International Standard

ISO 3643

First edition
2024-09

Rolling bearings — Ceramic rolling elements — Terms and characteristics of surface imperfections

Roulements — Éléments roulants en céramique — Termes et caractéristiques des imperfections de surface

Reference number
ISO 3643:2024(en)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ... **iv**
Introduction ... **v**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **1**
4 Classification of surface imperfections ... **2**
5 Surface imperfections ... **3**
5.1 General ... 3
5.2 Crack ... 3
5.2.1 General ... 3
5.2.2 Open crack ... 3
5.2.3 Partially healed crack ... 5
5.2.4 C-crack ... 5
5.2.5 Star crack ... 7
5.3 Linear hollow indication ... 8
5.3.1 General ... 8
5.3.2 Scratch ... 8
5.3.3 Cut ... 9
5.3.4 Contact mark ... 10
5.4 Irregular or rounded shaped hollow indication ... 12
5.4.1 General ... 12
5.4.2 Pore ... 12
5.4.3 Missing material ... 13
5.4.4 Flat ... 14
5.5 Optically variable region ... 15
5.5.1 General ... 15
5.5.2 Snowflakes ... 15
5.5.3 Inclusion ... 17
5.5.4 Colour variation ... 22
5.5.5 Smearing ... 23
5.5.6 Healed crack ... 23
5.5.7 Non cleaned-up area ... 25
Annex A (informative) **Explanations for the terms used in inspection means** ... **26**
Annex B (informative) **Dye penetrant inspection** ... **29**
Annex C (informative) **Scanning electron microscope** ... **31**
Bibliography ... **33**

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 4, *Rolling bearings.*

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

Surface appearance provides the first impression of quality and gives confidence in product performance and function to the user and customer. The presence of a surface imperfection can have an impact on the actual performance and function.

Ceramic rolling elements are produced in different main steps, which can be realized by the same company or by different companies. Industrial production of ceramic rolling elements, as all manufacturing processes, is subject to a variability coming from materials, process parameters and/or manufacturing steps, which can lead to imperfections on the surface. In addition, handling of parts can also induce some imperfections on the finished surface.

So far, no common vocabulary exists and in industry different words are used to describe surface imperfections of finished ceramic rolling elements for bearing applications. This leads to different interpretations and makes objective comparison difficult.

This document aims to describe imperfections of ceramic finished rolling elements before use. However, some of these imperfections can also be detected on blanks (before machining) or after use.

Imperfections can correspond to:

— material imperfection, which can constitute a defect or not, depending on the morphology of the imperfection (shape, size), on the position on the rolling element and on the requirements of the application; the acceptance limits of the imperfections are defined by customers and/or suppliers, depending on the application;

— local surface imperfection, which corresponds to irregularity on a part of the surface; as for material imperfection, it can correspond or not to a defect depending on characteristics of this imperfection and requirements of the application;

— surface appearance deviation, which is a deviation from the optical appearance of the usual surface pattern or colour.

At the time this document is prepared, visual inspection is the method of choice to identify surface imperfections, in combination or not with dye penetrant inspection (see Annex A and Annex B). Other NDT (non-destructive testing) methods can also be used as a complement, such as acoustic or thermal microscopy, resonant ultrasound spectroscopy or laser spectroscopy to give a few examples.

Inspection of ceramic rolling elements is performed with naked eyes or under small magnification for mass production control. Scanning electron microscope (SEM – see Annex C) is only used to specify the pattern identified by NDT but is not a method suitable with mass production control.

The inspection methods and parameters used for rolling element inspection are subject to agreement between customer and supplier and are not the topic of this document.

Concerning these controls: steel rolling elements are more widespread than ceramic rolling elements. They have some characteristics in common, but methods and parameters of inspection are different.

Rolling bearings — Ceramic rolling elements — Terms and characteristics of surface imperfections

1 Scope

This document establishes terms, descriptions and characteristics and provides typical photos of specified surface imperfections which can be found on finished silicon nitride rolling elements.

