigue

5.2 Wear

5.2.1 General definition

Wear is the progressive removal of material resulting from the interaction of the asperities of two sliding or rolling/sliding contacting surfaces during service.

5.2.2 Abrasive wear

(particle wear; three body wear)

Abrasive wear is the result of inadequate lubrication or the ingress of foreign particles. The surfaces become dull to a degree, which varies according to the coarseness and nature of the abrasive particles (see Figure 7). These particles gradually increase in number as material is worn away from the running surfaces and cage. Finally, the wear becomes an accelerating process that results in a failed bearing.

NOTE The "running-in" of a rolling bearing is a natural short process after which the running behaviour, e.g. noise or operating temperature, stabilizes or even improves.

5.2.3 Adhesive wear

(smearing; skidding; galling)

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

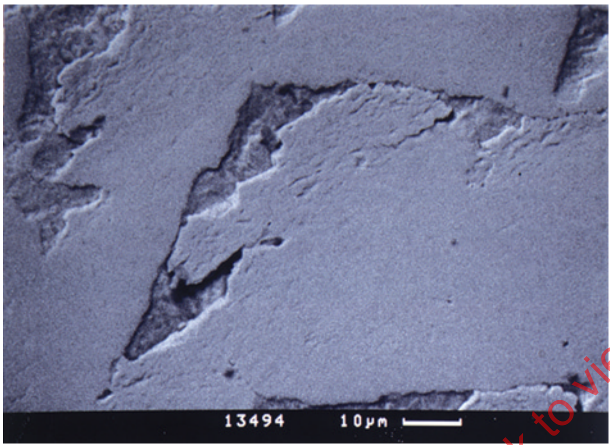


Figure 4 — Microcracks forming a "fish-scale" appearance

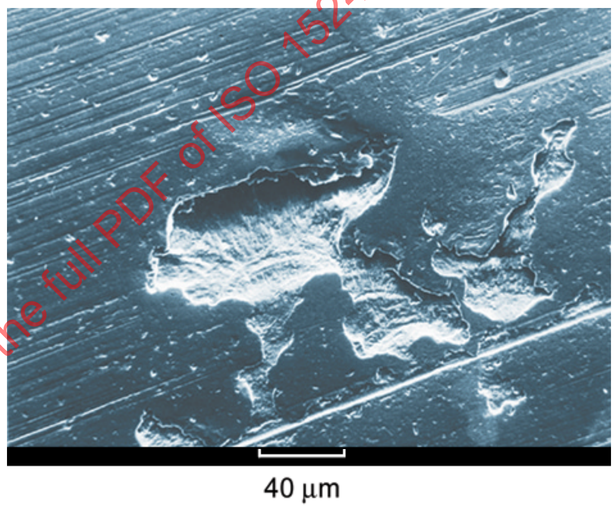


Figure 5 — Microspalls

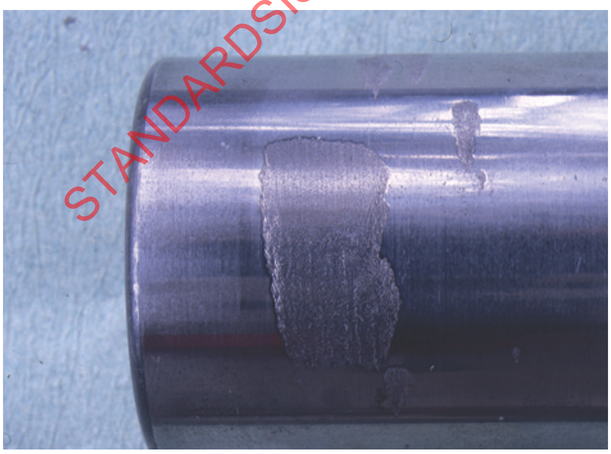


Figure 6 — Heavy grey stained areas
(Scale 1,25:1)

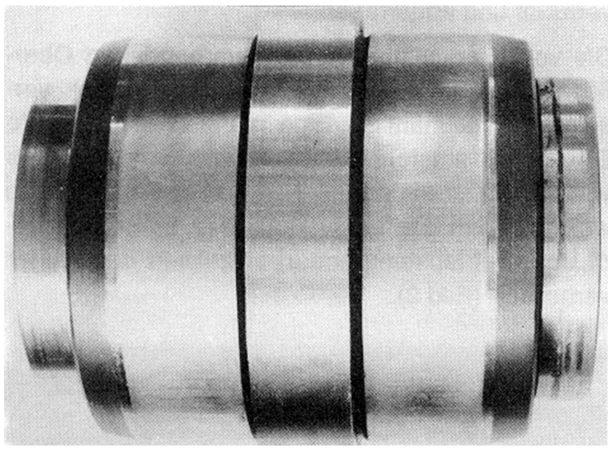


Figure 7 — Abrasive wear on the inner ring raceways of a double-row cylindrical roller bearing with central rib

Smearing (skidding) can occur between rolling elements and raceways due to the fact that the rolling elements are lightly loaded and subjected to severe acceleration on their re-entry into the load zone (see Figure 8). Smearing can also occur between rolling elements and raceways when the load is too light in relation to the speed of rotation.

