INTERNATIONAL STANDARD

ISO 7146-1

Second edition
2019-05

Plain bearings — Appearance and characterization of damage to metallic hydrodynamic bearings —

Part 1: General

Paliers lisses — Aspect et caractérisation de l'endommagement des paliers métalliques à couche lubrifiante fluide —

Partie 1: Généralités

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 123 *Plain bearings*, Subcommittee SC 2, *Materials and lubricants, their properties, characteristics, test methods and testing conditions.*

This second edition cancels and replaces the first edition (ISO 7146-1:2008), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

— Adjustment to the ISO Directives, including the replacement of "may" with "can" throughout.

A list of all parts in the ISO 7146 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In practice, damage to a bearing can often be the result of several mechanisms operating simultaneously. The complex combination of design, manufacture, assembly, operation, maintenance and possible reconditioning often causes difficulty in establishing the primary cause of damage.

In the event of extensive damage or destruction of the bearing, the evidence is likely to be lost, in which case it is impossible to identify how the damage came about.

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 damage established in this document is based primarily upon the features visible on the running surfaces and elsewhere, and consideration of each aspect is needed for reliable determination of the cause of bearing damage.

Since more than one process can cause similar effects on the running surface, a description of appearance alone is occasionally inadequate in determining the cause of damage. Thus Clause 4 is subdivided into several subclauses including damage appearance and damage characteristics.

For the procedure of damage analysis, Clause 5 can be a helpful guide.

In Clauses 6 and 7, examples of all damage characteristics with typically associated damage appearance are given.

Plain bearings — Appearance and characterization of damage to metallic hydrodynamic bearings —

Part 1:
General

1 Scope

This document defines, describes and classifies the characteristics of damage occurring in service to hydrodynamically lubricated metallic plain bearings and journals. It assists in the understanding of the various characteristic forms of damage which can occur.

Consideration is restricted to damage characteristics which have a well-defined appearance and which can be attributed to particular damage causes with a high degree of certainty. Various appearances are illustrated with photographs and diagrams.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 4378-1, *Plain bearings — Terms, definitions, classification and symbols — Part 1: Design, bearing materials and their properties*

ISO 4378-2, *Plain bearings — Terms, definitions, classification and symbols — Part 2: Friction and wear*

ISO 4378-3, *Plain bearings — Terms, definitions, classification and symbols — Part 3: Lubrication*

ISO 4378-4, *Plain bearings — Terms, definitions, classification and symbols — Part 4: Basic symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4378-1, ISO 4378-2, ISO 4378-3, ISO 4378-4 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
damage to plain bearings
bearing damage
change in appearance occurring on the bearing surface and/or on the bearing back during operation that adversely affect the performance of the bearing

4 Descriptions, causes and features of damage

4.1 Damage

4.1.1 General

Damage to plain bearings is a phenomenon that adversely changes their tribological function and is usually accompanied with a change in appearance. The damage is initiated by the damage cause and develops to the end of service life.

As long as no abnormal conditions occur, service life of the plain bearing relates to the service life of the machine.

4.1.2 Indicators of damage

Typical indicators observed during machine operation are: continuously increasing service temperature, decline of lubricant pressure, noise, vibration and bad smell.

4.2 Damage causes

The cause is the practical event that initiates and leads to damage. The majority of damage causes are found outside the bearing.

4.3 Damage appearances

Damage appearance is a defined visible picture of the bearing surface and/or of the bearing back. Damage appearances are clearly different from each other.

A plain bearing failure can show various damage appearances. Usually, damage appearances are directly associated with damage characteristics, but not directly with the damage cause (for exceptions, see 6.8 and 6.9).

Damage appearances include:

a) depositions;

b) creep deformation;

c) deformation due to temperature cycles;

d) thermal cracks;

e) fatigue cracks;

f) material relief (loss of bond);

g) frictional corrosion;

h) melting out, seizure;

i) polishing, scoring;

j) traces of mixed lubrication, worn material;

k) discolouration (blue, black colour);

l) corrosion, fluid erosion;

m) embedded particles, particle-migration tracks, formation of wire wool;

n) electric arc craters;

o) cavitation erosion appearance: worn-out material.

4.4 Damage characterization

4.4.1 General

A damage characterization is a description of what has happened based on a detected typical combination of damage appearances. Defined characteristics provide the basis for establishing the cause of damage.

Damage characterizations are clearly different from each other, as specified in 4.4.2 to 4.4.11.

4.4.2 Static overload

Material is loaded above compressive yield strength corresponding to actual operation temperature.

4.4.3 Dynamic overload

Material is loaded above fatigue strength corresponding to actual operation temperature. Intensive dynamic load also favours damage by weakening the fit.

4.4.4 Wear by friction

Wear by friction is confined to changes in microgeometry and to the loss of material as a result of interaction between journal and bearing. Movement between backing and housing also favours wear by friction.

4.4.5 Overheating

The heat balance in the lubricant, the bearing, the environment and the cooling system as required at design stage is not realized resulting in a higher temperature than anticipated. The viscosity and, therefore, the load capacity decrease with increasing temperature. This results again in temperature increase. The bearing, therefore, cannot operate stably if cooling cannot stop further temperature increase.

4.4.6 Insufficient lubrication (starvation)

This affects the tribological system.

4.4.7 Contamination

Contamination of lubricant with foreign particles or reaction products can result in damage to a bearing. Foreign particles embedded between bearing backing and housing also favour damage.

4.4.8 Cavitation erosion

Decreased pressure in liquids leads to evaporation of liquids and formation of vapour bubbles, which, when liquid pressure increases, implode, generating locally very high pressure, and cause erosion on sliding surfaces.

4.4.9 Electroerosion

A potential difference between journal and bearing can lead to an electric arc with locally high current flow which damages journal and bearing surface.

4.4.10 Hydrogen diffusion

Hydrogen can be incorporated in the steel backing or in an electroplated layer of the bearing. If hydrogen diffusion is blocked by a layer, blisters occur.

4.4.11 Bond failure

Bond failure is delamination between lining and backing or between layers. A metallographic examination is required to distinguish it from other damage characterizations.

4.5 Relationship between damage appearance and damage characterizations

Damage characterization and damage appearance alter with the progress of damage from a primary to a secondary characteristic (see Figure 1).

Different damage characterizations can correspond to the same damage appearance.

One damage characterization can correspond to various damage appearances.

Multiple damage characteristics can be found in one failure event.

The damage characteristics provide the basis for analysing the cause (see Figure 2).

Typical relationships are shown in Table 1 for damage to sliding surface and to bearing back. In most cases, Table 1 is the guideline for diagnosis of the final damage cause from the damage appearances via the damage characteristics.

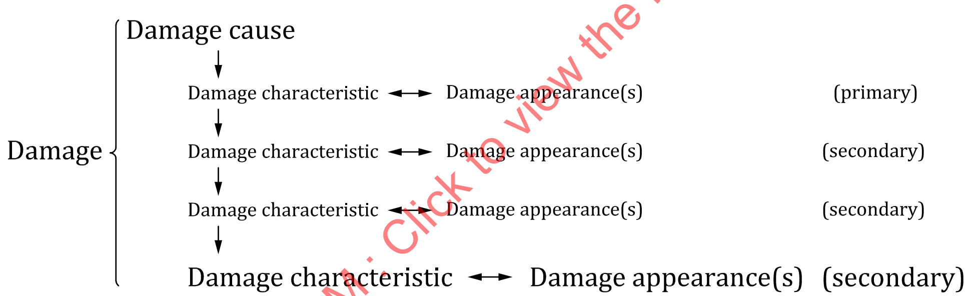
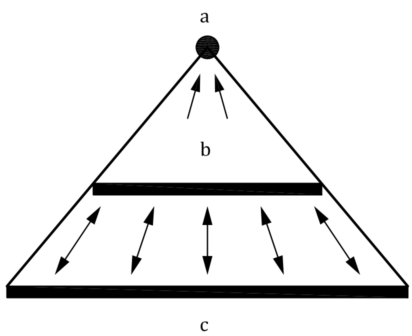


Figure 1 — Damage appearances altering with the progress from primary to secondary characteristics



Key

a Damage cause.

b Damage characteristics.

c Damage appearances.

Figure 2 — Damage characteristics provide the basis for analysing the cause

5 Guidelines for damage analysis

Table 1 — Interaction of damage appearances and damage characterizations

Damage appearance																Damage characterizations	Subclause
Depositions	Creep deformation	Deformations due to temperature cycles	Thermal cracks	Fatigue cracks	Material relief (loss of bond)	Frictional corrosion	Melting out, seizure	Polishing, scoring	Trace of mixed lubrication, worn material	Blue, black colour	Corrosion	Fluid erosion	Embedded particles, particle-migration tracks, formation of wire wool	Electric arc craters	Cavitation erosion appearance: material worn out		
×	×		×						×							Static overload	6.2
				×	×											Dynamic overload[a]	6.3
				×		×										Dynamic overload[b]	7.2
								×	×							Wear by friction[a]	6.4
								×								Wear by friction[b]	7.3
×	×	×	×						×							Overheating	6.5
							×		×	×						Insufficient lubrication (starvation)	6.6
×								×	×		×	×	×			Contamination (particles, chemicals)[a]	6.7
×								×	×		×		×			Contamination (particles, chemicals)[b]	7.4
															×	Cavitation erosion	6.8 and ISO 7146-2
														×		Electro-erosion	6.9
					×											Hydrogen diffusion	6.10
					×											Bond failure	6.11

[a] Damage to the sliding surface.

[b] Damage to the bearing back.

5.1 General

Analysis should be undertaken only by experts experienced in bearing metallurgy, bearing technology and bearing damage. Damage analyses based on photos alone are mostly unsuccessful.

The following steps are a guideline for damage analysis.

5.2 Step 1

Establish service life. There is significant difference between damage after a short service life and damage after a long service life. With both cases, similar damage appearances occur, but the cause is usually different.

Typical causes of damage after short service life: faults in geometry or assembling, dirt, effect from a previous damage, modified service conditions since last start up.

Typical cause of damage after long service life: modified service conditions.

Typical cause of damage after very long service life: reduced dynamic material capability due to fatigue.

5.3 Step 2

Strict differentiation between damage characterization and damage appearance is important. For a thorough analysis, all visible damage appearances shall be evaluated and combined in one or more damage characterizations, based on Table 1.

5.4 Step 3

Take into consideration the total system: bearing — shaft — lubricant — housing.

It is helpful to make a chemical analysis of a sample from the bearing layer and to check its microstructure. If necessary, lubricant and filter content should be analysed.

5.5 Step 4

All information in connection with the period before the detected damage and the period during the damage should be brought together.

5.6 Step 5

Reviewing the initial list of damage characteristics together with the information from steps 3 and 4 usually leads to a reduction of the number of damage characteristics under consideration. This leads to the possible damage cause.

See Annex A for an example of use of Table 1.

6 Damage to the bearing surface — Damage characteristics, typical damage appearances and possible damage causes

6.1 General

A discussion of damage to the bearing surface follows. For each damage characterization given in 4.4, typical damage appearances, possible damage causes and typical examples are given.

6.2 Static overload

6.2.1 Typical damage appearances

— Creep deformation: shallow depressions of bearing material in the region of maximum load and temperature, beginning smooth and ending in crack-free semicircular bulges in the direction of rotation, sometimes like crests of waves (see Figure 3).

— Traces of mixed lubrication (see Figure 4), depositions, thermal cracks.

6.2.2 Possible damage causes

Loading of the bearing was higher than that allowed for in the design and/or the bearing temperature was higher than estimated for an extended period.

6.2.3 Typical examples

See Figures 3 and 4.

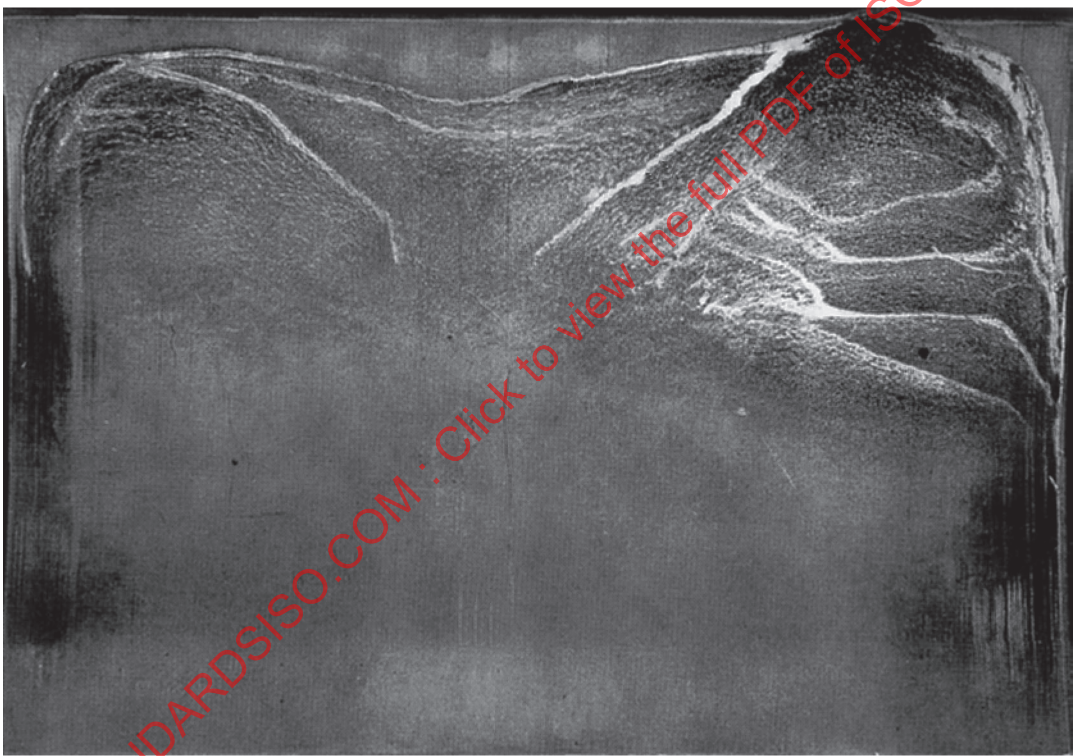


Figure 3 — Creep deformation, shown by crack-free semicircular bulges in the direction of rotation (material: steel/tin-based white metal)

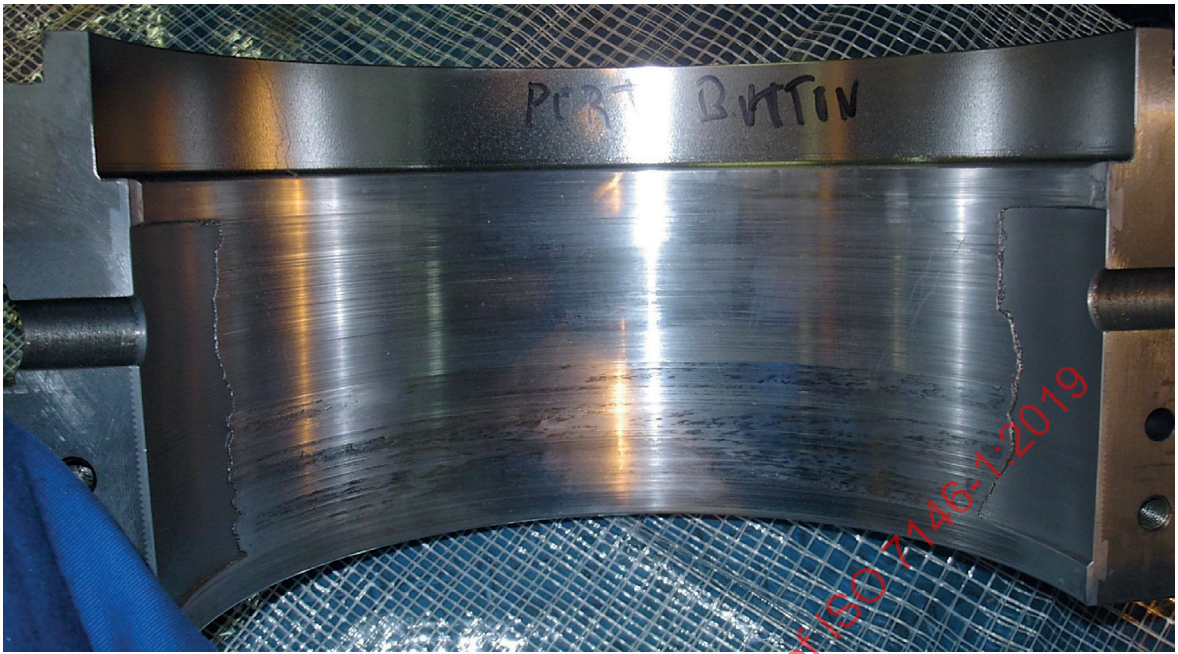


Figure 4 — Propeller shaft bearing, showing the effects of too slow a speed in relation to load capacity (material: steel/tin-based white metal)

6.3 Dynamic overload

6.3.1 Typical damage appearances

Fatigue cracks are cracks which extend from the sliding surface in the loaded zone propagating as a network. The cracks change direction above the bonding area.