Rolling elements refer to balls and rollers. Imperfections defined in this document correspond to patterns found on finished rolling elements before use.

Deviations for the geometric product specifications (GPS) are not addressed in this document.

This document does not give criteria for the acceptance limits of these imperfections. The identification of an imperfection is done between the different actors involved in the manufacturing, assembly or final use of the silicon nitride parts, depending on the technical specifications and the criticality of the application.

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 5593, *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.

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

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

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

3.1
surface imperfection
DEPRECATED: surface defect
element, irregularity or group of elements and irregularities of the real surface unintentionally or accidentally caused during manufacture, storage or use of the surface

Note 1 to entry: See definition of "defect" in ISO 9000.

Note 2 to entry: Such types of elements or irregularities differ considerably from those constituting a rough surface.

Note 3 to entry: The presence of imperfection on the real surface does not necessarily mean that the given surface is unsuitable for use. The acceptability of an imperfection is dependent on the application or function of the surface and is specified in appropriate terms, e.g. length, depth, width, height, number per unit area, etc.

Note 4 to entry: The term "indication" can also be used, as a synonym of imperfection, in the frame of visual inspections. The term "indication" is classically used in non-destructive testing field.

Note 5 to entry: The term "real surface" corresponds to the homogeneous, free from irregularities, finished surface of the component.

[SOURCE: ISO 8785:1998, 2.4, modified — The deprecated term has been added; Note 1 to entry has been modified; Notes 4 and 5 to entry have been added.]

3.2
blank
ceramic rolling element after sintering and/or after hot isostatic pressing (HIP) but before grinding

3.3
characteristic
description of the imperfections in terms of size, shape and aspect by the way it appears by visual inspection under naked eyes or small magnification (<100×)

Note 1 to entry: Information related to the origin of the imperfections can be given.

Note 2 to entry: If the term used to describe the same imperfection is already defined in another standard, it is specified, and comments related to the observation of this imperfection can be added.

Note 3 to entry: If other terms can also be used to describe the same imperfection, they are also named for information.

4 Classification of surface imperfections

Several classifications are possible for ceramic rolling element imperfections, depending on the intended goal. In this document, imperfections are classified in four families based on their optical appearance. The terms and descriptions of these four families are given in Figure 1.