Smearing can occur on the guiding flange faces and on the ends of the rollers due to insufficient lubrication (see Figure 9). In full complement bearings (cageless), smearing can also occur in the contacts between rolling elements depending on lubrication and rotation conditions.

If a bearing ring “rotates” relative to its seating, i.e. mounting shaft or housing, then smearing can occur in the contact between the ring end face and its axial abutment, which can also cause cracking of the ring as shown in Figure 10. This type of damage generally occurs when the radial load on the bearing rotates relative to the bearing ring and the bearing ring is mounted with a very small clearance (loose fit) to its seating. Because of the minute difference in the diameters of the two components, they will have a minute difference in their circumferences and, consequently, when brought into contact at one point by the radial load, will rotate at minutely different speeds. This rolling motion of the ring against its seating with a minute difference in the rotational speeds is termed “creep”.

When creep occurs, the asperities in the ring/seating contact region are over-rolled, which can cause the surface of the ring to take on a shiny appearance (see A.2.4.7). The over-rolling during creeping is often, but not necessarily, accompanied by sliding in the ring/seating contact, and then other damage will also be visible, e.g. scratches, fretting corrosion and wear. Under certain loading conditions and when the ring/seating interference fit is insufficiently tight, then fretting corrosion will predominate (see A.2.4.5).

Figure 8 — Smearing on raceway surfaces

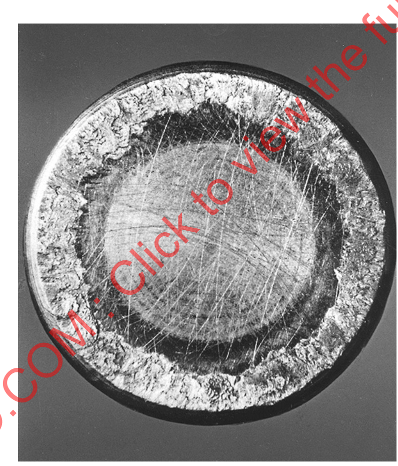


Figure 9 — Smearing of roller end

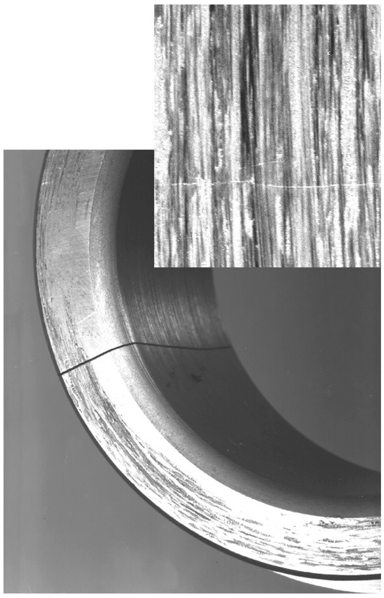


Figure 10 — Smearing on ring end face (ring is also fractured)

5.3 Corrosion

5.3.1 General definition

Corrosion is a chemical reaction on metal surfaces.

5.3.2 Moisture corrosion

(oxidation; rust)

When steel, used for rolling bearing components, is in contact with moisture, e.g. water or acid, oxidation of surfaces takes place. Subsequently the formation of corrosion pits occurs and finally flaking of the surface (see Figure 11).

A specific form of moisture corrosion can be observed in the contact areas between rolling elements and bearing rings where the water content in the lubricant or the degraded lubricant reacts with the surfaces of the adjacent bearing elements. The advanced stage will result in dark discolouration of the contact areas at intervals corresponding to the ball/roller pitch, eventually producing corrosion pits (see Figures 12 and 13).

5.3.3 Frictional corrosion

(tribocorrosion; tribo-oxidation)

5.3.3.1 General definition

Frictional corrosion is a chemical reaction activated by relative micromovements between mating surfaces under certain friction conditions. These micromovements lead to oxidation of the surfaces and material, becoming visible as powdery rust and/or loss of material from one or both mating surfaces.