Lining material from the backing is the final result of the development of fatigue cracks (see Figure 5).

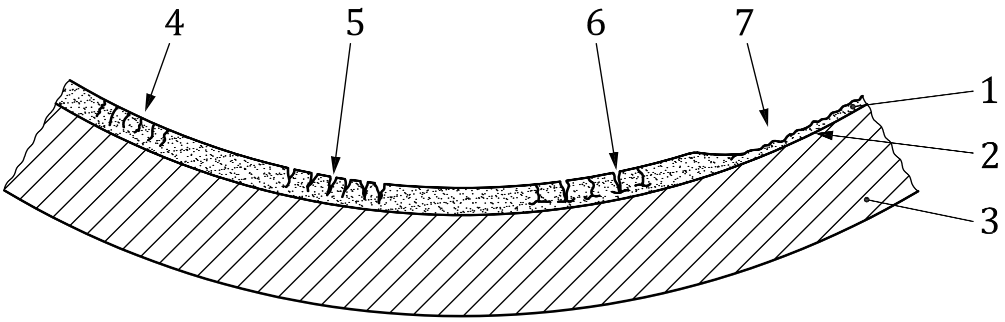
See also possible damage appearances such as frictional corrosion on the bearing back (Clause 7).

6.3.2 Possible damage causes

The cracks start when the fatigue limit of the bearing material is exceeded due to high dynamic load at the operating temperature. The damage is not based on bond faults.

6.3.3 Typical examples

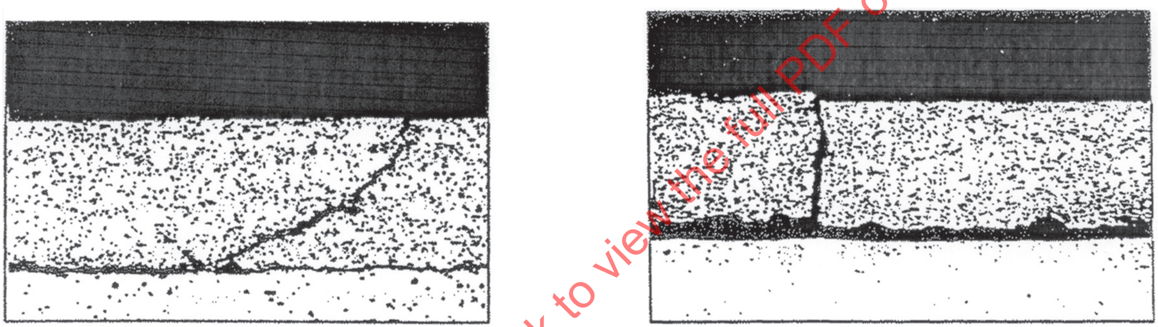
See Figures 5 to 12.



Key

1 lining material
2 bonding area
3 backing material
4 cracks
5 eroded cracks
6 cracks with perpendicular propagation
7 material relief

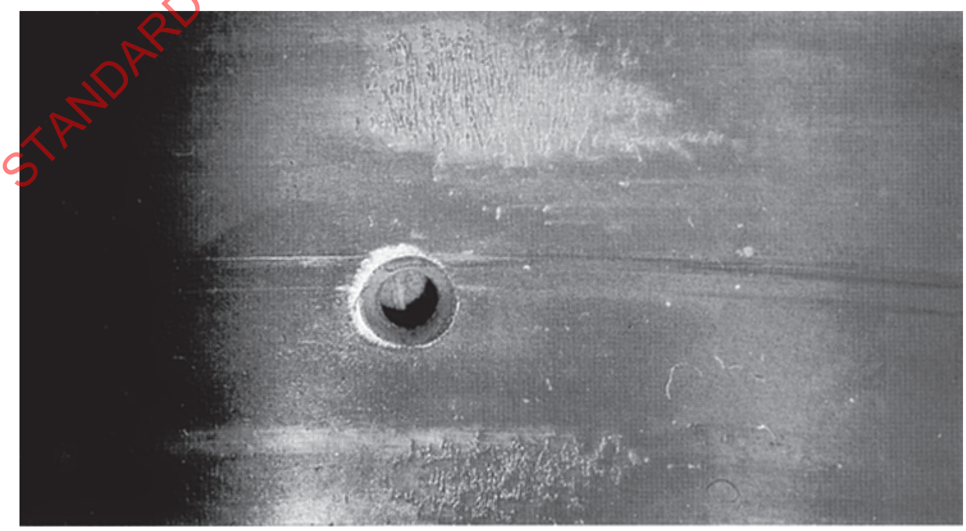
Figure 5 — Schematic diagram of progress of fatigue cracks



a) Under inertial load **b) Under gas load**

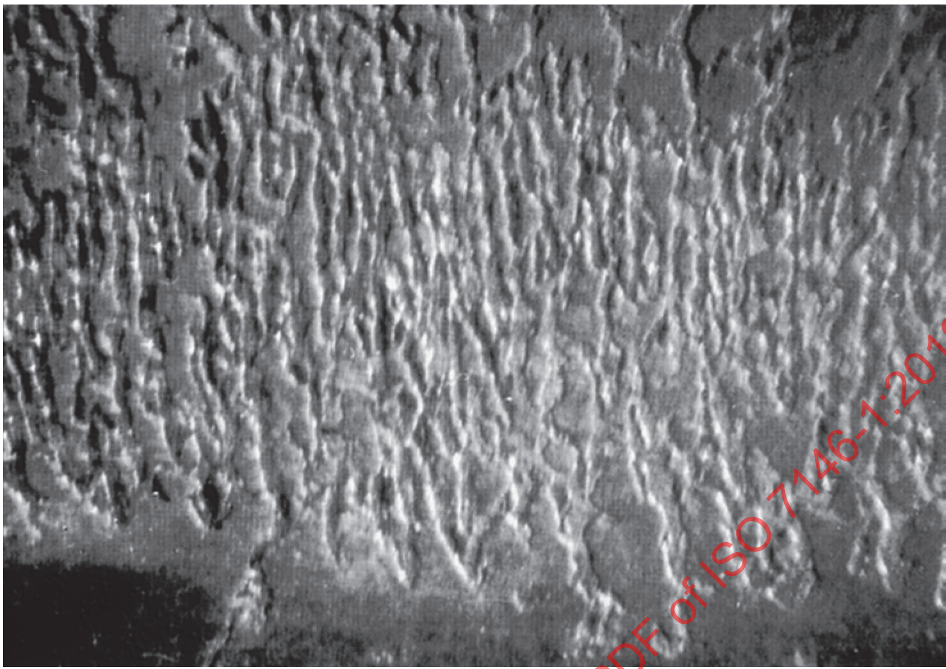
Figure 6 — Typical fatigue cracks of internal combustion engine bearing (material: steel/aluminium alloy)

Direction of shaft rotation →



a)

Direction of shaft rotation →



b) Section from Figure 7 a) showing the lower half at increased magnification

Figure 7 — Cracks in the electroplated overlay (material: steel/lead bronze/electroplated overlay)

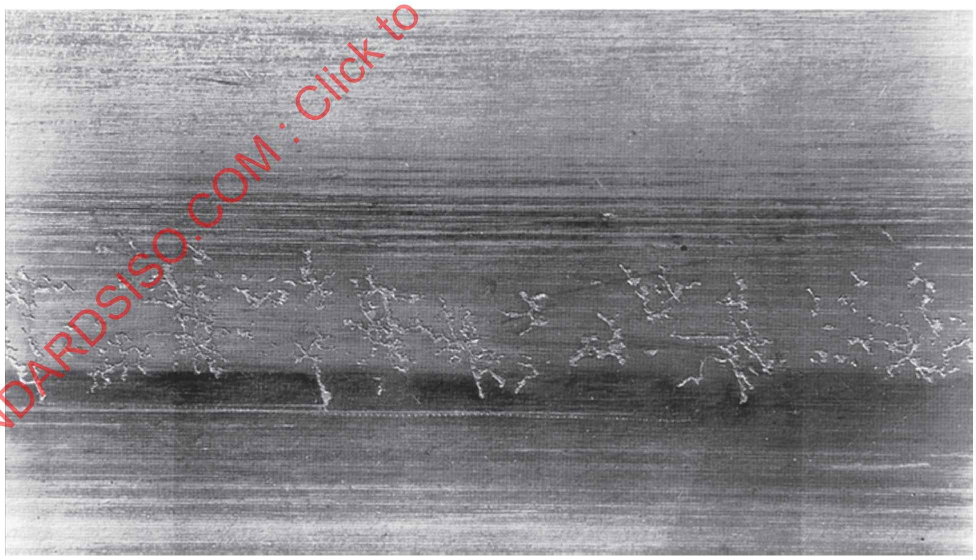
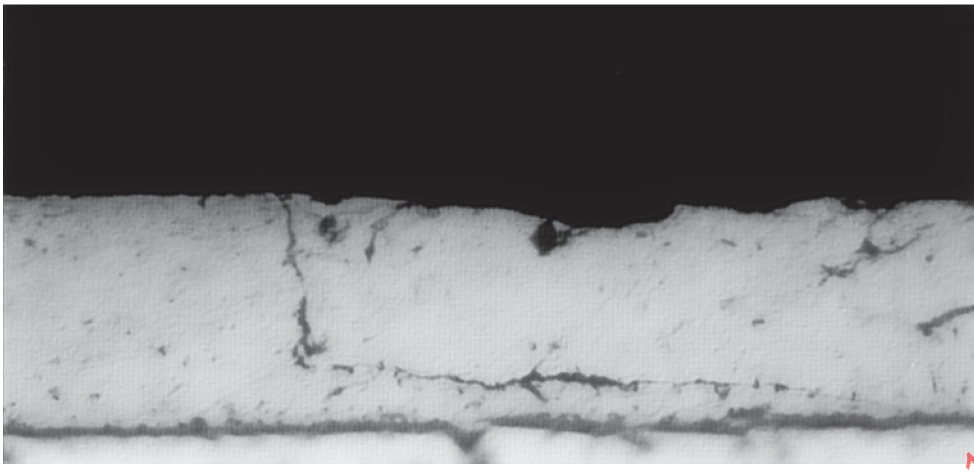
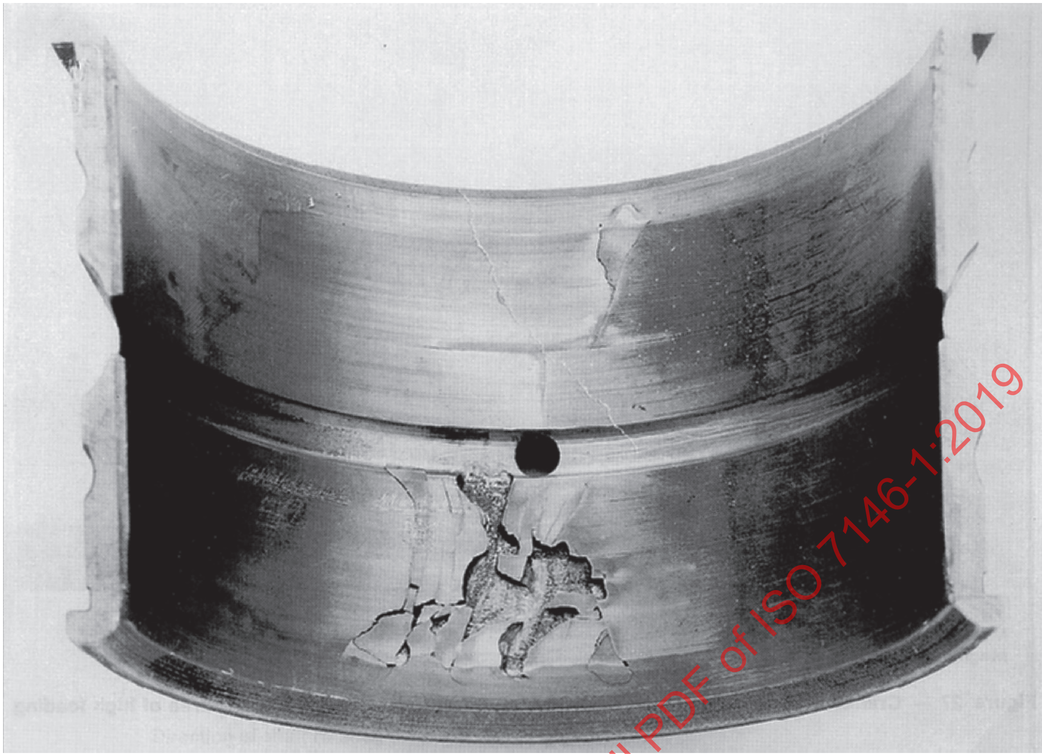


Figure 8 — Cracks in the overlay of a multilayer bearing in a narrow area of high loading (material: steel/lead bronze/electroplated overlay)



NOTE The crack runs at a small distance from the bonding area.