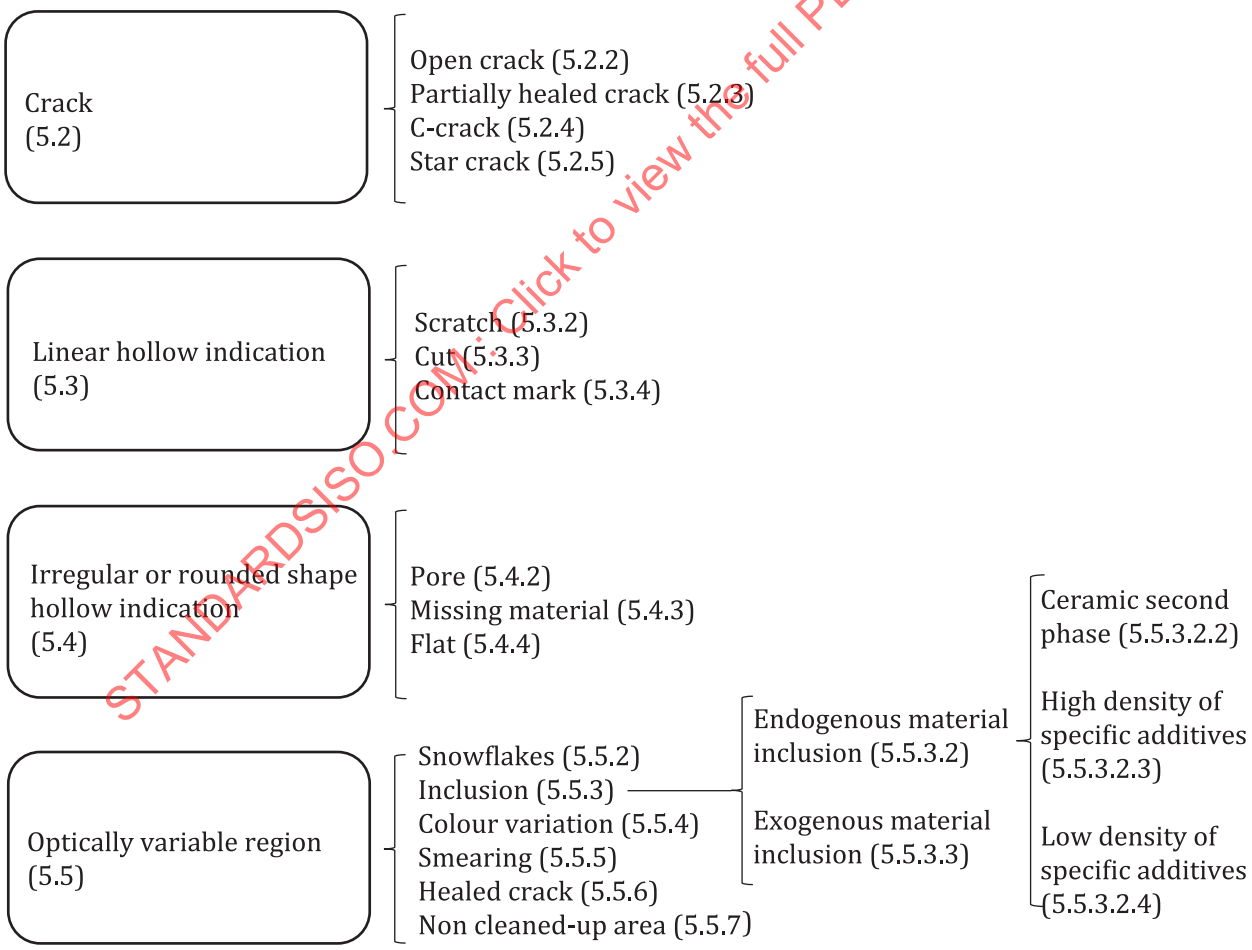


Figure 1 — Families of imperfections

5 Surface imperfections

5.1 General

The following paragraphs give the name, a description of its characteristics and representative pictures of the imperfection at different magnifications. The pictures are obtained by:

— stereo microscope (also known as binocular) and reflected light microscope in bright field [BF] or dark field [DF]; these pictures are named “optical view [BF]” and “optical view [DF]”;

— scanning electronic microscope (SEM) in secondary electrons [SE] or back-scattered electrons [BSE]; these are the pictures named “electronic view [SE]” or “electronic view [BSE]”.

Descriptions of these imaging and illumination methods are described in Annex A and Annex C.

For each imperfection, several pictures of the same type of imperfection are provided to illustrate the different cases which can occur. The pictures are displayed in three types as follows:

a) Type 1 shows a picture taken under optical view BF;

b) Type 2 shows a picture taken under optical view DF;

c) Type 3 shows a picture taken under electronic microscope.

For some terms, there are synonyms used in the field. With the goal of clarifying and homogenising to enable better communication between the different actors of the market, deprecated terms are mentioned in NOTES.

5.2 Crack

5.2.1 General

A crack corresponds to a thin discontinuity in the surface. Its shape is variable and depends on the type of the crack. The bottom of the imperfection is not visible by optical inspection. See Figure 2 to Figure 9.

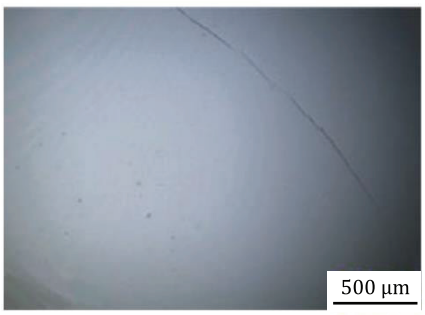
NOTE There are several types of cracks depending on the morphology and the origin of the indication (crack generated during blank manufacturing, during machining or handling).