Figure 11 — Corrosion on a roller bearing outer ring

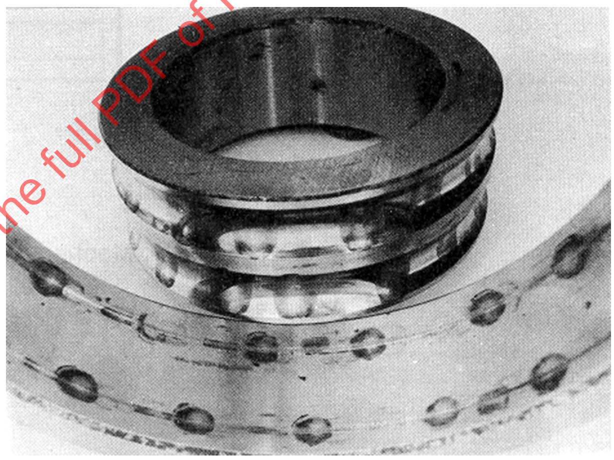


Figure 12 — Contact corrosion on a ball bearing inner ring and outer ring raceways

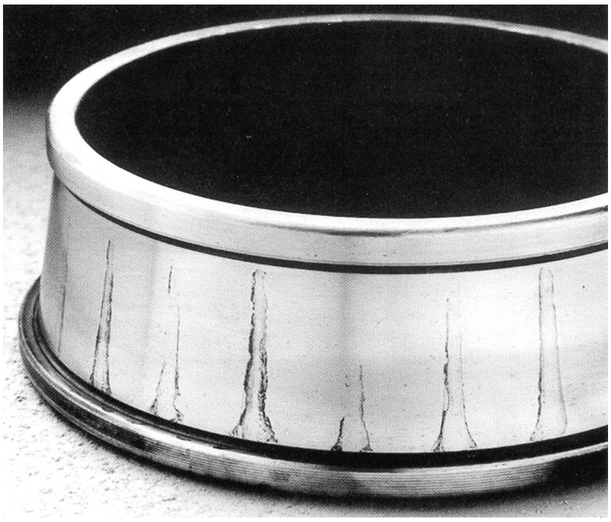


Figure 13 — Contact corrosion on a bearing raceway

5.3.3.2 Fretting corrosion
(fretting rust)

Fretting corrosion occurs in fit interfaces that are transmitting loads under oscillating contact surface micromovements. Surface asperities oxidize and are rubbed off and vice versa; powdery rust develops (iron oxide). The bearing surface becomes shiny or a discoloured blackish red (see Figure 14). Typically, the failure develops in incorrect fits, either too light an interference fit or too high a surface roughness, in combination with loads and/or vibrations.

5.3.3.3 False brinelling
(vibration corrosion)

False brinelling occurs in rolling element/raceway contact areas due to micromovements and/or resilience of the elastic contacts under cyclic vibrations. Depending on the intensity of the vibrations, the lubrication conditions and load, a combination of corrosion and wear occurs, forming shallow depressions in the raceways.

In the case of a stationary bearing, the depressions appear at rolling element pitch and can often be discoloured reddish or shiny (see Figure 15).

False brinelling caused by vibrations occurring during rotation shows itself in closely spaced flutes (see Figure 16). These should not be mistakenr for electrically caused flutes (see 5.4.3 and Figure 19). The fluting resulting from vibration has bright or fretted bottoms to the depressions compared to fluting produced by the passage of electric current, where the bottoms of the depressions are dark in colour. The damage caused by electric current is also distinguishable by the fact that the rolling elements are also marked.

NOTE In this International Standard false brinelling is classified under corrosion. In other documents it is sometimes classified as wear.

5.4 Electrical erosion

5.4.1 General definition

Electrical erosion is the removal of material from the contact surfaces caused by the passage of electric current.

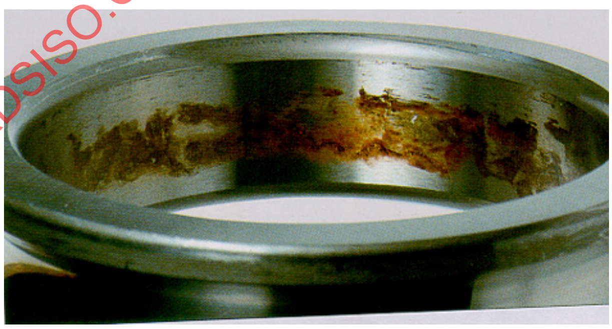


Figure 14 — Fretting corrosion in inner ring bore

Figure 15 — False brinelling on inner ring raceway of cylindrical roller bearing

Figure 16 — False brinelling — Fluting on outer ring of tapered roller bearing

5.4.2 Excessive voltage
(electrical pitting)

When an electric current passes from one bearing ring to the other through the rolling elements and their lubricant films, sparking will occur in the contact areas because of insufficient or defective insulation. In the contact areas between rings and rolling elements, the flow lines of the current are condensed, resulting in localized heating within very short time intervals, so that the contact areas melt and weld together.