Figure 9 — Section of spalled layer (material: steel/tin-based white metal)



a)

b)

Figure 10 — Fatigue cracks and material relief by dynamic overload (material: steel/tin-based white metal)

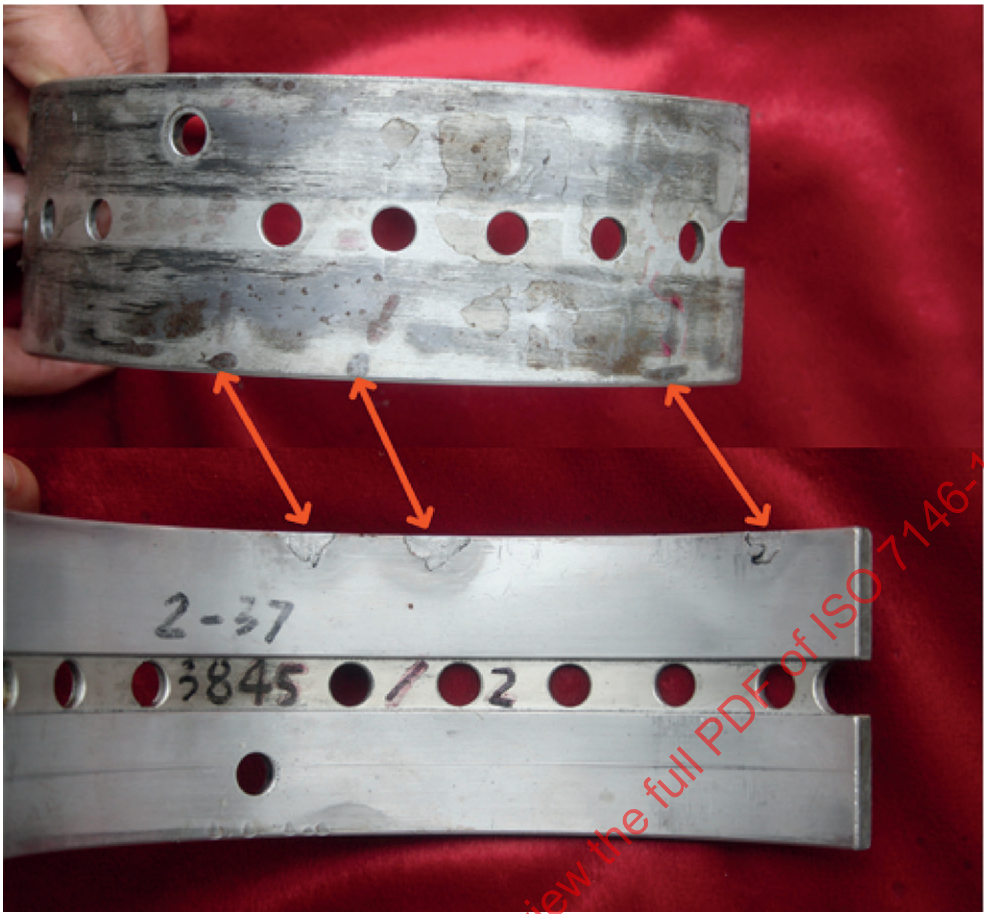
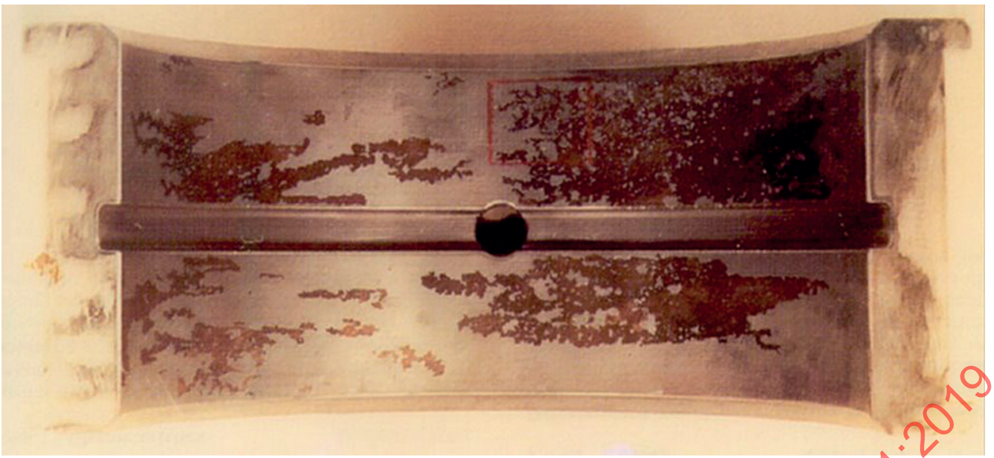
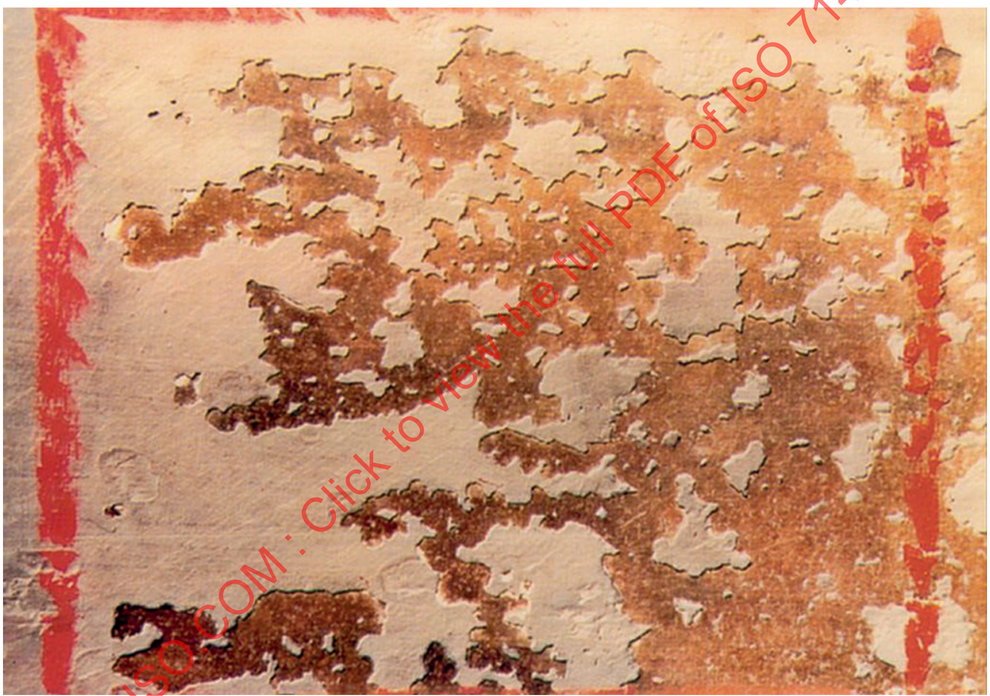


Figure 11 — Material relief by dynamic overload because of insufficient fit on the bearing back (see also 7.2)



a)



b) Section from Figure 12 a): clear illustration of the defect at increased magnification

Figure 12 — Detachment of the overlay leaving occasional residual islands relieved by a dark background (material: steel/lead bronze/electroplated overlay)

6.4 Wear by friction

6.4.1 Typical damage appearances

Polishing happens during a short period of mixed lubrication on start and stop conditions. As long as this polishing does not give rise to a detectable reduction in wall thickness, such running-in marks are normal. This is not damage in the sense of the definitions of this document (see Figure 13).

Scoring occurs under continuous or recurrent mixed-film lubrication conditions for longer periods. Scoring marks appear in the most highly loaded region of the bearing, across the whole width of the bearing. The transition from unmarked to marked areas is quite gradual. The reduction in wall thickness is significant.

Segmented plain bearings experiencing appreciable wear at high rubbing surface temperatures often initially show traces of mixed lubrication; later, worn material from one segment is deposited on the leading edge of the next segment in the direction of rotation (see Figure 16).

For information on possible damage appearance on the bearing back, see 7.3.

6.4.2 Possible damage causes

Extreme operating conditions such as slow turning or starting under load, short and hard contact with the counterface, inadequate clearance or other geometrical defects (misalignment or faulty mounting) lead to wear by friction.

6.4.3 Typical examples

See Figures 13 to 17.

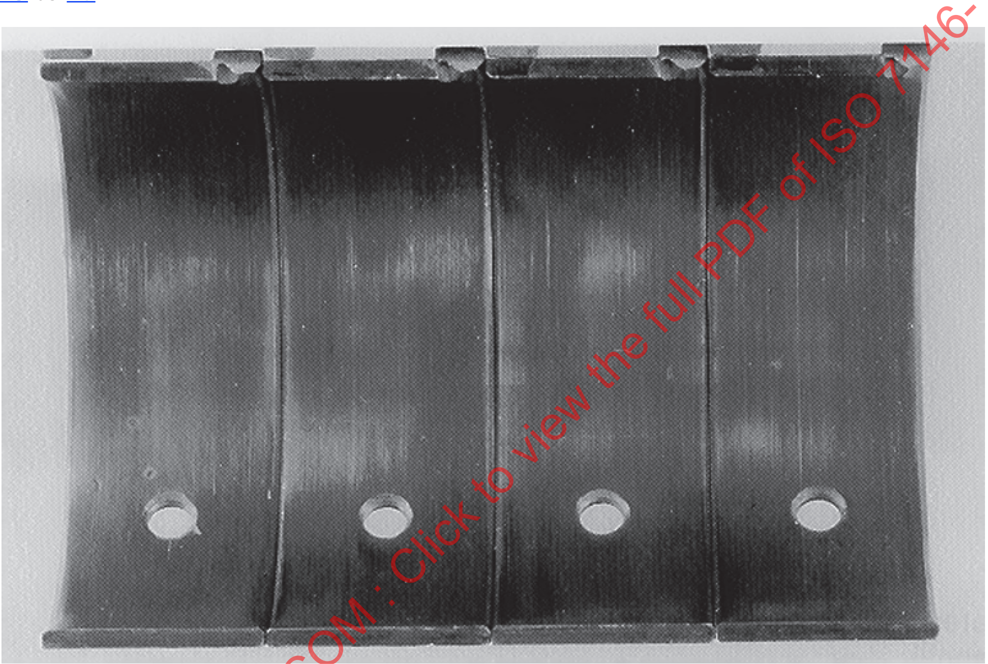


Figure 13 — Running-in polishing and burnishing in the main loaded area of a thin-walled bearing (material: steel/AlSn)

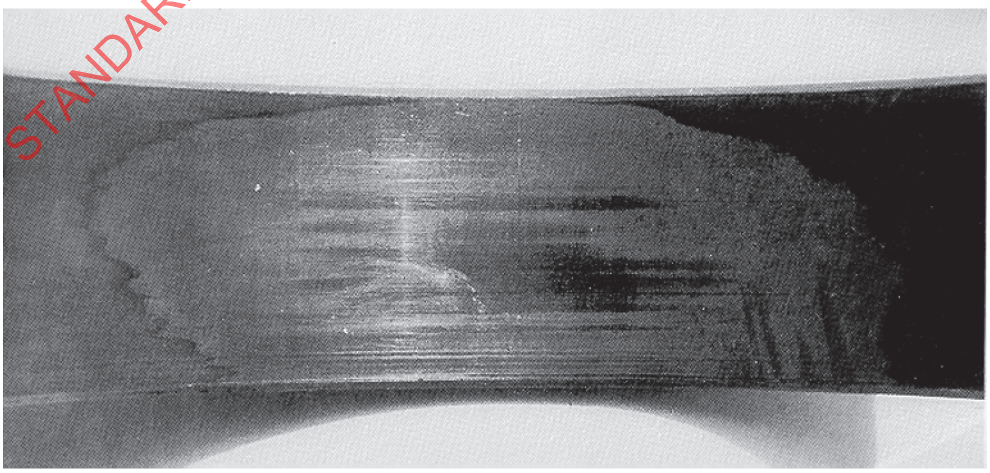


Figure 14 — Abrasive wear of the overlay in the main loaded area on a thin-walled bearing (material: steel/lead bronze/electroplated overlay)

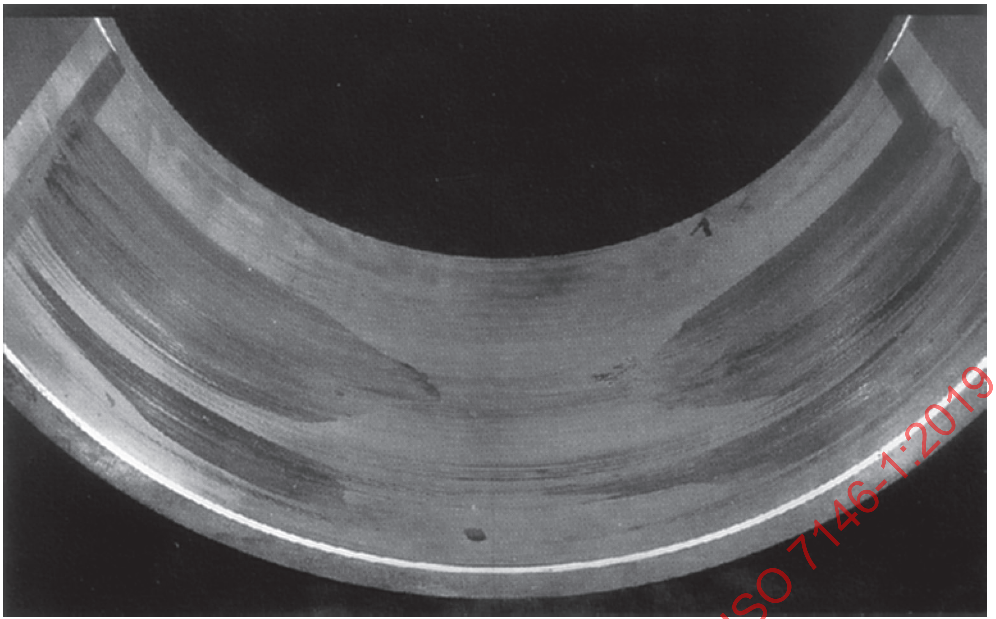
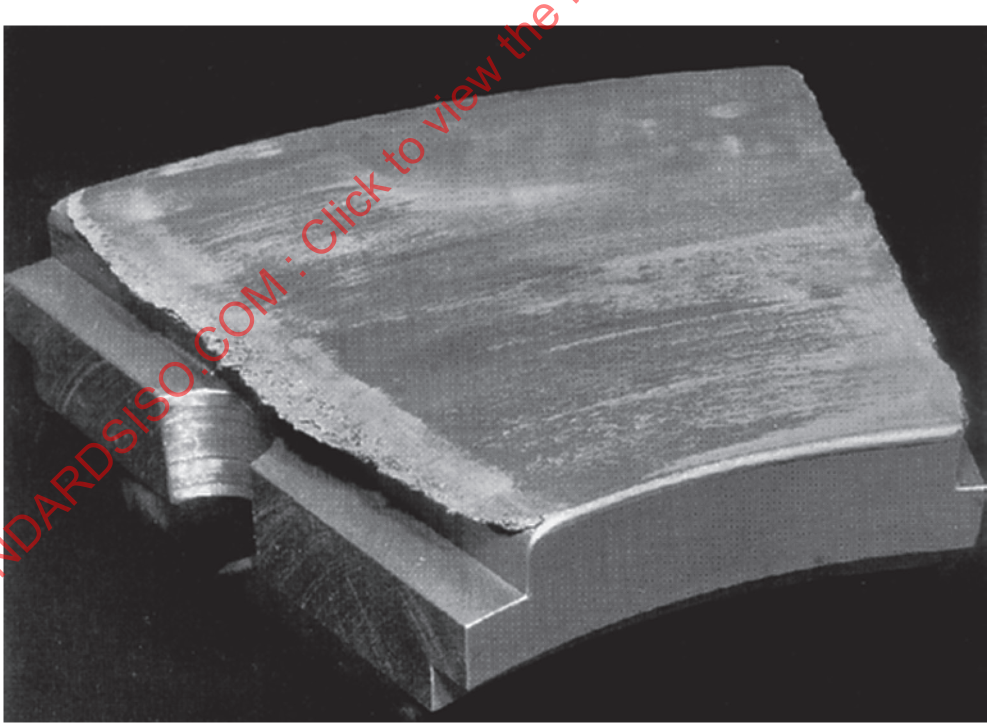


Figure 15 — Abrasive wear near the ends of the bearing (joint face area) in a thick-walled journal bearing, due to faulty mounting (material: steel/tin-based white metal)

Direction of shaft rotation →



NOTE The segment shown gets a reduction in oil supply (secondary damage characteristic: loss of lubricant).