5.2.2 Open crack

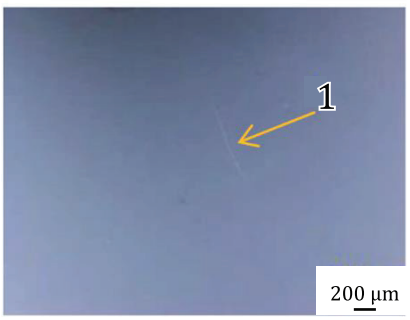
An open crack is an irregular, narrow, opened break in the surface of the element, with straight or jagged edges. A crack can be linear or non-linear.

NOTE 1 Under SEM, Si_3N_4 grains can be visible inside the crack.

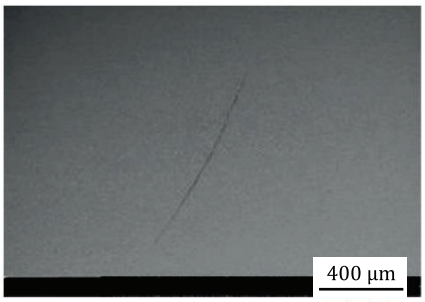
NOTE 2 The deprecated terms for "open crack" are “pressing defects” and “green crack”.



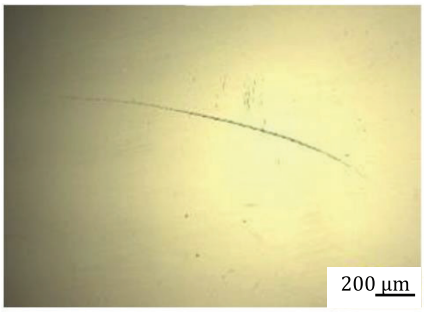
a) Sample 1: surface of a ball – Optical view – [BF]



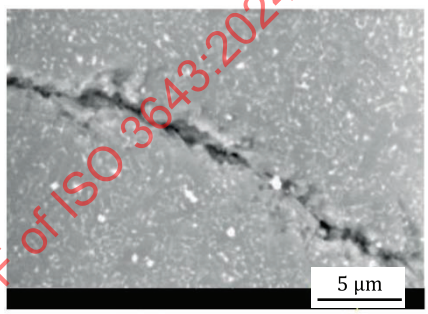
b) Sample 2: surface of a ball – Optical view – [DF]



c) Sample 3: surface of a ball – Electronic view – [BSE]



d) Sample 4: surface of a ball – Optical view – [BF]

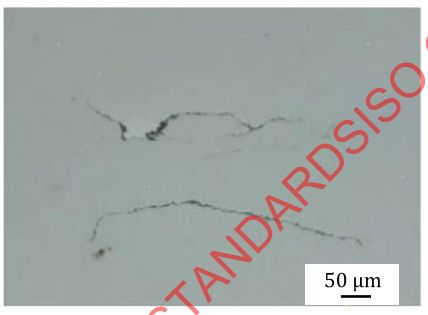


e) Sample 5: surface of a ball (zoom in an open crack) – Electronic view – [BSE]