This damage may appear as a series of small craters with diameters of up to 100 µm (see Figure 17). The craters are duplicated on the rolling element and raceway contact surfaces in bead-like procession in the rolling direction (see Figure 18).

5.4.3 Current leakage
(electrical fluting)

Initially the surface damage takes the shape of shallow craters, which are closely positioned to one another and small in size. This happens even if the intensity of the current is comparatively low. Flutes will develop from the craters in time, as shown in Figure 19. They can be found on roller and ring raceway contact surfaces, but not on balls, which have dark colouration only (see Figure 20). The flutes are equally spaced. The raceways are dark in the bottoms of the depressions (see Figures 20 and 21). Eroded patches, next to the flutes on Figure 21, indicated by the pencil point, were caused by contact of the cage ribs with the inner ring.

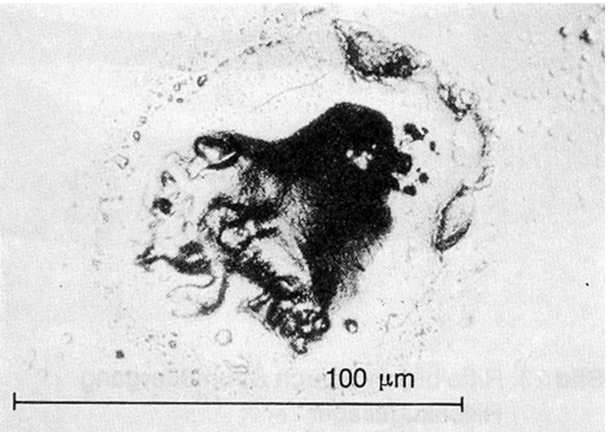


Figure 17 — Craters formed by the passage of electric current

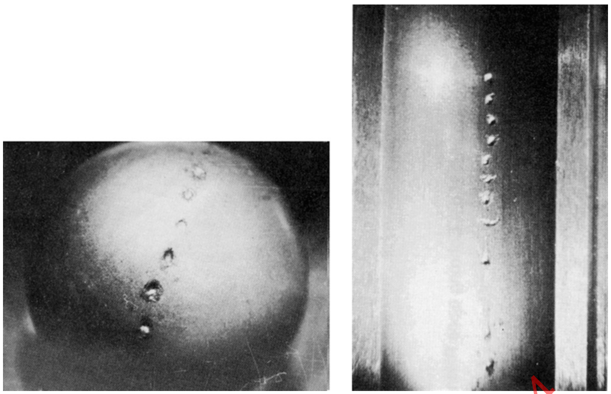


Figure 18 — Craters in bead-like procession on ball and raceway

Figure 19 — Craters formed by current leakage resulting in fluting

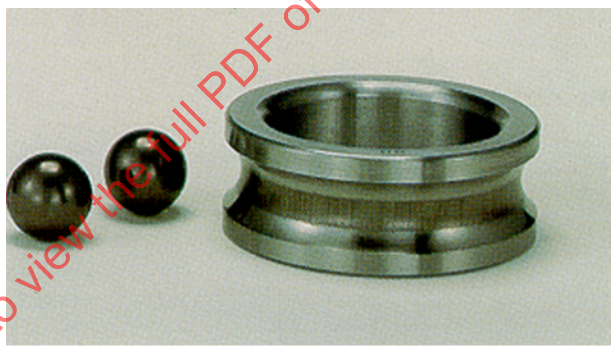
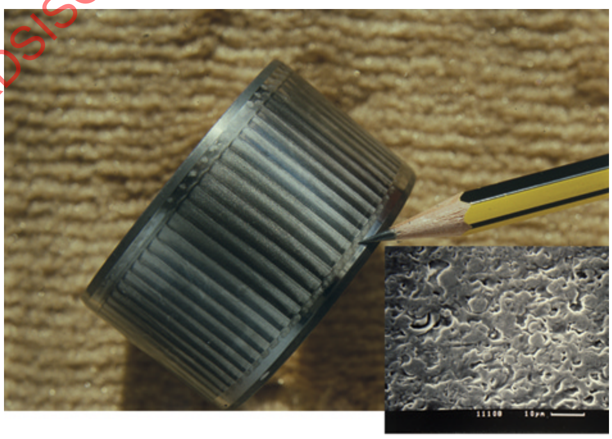


Figure 20 — Fluting on inner ring raceway — Dark coloured balls



10 µm

Figure 21 — Fluting on a needle roller bearing inner ring
(Enlarged surface detail is seen behind the bearing ring and an enlarged view using scanning electron microscopy is in the lower right corner.)