Figure 16 — Wear by friction due to segment assembling on different levels — Worn material from one segment deposited on the leading edge of the next segment in the direction of rotation (material: steel/tin-based white metal)

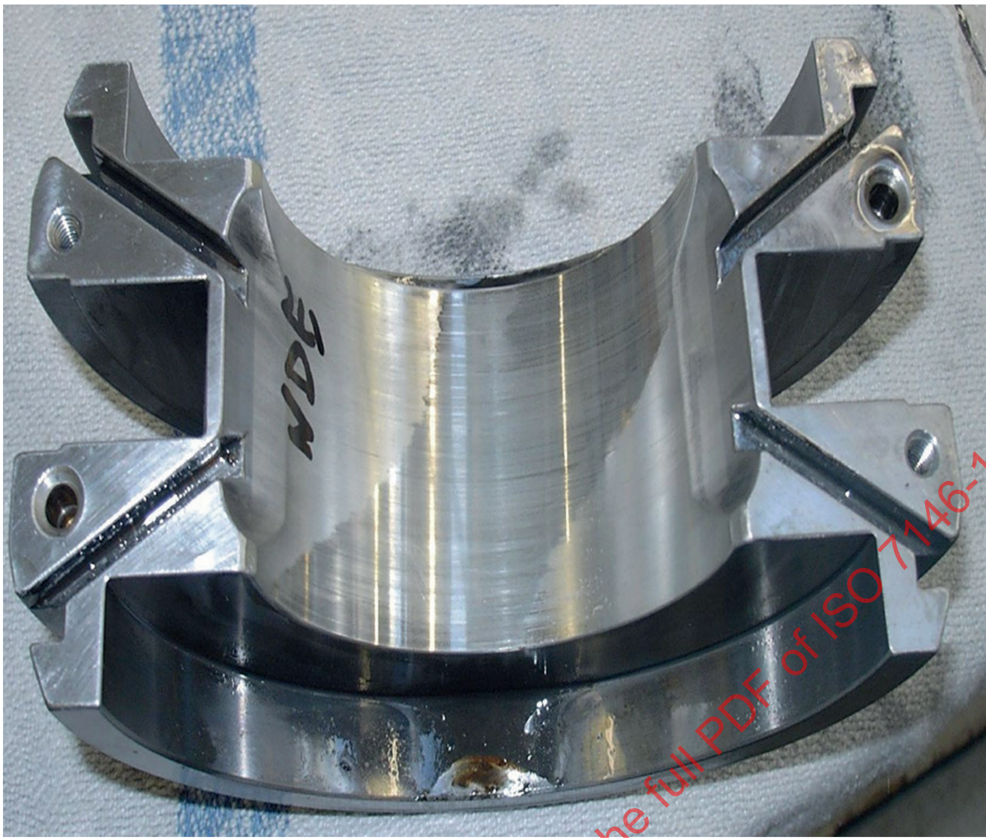


Figure 17 — Wear by misalignment between bearing backing and shaft (material: steel/tin-based white metal)

6.5 Overheating

6.5.1 Typical damage appearances

Deposition: overheating leads to ageing of the lubricant, its thermal decomposition, and finally to depositions. The phenomenon is concentrated in the minimum oil film region, or in other places in the oil circulatory system, occurring more severely when oil additives have become depleted (see Figure 19).

Brown or black deposits appear on the bearing surface, but not as a result of chemical attack between the bearing material and the lubricant. The discoloration is due to very thin lacquer-like oxidized layers in areas of maximum temperature. It is relatively soft and can generally be removed using a solvent cleaning fluid or scratched off using a pointed instrument (see Figure 20).

Creep deformation: shallow depressions of bearing material in the region of maximum load and temperature, initially smooth and ending in crack-free semicircular bulges in the direction of rotation, sometimes like crests of wave (see Figure 18).

Deformations due to temperature changes: as tin crystals have anisotropic thermal expansion along the different crystal axes, an extended period of excessive start-up cycles can cause thermal ratcheting between crystals (in extreme cases, this can lead to intercrystalline cracking).

Thermal cracks have an irregular unsystematic orientation characteristic. These typical appearances can be characterized as creep deformation, traces of mixed lubrication and worn material (see Figure 21).

6.5.2 Possible damage causes

— Failure of heat flow, resulting in overheating.

— Defects in oil cooling, increased surrounding temperature, hot oil carry-over.

— Reduced melting point due to alloy impurities favours thermal cracks.

6.5.3 Typical examples

See Figures 18 to 21.

Direction of shaft rotation →

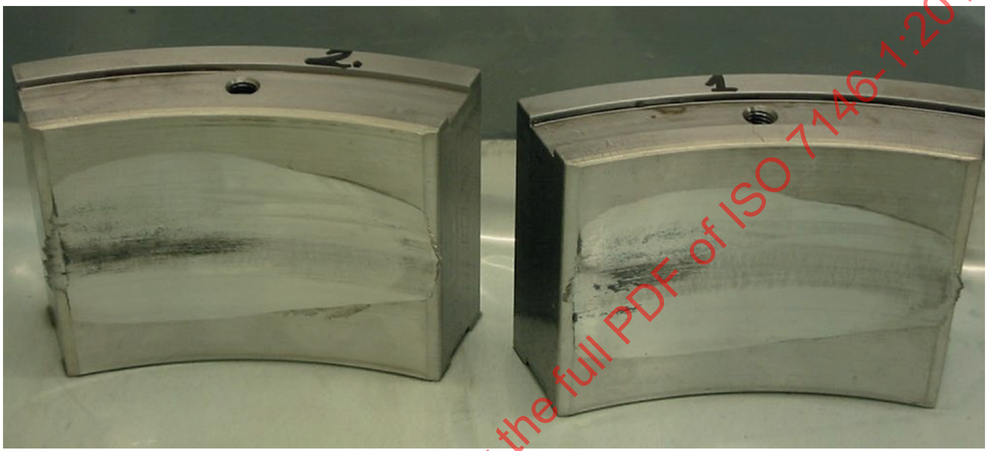


Figure 18 — Creep deformation due to overheating with formation of black depositions (material: steel/tin-based white metal)

Direction of shaft rotation →

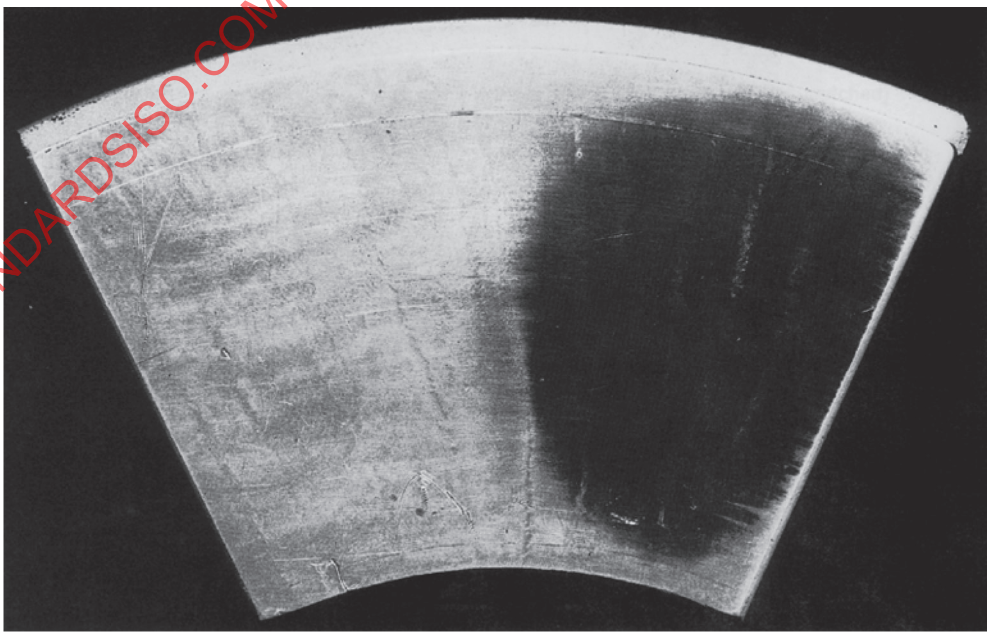
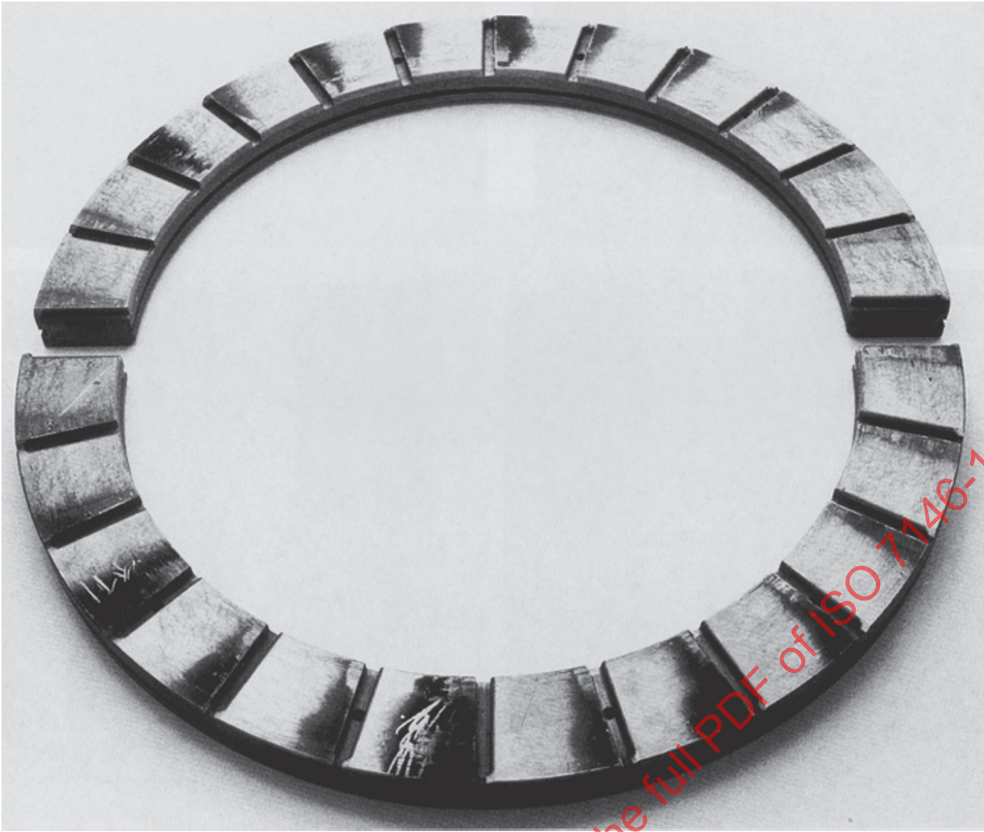


Figure 19 — Thrust bearing tilting pad with deposits of oil carbon (material: steel/tin-based white metal)



NOTE The black/brown deposit is easily removed using the thumbnail (see lowest segment).

Figure 20 — Deposit of oil carbon on a thrust bearing ring (material: steel/tin-based white metal)

Direction of shaft rotation →

Figure 21 — Radial segments with thermal cracks and worn material (material: steel/tin-based white metal)

6.6 Insufficient lubrication (starvation)

6.6.1 Typical damage appearances

— Blue, black colour on the bearing, shaft, housing.

— Traces of mixed lubrication, worn material.

— Melting out, seizure (adhesive wear).

6.6.2 Possible damage causes

— Insufficient lubricant supply.

— Reduction of lubricant supply due to geometric deviations (e.g. missing wedge gap or missing bearing clearance).

— Most damages in a late secondary stage end with loss of lubrication.

6.6.3 Typical examples

See Figures 22 to 27.

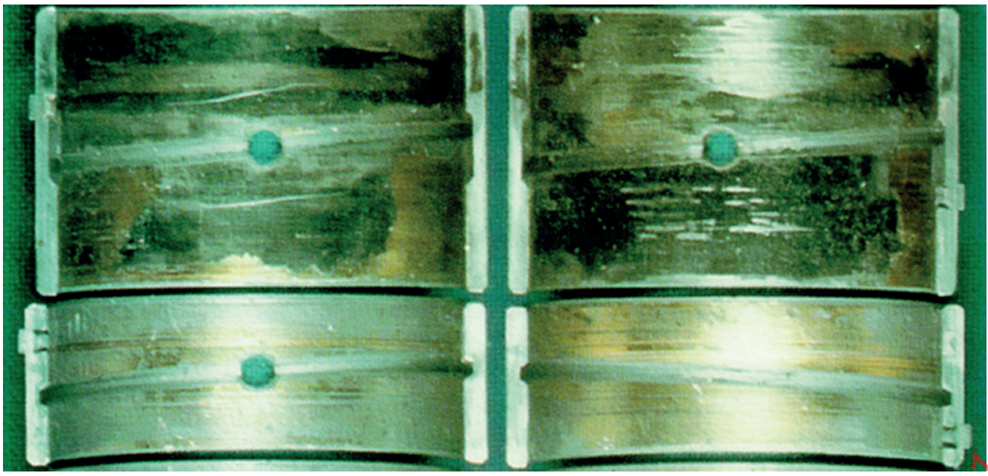


Figure 22 — Seizure on a multilayer plain bearing with totally detached intermediate layer, accompanied by melting, metal wear and severe scoring (material: steel/lead bronze/electroplated overlay)