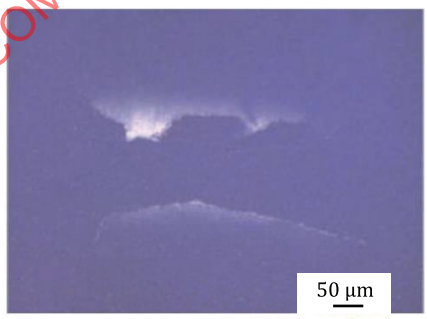
Key

1 open crack without Si_3N_4 grains

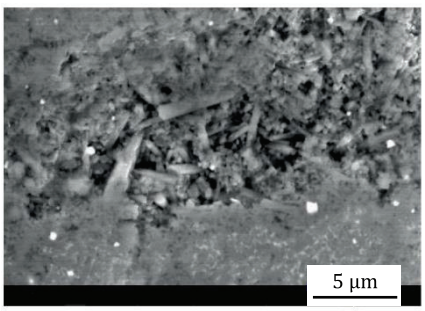
Figure 2 — Examples of open crack without Si_3N_4 grains visible inside the crack



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 1: surface of a ball, same as a) – Optical view – [DF]



c) Sample 2: surface of a ball (zoom in an open crack) – Electronic view – [BSE]

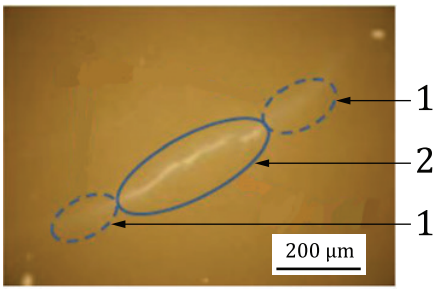
Figure 3 — Examples of open crack with Si_3N_4 grains visible inside the crack

5.2.3 Partially healed crack

A partially healed crack is a mix between open crack (5.2.2) and healed crack (5.5.6). This type of crack can be linear or branched.

NOTE 1 In partially healed crack, sintering additives [oxides of Al (aluminium), Y (yttrium), Mg (magnesium), Ti (titanium)...] can be identified inside the crack with SEM under back-scattered electrons (BSE) detector. In this case, sintering additives appear darker or lighter than the matrix and chemical analysis confirms the nature of the area.

NOTE 2 The deprecated terms for "partially healed crack" are “pressing defects” and “green crack”.



Key

1 healed crack

2 open crack

Figure 4 — Example of partially healed crack (surface of a ball – Optical view – [DF])

5.2.4 C-crack

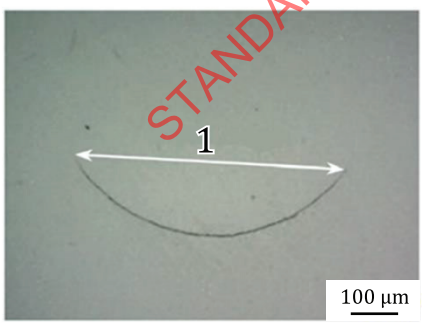
A C-crack is a curved crack, which can be C-shaped or O-shaped when the crack propagation is total. C-cracks can also be stacked. In this case, several concentric C-cracks or O-cracks can be observed.

NOTE 1 Opening of this type of crack is very thin, usually less than 1 µm, which makes them difficult to detect (diffraction on the lips of the crack is needed).

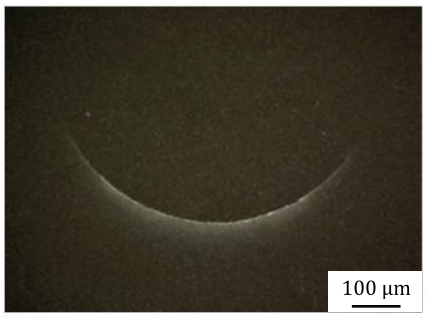
NOTE 2 C-cracks are characterized by the angle of the chord if it is less than 180° or by the diameter for larger chord lengths, as illustrated by Figure 5 a) and Figure 7 a) respectively. For stacked C-crack, the largest is characterized.

NOTE 3 Under SEM observation, no Si_3N_4 grains are observed inside the crack. Crack propagation occurs in a transgranular and intergranular way.