← Direction of shaft rotation

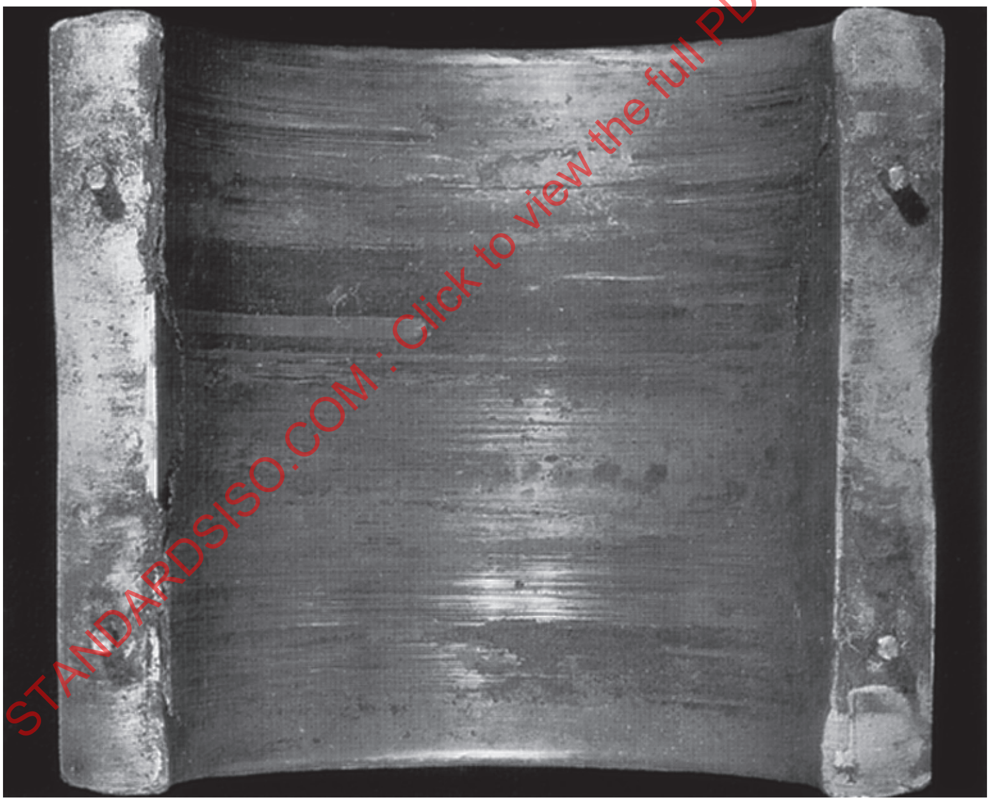
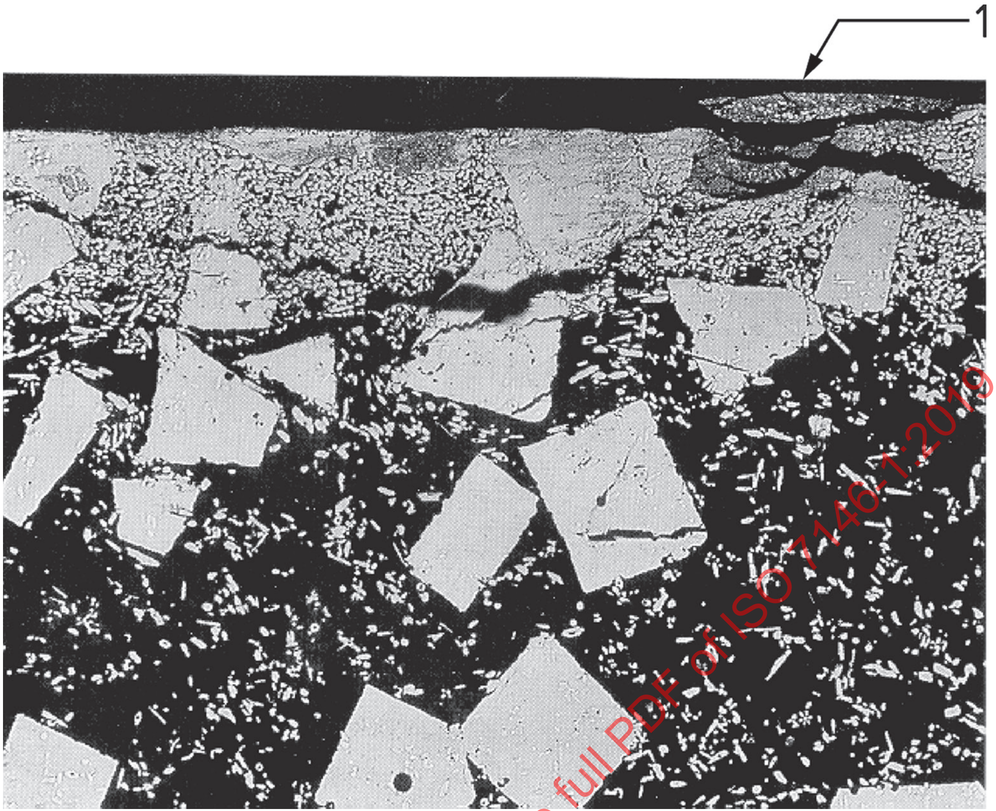


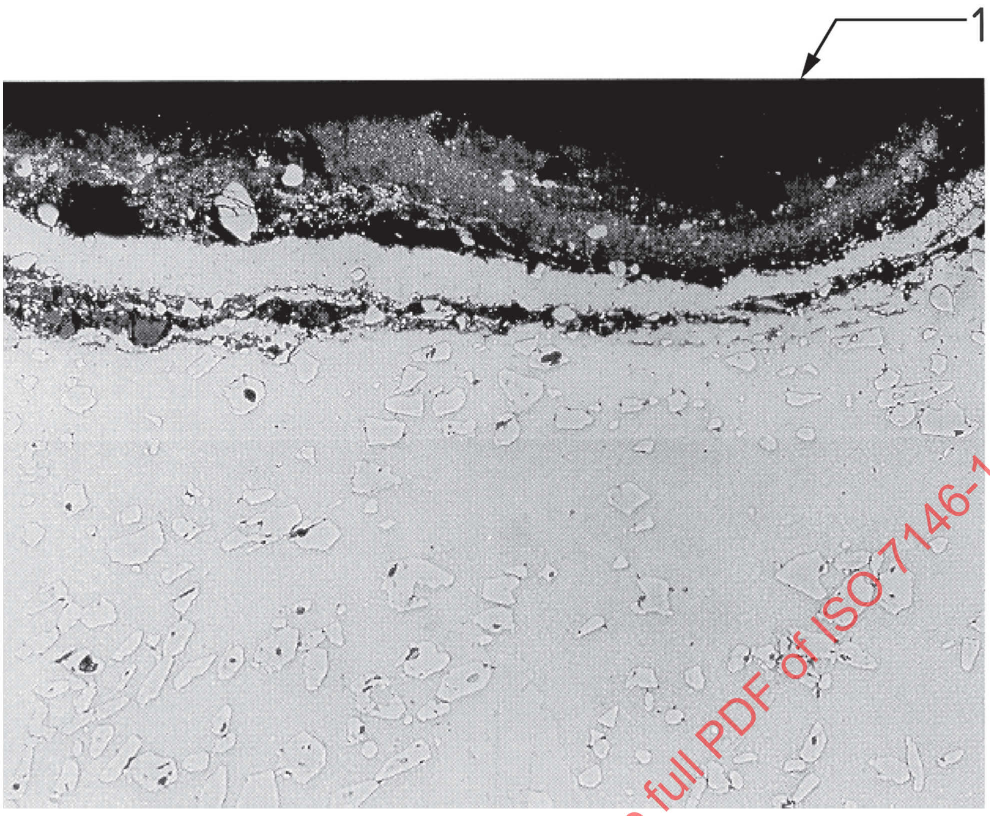
Figure 23 — Destruction of bearing metal due to loss of lubricant in a thick-walled bearing (material: steel/tin-based white metal)



Key

1 sliding surface

Figure 24 — Bearing metal molten along the surface due to overheating and loss of lubricant, followed by cracking of the (etched) bearing metal (material: steel/tin-based white metal)



Key

1 sliding surface

Figure 25 — Bearing metal layer exhibiting surface melting with entrained carbonaceous residue, unetched (material: steel/tin-based white metal)

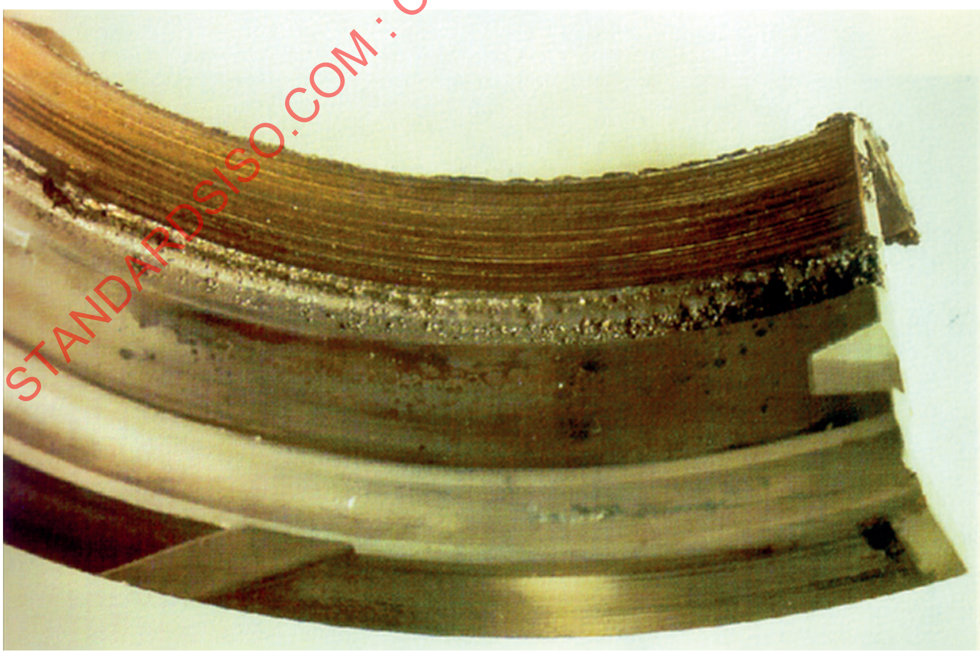


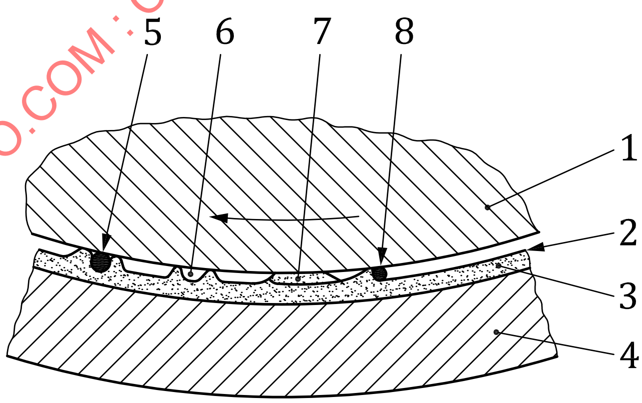
Figure 26 — Melting at the bearing edge and within the groove (material: steel/lead bronze/electroplated overlay)

Figure 27 — Coloured surface due to loss of lubricant, melting out, seizure (material: steel/tin-based white metal)

6.7 Contamination

6.7.1 Contamination with particles

See Figure 28.



Key

1 journal
2 lubricant
3 lining material
4 backing material
5 embedded particle usually with a highly reflective raised ring (halo) of bearing material around it (see also Figure 29)
6 craters or scratches left by displaced particles (see also Figures 30 and 32)
7 particle of bearing metal from a damage site elsewhere in the bearing smeared onto the bearing surface (see also Figure 29)
8 particle with entry track

Figure 28 — Schematic diagram of possible embeddings

6.7.1.1 Typical damage appearances

— Embedded particles.

— Scoring (see Figure 31).

— Particle-migration tracks (see Figures 29, 32, 33 and 34).

Particles are embedded in the bearing surface, surrounded by raised bearing metal displaced as the particle is embedded. The raised bearing metal appears as a highly reflective halo around the embedded particle (see Figure 30). The halo comes in contact with the counterface. Traces of mixed lubrication and worn material occur.

The formation of wire wool can be caused by hard foreign particles partially embedded in the bearing surface cut into the rotating shaft thereby removing material from the shaft surface. Wire wool formed in this way can also be once more embedded in the bearing metal and usually brings about total failure very quickly (see Figure 35).

Chevron appearances are particle-migration tracks generated by hard particles. The chevrons point in a direction opposite to the direction of rotation of the journal (see Figure 36).

Foreign particles in the oil can also lead to fluid erosion.

With regard to possible damage appearances on the bearing back, see also 7.4.

6.7.1.2 Possible damage causes

Particle contamination of the oil by residues from manufacturing, assembly or commissioning (metal turnings, casting sand, paint) can result from poor maintenance or damage to the filter. Particles can be produced by wear or damage to other bearings or machine components. Damaged seals result in contamination with particles from the area surrounding the machine (e.g. cement in the cement industry).

The formation of wire wool can be expected when the shaft steel contains chromium. Hard particles embedded in the bearing surface cut into the rotating shaft thereby removing material from the shaft surface (wire wool).

Chevron appearances: the migration tracks are caused by particles originating from the surface of nitrided journals. Particles with magnetic properties spall from the journal due to insufficient grinding and removal of the white friable layer.

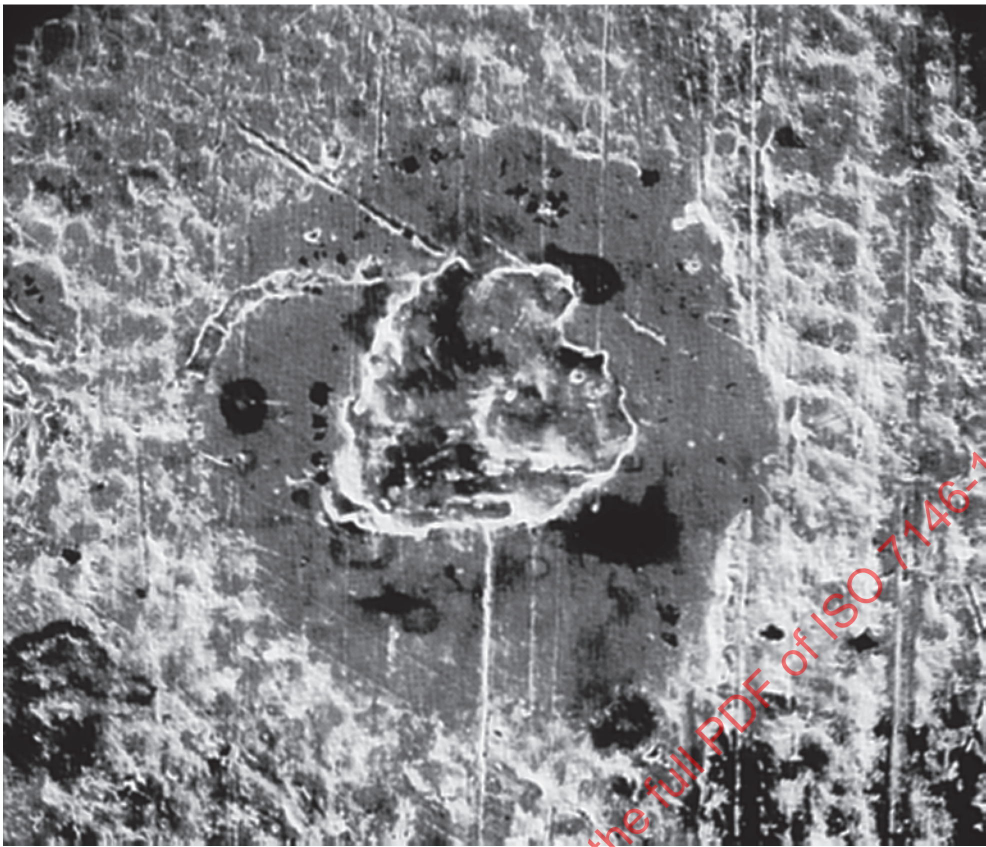
Fluid erosion is caused by lubricant under high shear rate with included foreign hard particles such as wear debris, dust, and combustion residue.

6.7.1.3 Typical examples

See Figures 29 to 36.

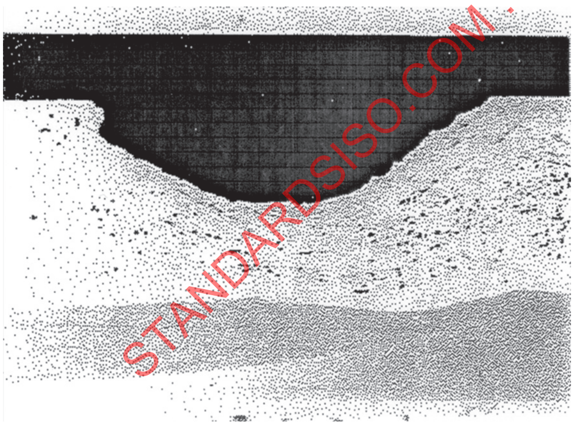
NOTE See also Figure 28.

Figure 29 — Embedding of particles, characteristic of embedding and migration tracks (material: steel/AlSn)

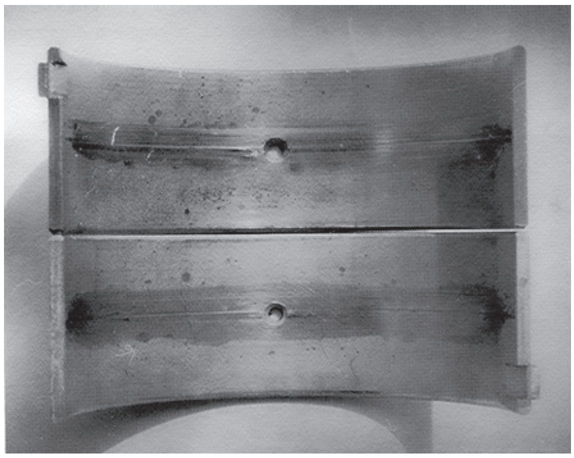


NOTE See also Figure 28, item 6.

Figure 30 — Crater left by displaced particle surrounded by reflective ring (halo), characteristic of embedding (material: steel/lead bronze/electroplated overlay)



a) Deformation at the lining surface cross-section



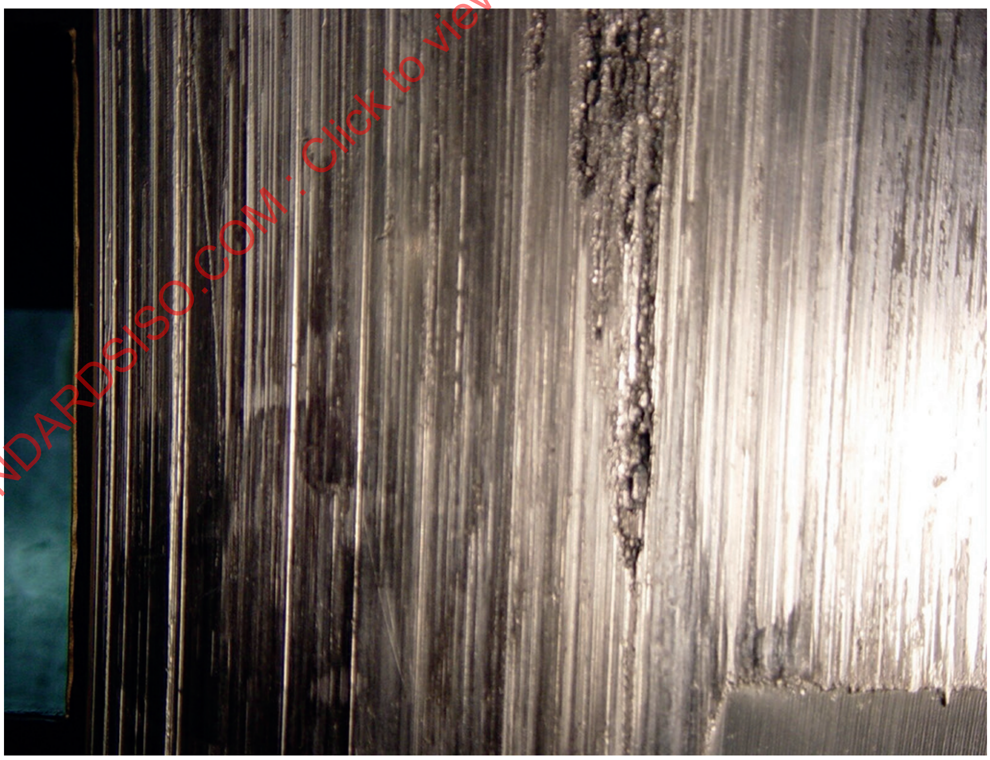
b) Material: steel/lead bronze/electroplated overlay

Figure 31 — Deep circumferential score with displaced bearing metal alongside

Direc-
tion
of shaft
rotation
↓

NOTE Particle-migration tracks are visible.

Figure 32 — Cement mill bearing with contamination by cement particles entrained by the oil as a result of damaged seals (material: steel/tin-based white metal)



NOTE Particle-migration tracks are visible.

Figure 33 — Contamination by foreign particles containing Fe

← Direction of shaft rotation

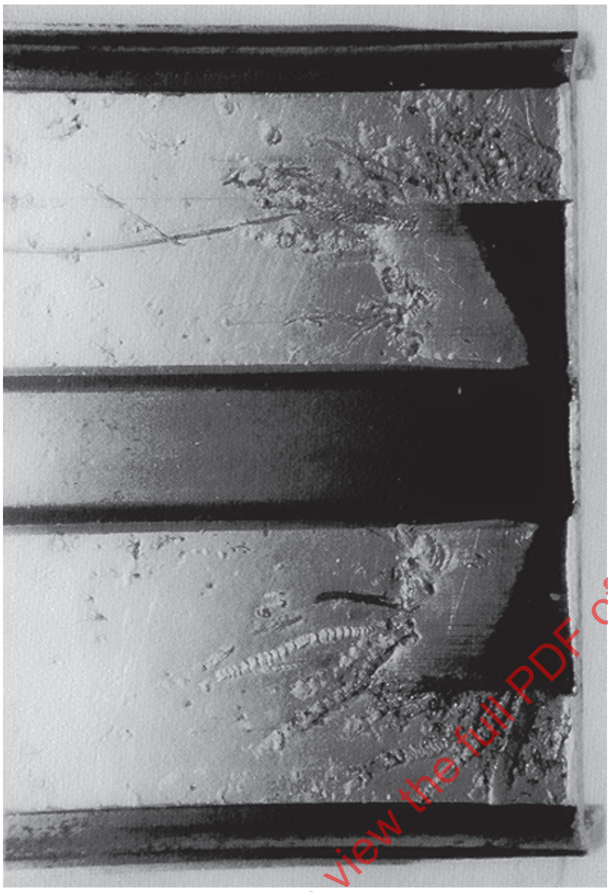
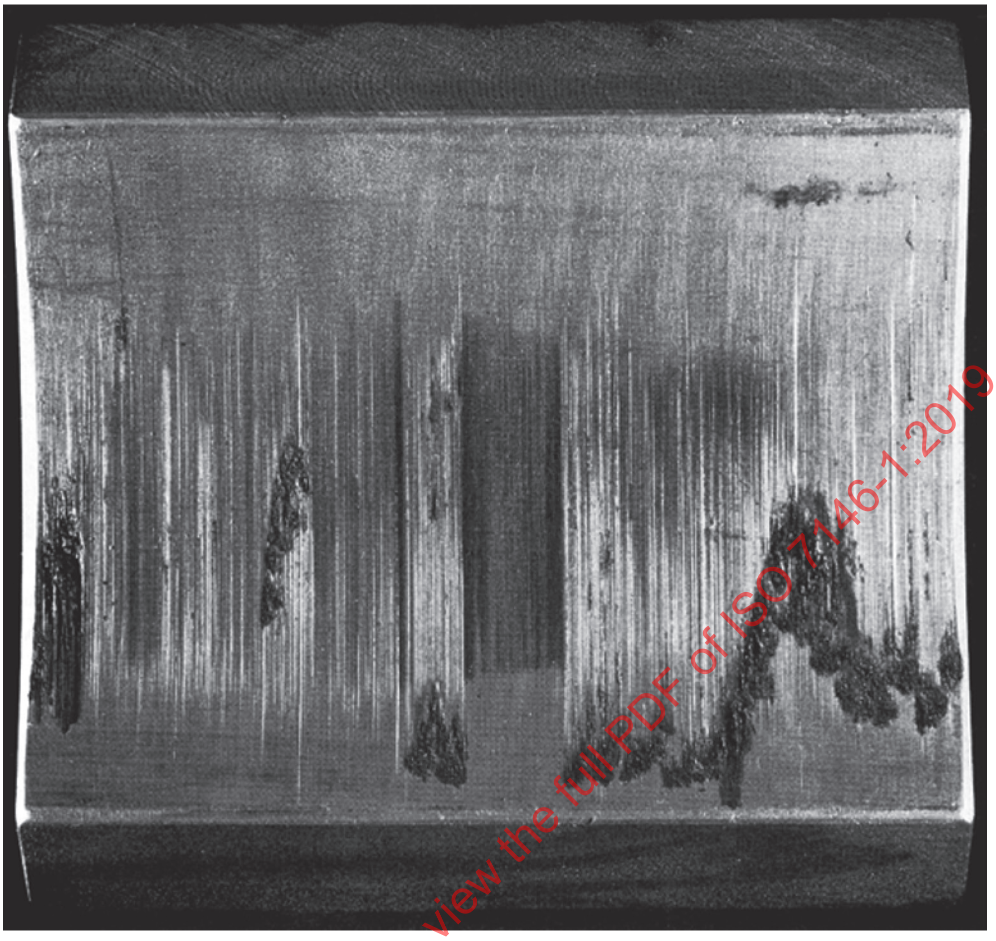
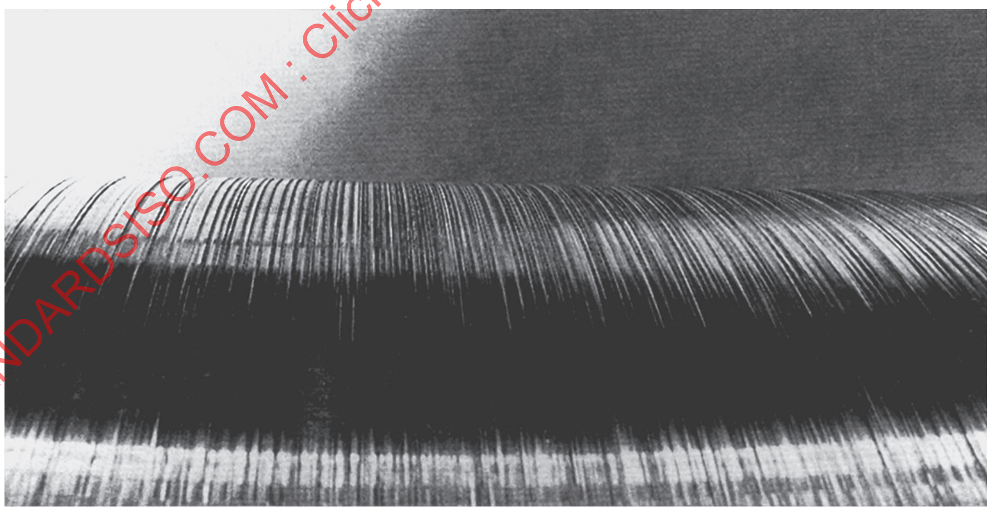


Figure 34 — Particle-migration tracks concentrated to the pocket area of a thin-walled bearing (material: steel/AlSn)



a) Wire wool on a journal pad (material: steel/tin-based white metal)



b) Wire wool on the shaft

Figure 35 — Attack caused by abrasive and adhesive effects in the initial stage (wire wool) (material: steel)

Direction of shaft rotation →

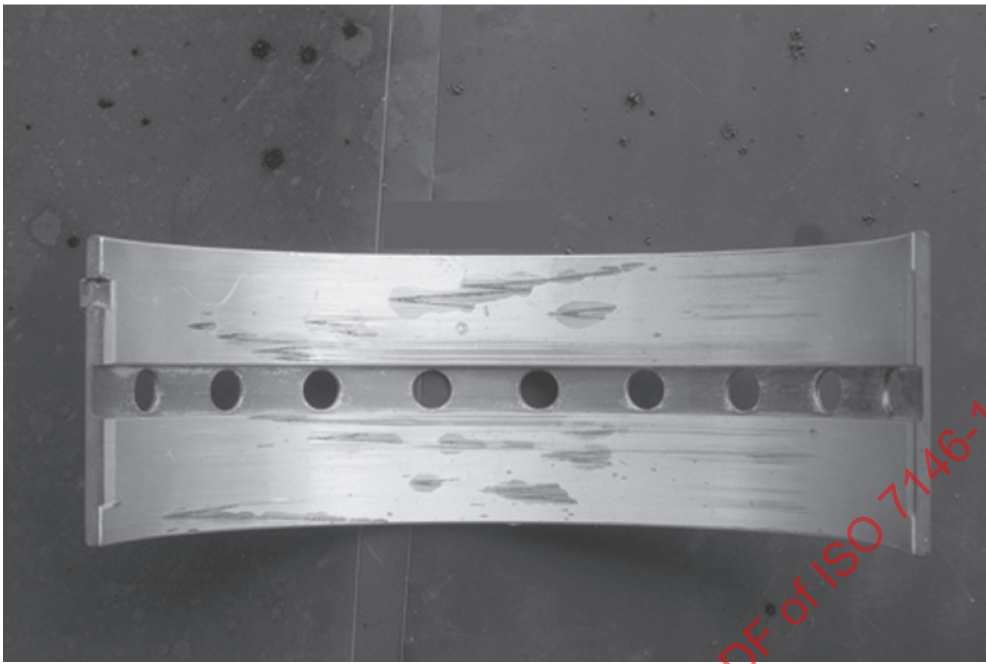


Figure 36 — Chevron-like defect caused by particles from iron nitride compound layer of nitrided shafts (material: steel/lead bronze/electroplated overlay)

6.7.2 Contamination with chemicals

6.7.2.1 Typical damage appearance

— Corrosion.

— Fluid erosion.

6.7.2.2 Possible damage causes

Corrosive elements can be present in the lubricant from the outset, or can develop during long periods of operation as a result of contamination by water, antifreeze or combustion residues, etc. The smallest leakages in the lubrication system can lead to chemical reaction and corrosion. Corrosion of the overlay is accelerated when the corrosion-resistant constituents are missing in the original condition or are lost from the overlay as a result of diffusion processes taking place at elevated temperatures.

Contamination of the lubricant is possible by halogenated hydrocarbons from the refrigerant or by certain other chemicals. Copper can be dissolved from the oil cooler tubes. This copper can be deposited electrolytically on metal surfaces in tribological systems. High temperatures accelerate the reaction. This can be followed by copper diffusion and accompanying corrosion.