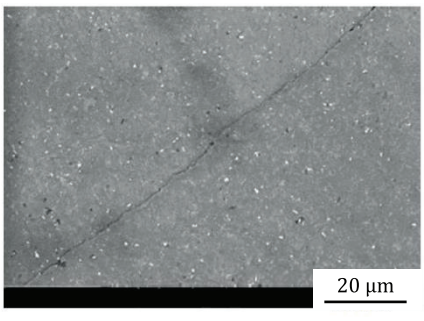
NOTE 4 Missing material (5.4.3) can be observed with C-crack.



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 1: surface of a ball, same as a) – Optical view – [DF]

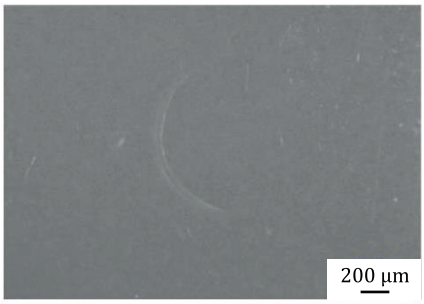


c) Sample 2: surface of a ball (zoom on a C-crack) - Electronic view – [BSE]

Key

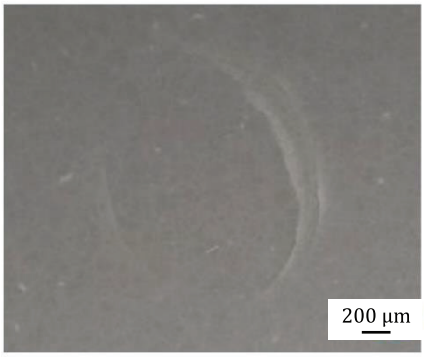
1 chord length

Figure 5 — Examples of C-crack with chordal angle < 180°

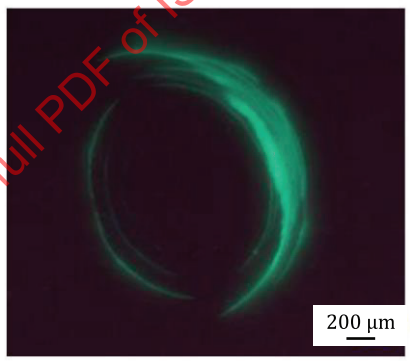


a) Sample 1: surface of a ball – Optical view – [DF] white light

b) Sample 1: surface of a ball, same as a) – Optical view – [DF] UV light

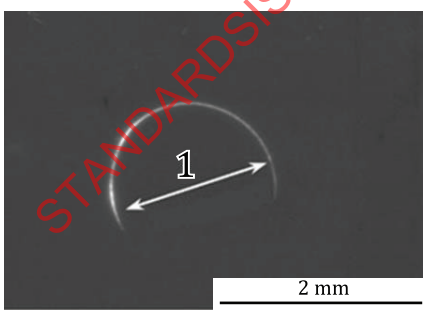


c) Sample 2: surface of a ball (several stacked C-cracks) – Optical view – [DF] white light

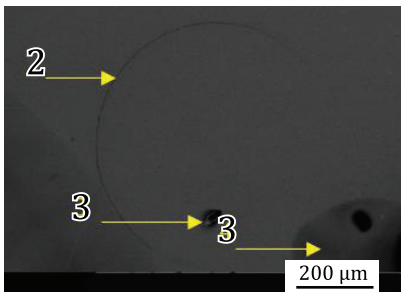


d) Sample 2: surface of a ball, same as c) – Optical view – [DF] UV light

Figure 6 — Examples of stacked C-crack



a) Sample 1: surface of a ball – Optical view – [DF]



b) Sample 2: surface of a ball – Electronic view – [BSE]

Key

1 diameter
2 C-crack
3 marker line

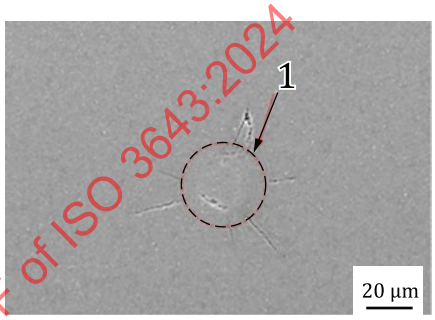
Figure 7 — Examples of C-crack with chordal angle ≥180°