For corrosion due to water in the oil, the critical water concentration depends on oil and operating conditions, but can occur generally when water is present in excess of 1 % volume fraction.

Dissolution of bearing material by corrosion leads to fluid erosion. Removal of an anti-oxidative layer by fluid erosion can initially lead to premature corrosion, which in turns leads to fluid erosion.

6.7.2.3 Typical examples

See Figures 37 to 42.

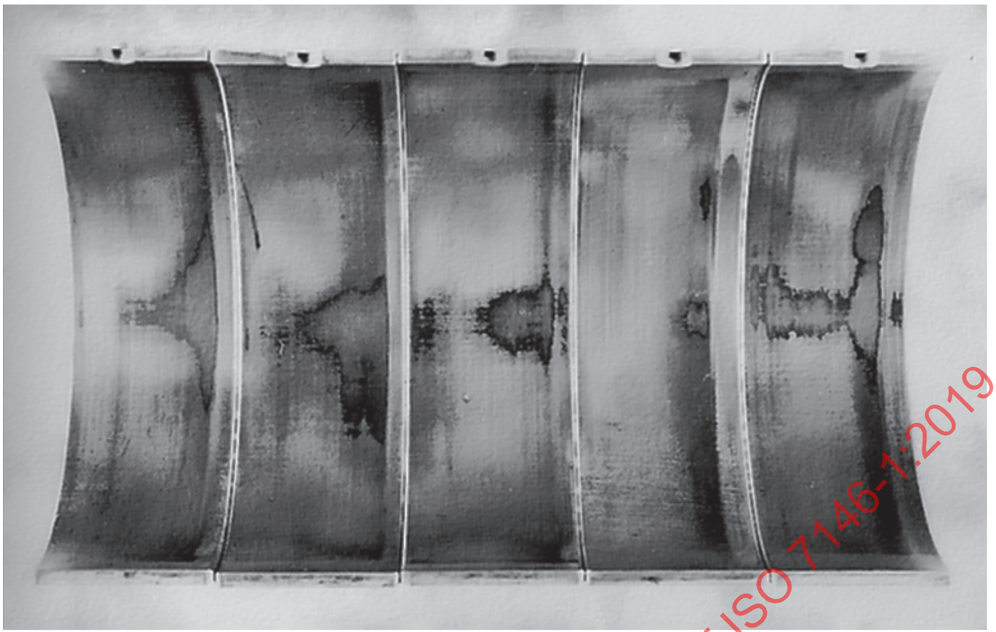
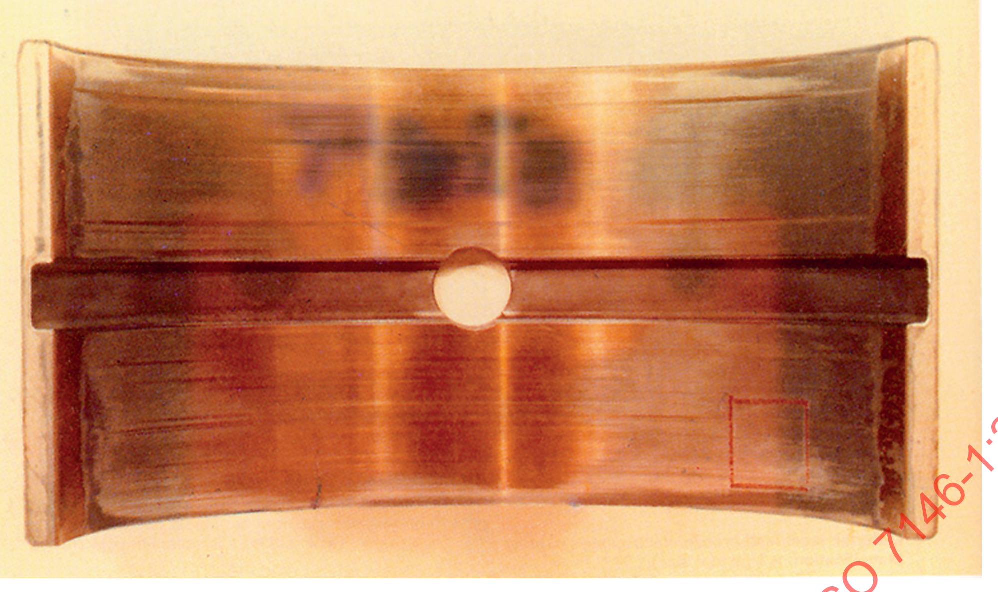
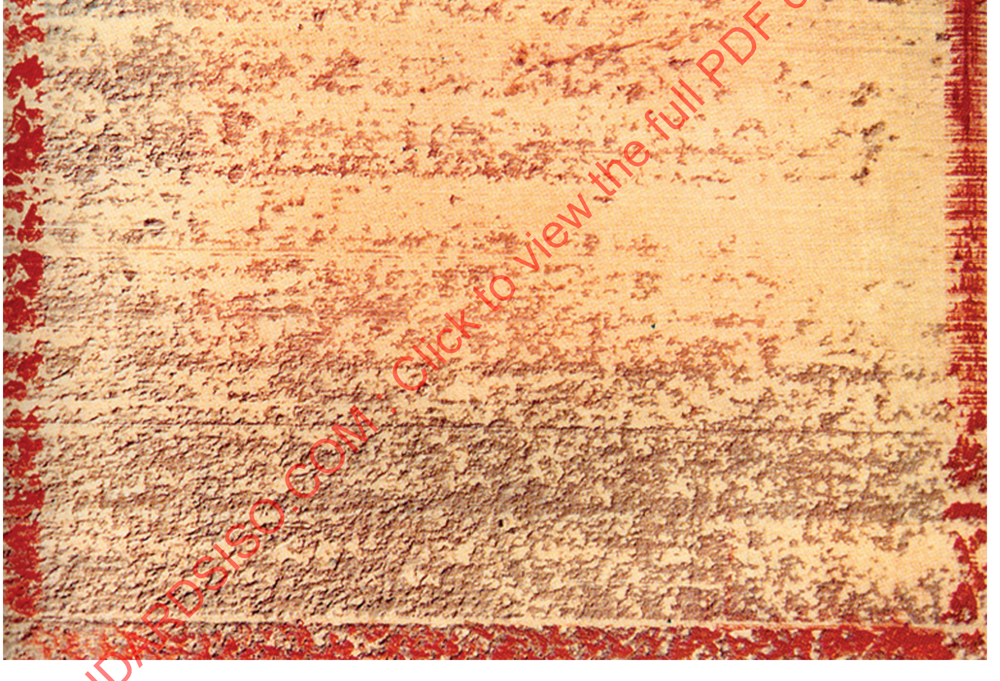


Figure 37 — Discoloration of the bearing surface in the main loaded zone by tribochemical reaction (material: steel/lead bronze/electroplated overlay)



a)



b) Section from the marked area of Figure 38 a) at increased magnification

Figure 38 — Corrosive detachment of the overlay in the area of the oil hole and selective corrosive detachment on the right-hand side of the bearing lining (material: steel/lead bronze/electroplated overlay)

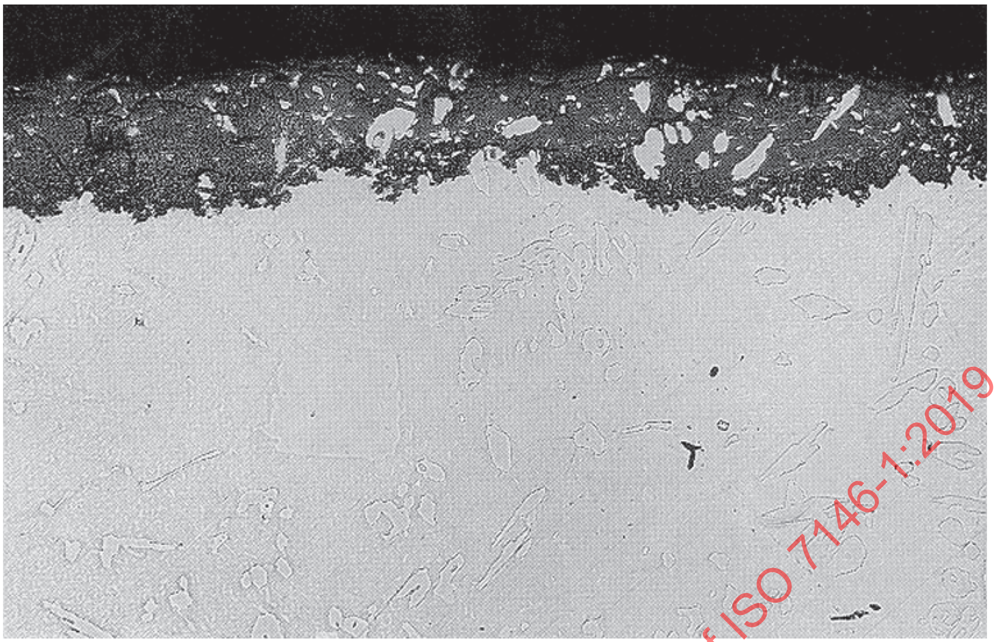


Figure 39 — Tin oxide corrosion due to water in the oil, unetched (material: steel/tin-based white metal)

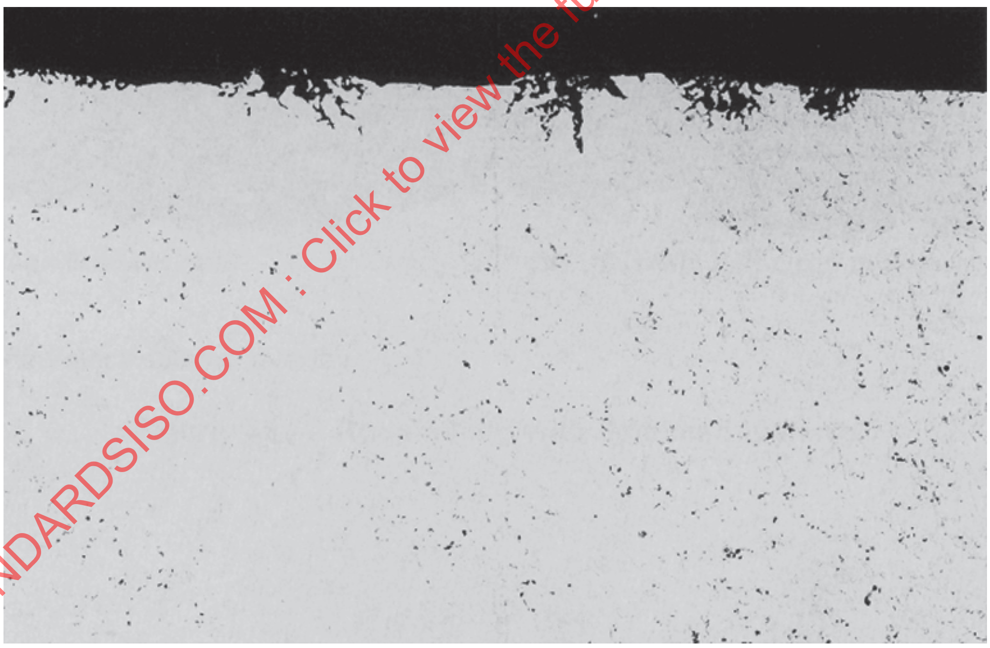
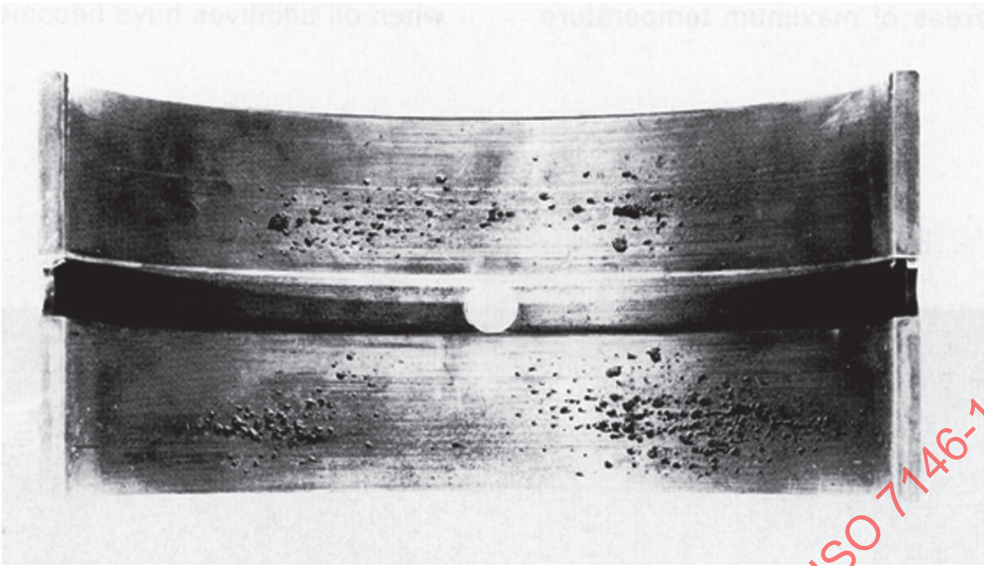
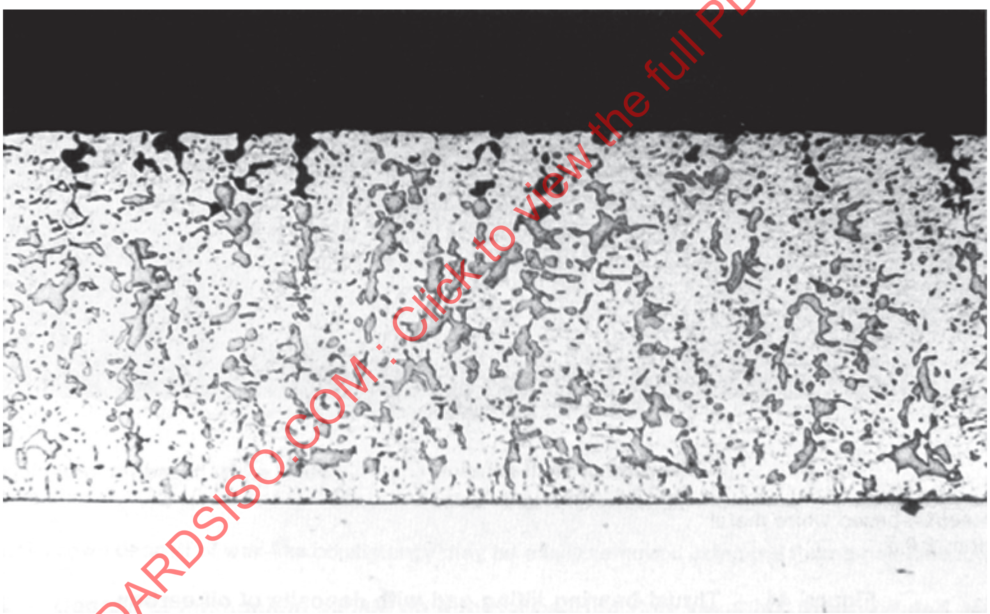


Figure 40 — Corrosion of the surface layer with selective attack on copper and lead in a tin-based material, unetched (material: steel/tin-based white metal)

← Direction of shaft rotation



a) Structure weakened by corrosion of lead phase after wear of overlay (material: steel/lead bronze/electroplated overlay)



b) Microcut at increased magnification (material: steel/lead bronze/electroplated overlay)

Figure 41 — Corrosion damage of lead phase after wear of overlay (material: steel/lead bronze/electroplated overlay)

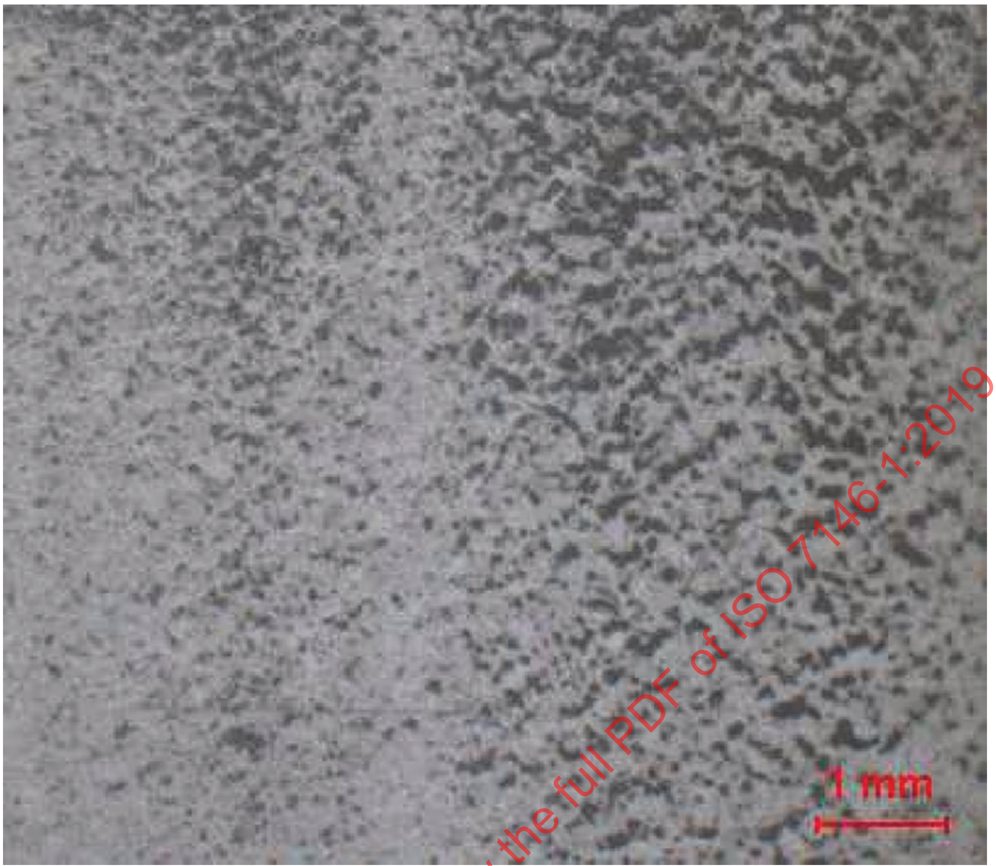


Figure 42 — Deposit of oil carbon on galvanic surface

6.8 Cavitation erosion

6.8.1 General

When the static pressure in a liquid is decreased below the vapour pressure of the liquid at the given temperature, evaporation occurs and vapour bubbles are generated in the liquid. This phenomenon is called cavitation.

With increase of pressure, these bubbles collapse and typically cause very strong local shockwaves in the liquid which damage the bearing surface resulting in cavitation erosion.

6.8.2 Typical damage appearances

Cavitation erosion appearances are characterized by typical worn-out material.

6.8.3 Possible damage causes

For information on cavitation erosion due to faulty design, geometry, material, operation conditions and contamination with foreign fluid elements, see ISO 7146-2. On proven machines, water inclusion is a frequent cause of cavitation erosion.

6.8.4 Typical examples

See Figures 43 and 44.

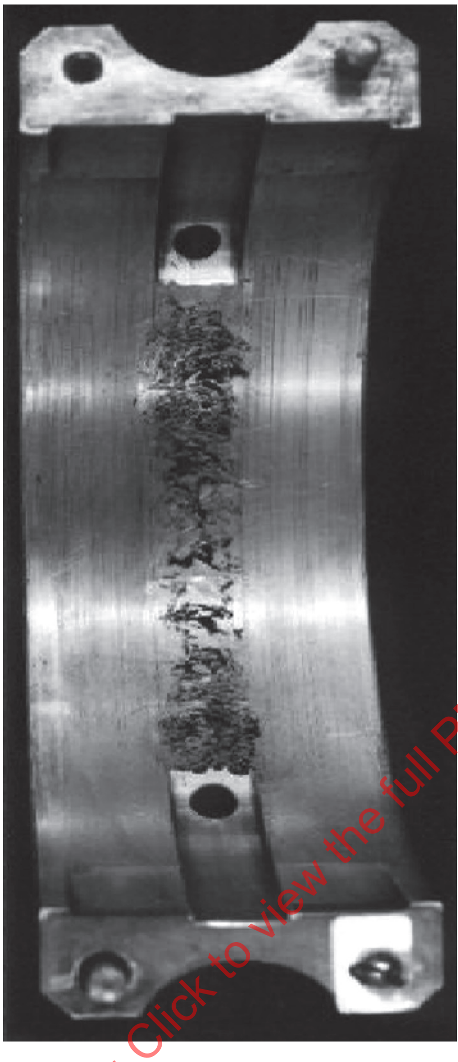


Figure 43 — Typical cavitation erosion on a thick-walled bearing (material: steel/tin-based white metal)

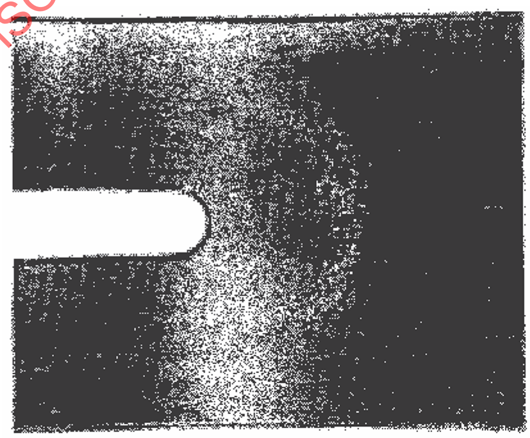


Figure 44 — Typical cavitation erosion on a thin-walled bearing

6.9 Electro-erosion

6.9.1 Typical damage appearance

The surfaces of journal and bearing show small craters.

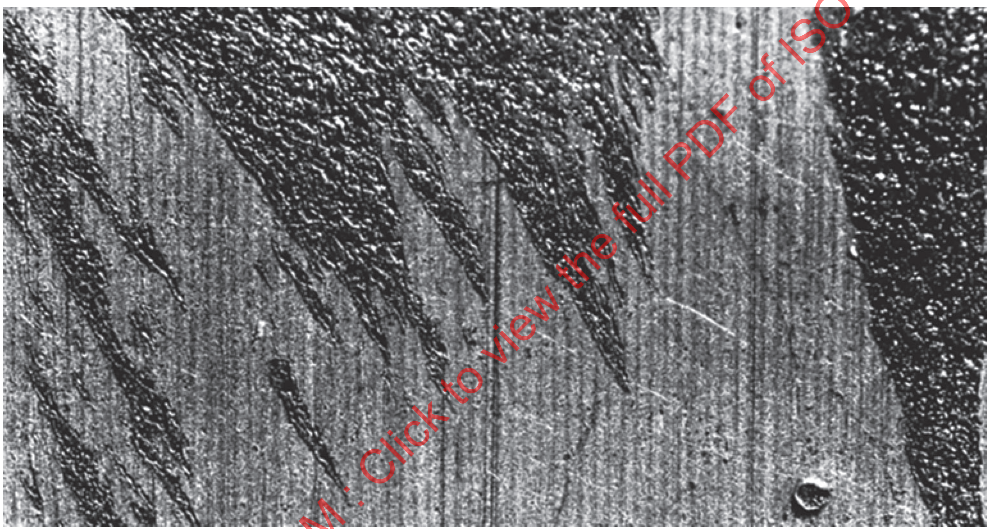
6.9.2 Possible damage causes

Magnetic fields and electrostatic charges can give rise to a potential difference between journal and bearing resulting in current flow.

Insufficient earthing (grounding) or improper insulation in operation or during maintenance, e.g. welding work on the machine, can be a contributory factor.

6.9.3 Typical examples

See Figures 45 to 47.



Direction of shaft rotation ↓

Figure 45 — Surface of a plain bearing attacked by electro-erosion (material: steel/lead bronze/electroplated overlay)

Figure 46 — Formation of electric arc craters

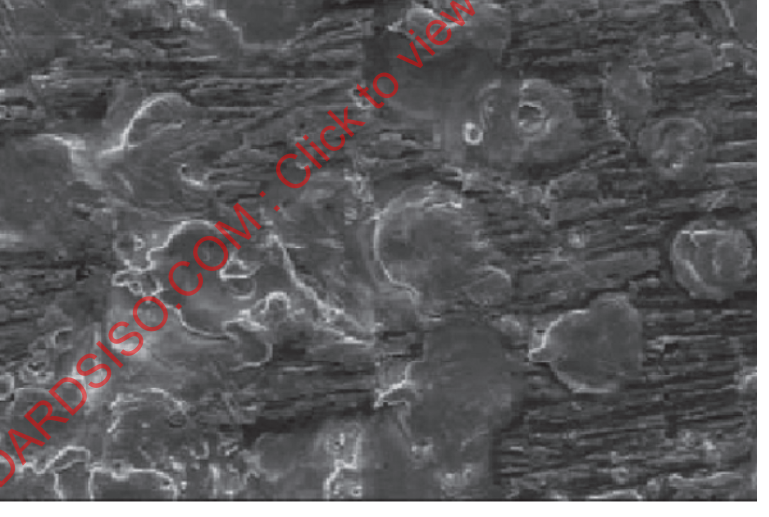


Figure 47 — Electric arc craters at increased magnification (material: tin-based white metal)

6.10 Hydrogen diffusion

6.10.1 Typical damage appearances

For thick-walled bearings: loss of bond between white metal and steel. White metal forms typical blisters (see Figure 48).

For electroplated layers: formation of pores with typical blisters on the layer surface (see Figure 49).

The hydrogen diffusion develops usually over a long time and is accelerated by temperature. These appearances occur either on operation or on spare part bearings after long storage time.

6.10.2 Possible damage cause

Missing additional heat treatment for hydrogen reduction on the steel backing or the electroplated layer. This additional heat treatment is recommended for steel backing thickness above approx. 60 mm.

6.10.3 Typical examples

See Figures 48 and 49.

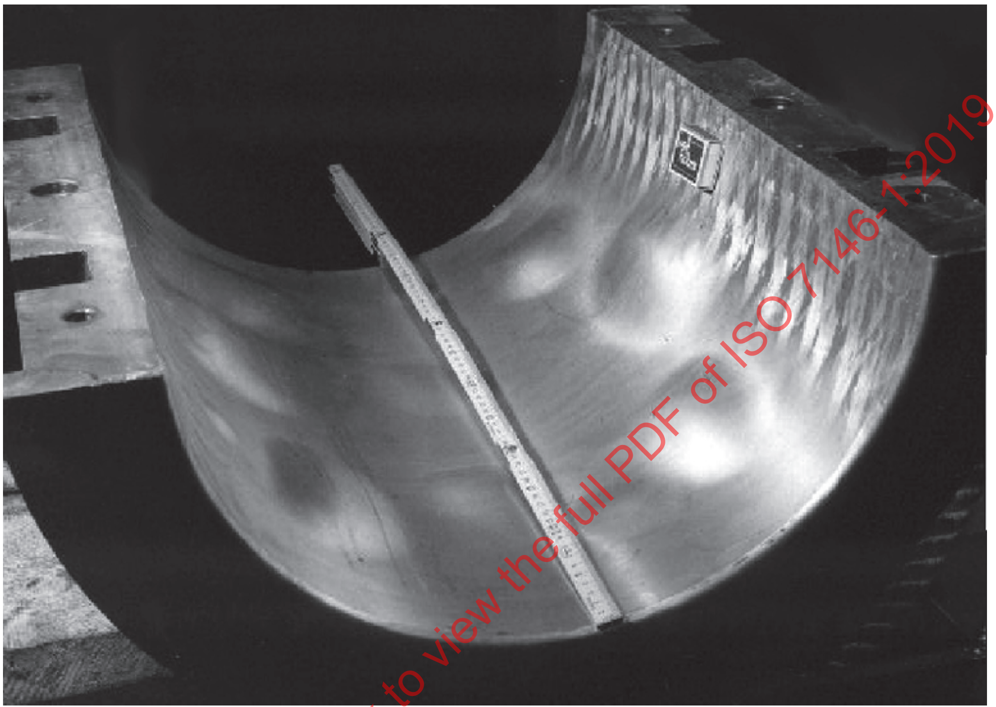


Figure 48 — Layer with loss of bond and formation of typical blisters, arising from hydrogen inclusion in the steel (material: steel/tin-based white metal)

Direction of shaft rotation →

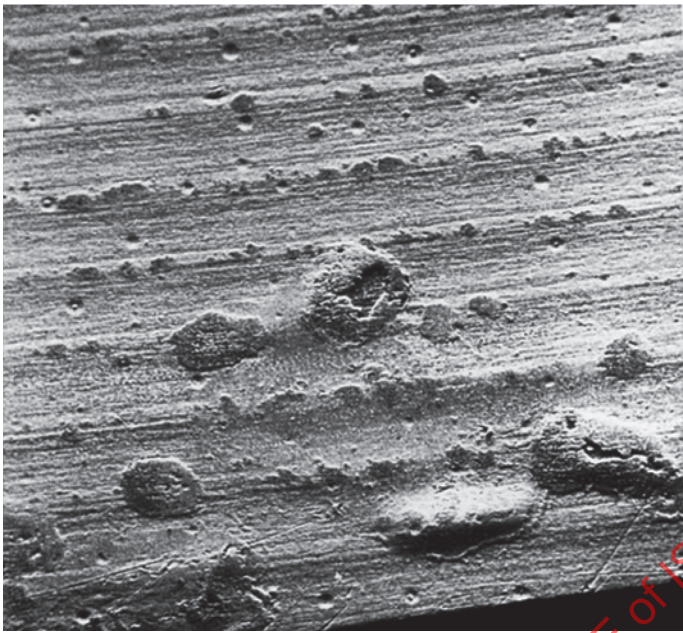


Figure 49 — Hydrogen inclusion arising from electroplating: small pores and larger blisters, partially perforated during running (Material: steel/lead bronze/electroplated overlay at increased magnification)

6.11 Bond failure

6.11.1 Typical damage appearances

Loss of bond: completely detached material in larger areas with clearly defined borders.

6.11.2 Possible damage causes

Faulty procedure during manufacturing process, e.g. missing heat treatment, insufficient cleaning, tinning, process temperatures.

6.11.3 Typical example

See Figure 50.