5.2.5 Star crack

The pattern of this type of crack depends on the mean of observation. It can appear as a circular or star shape. Radial cracks are formed around a central ring-crack. In some case, missing material (5.4.3) is observed.

a) Sample 1: surface of a ball – Optical view – [BF]

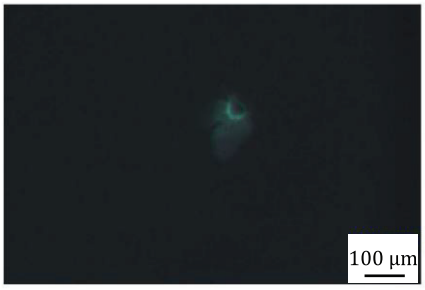
b) Sample 1: surface of a ball, same as a) – Optical view – [DF]



c) Sample 1: surface of a ball, same as a), different orientation – Electronic view – [SE]

d) Sample 2: surface of a ball – Optical view – [BF]

e) Sample 2: surface of a ball, same as d) – Optical view – [DF] white light

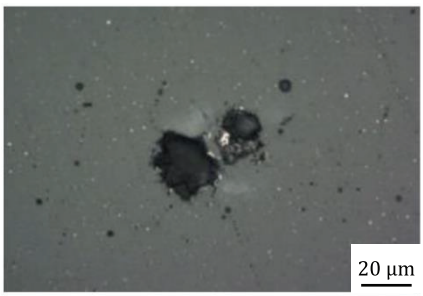


f) Sample 2: surface of a ball, same as d) – Optical view – [BF] UV light

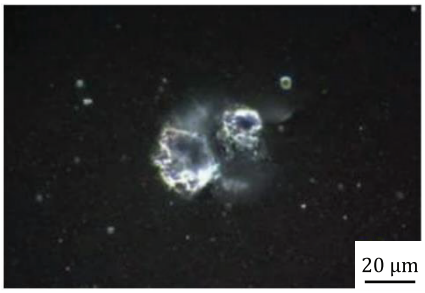
Key

1 star crack without missing material observed as circular shape

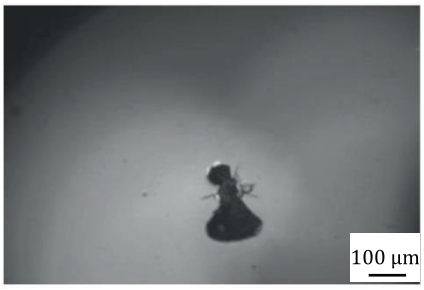
Figure 8 — Examples of star crack



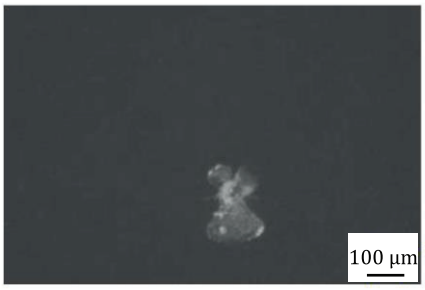
a) Sample 1: surface of a ball – Optical view – [BF]



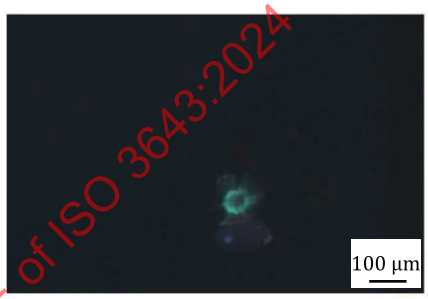
b) Sample 1: surface of a ball, same as a) – Optical view – [DF]



c) Sample 2: surface of a ball – Optical view – [BF]



d) Sample 2: surface of a ball, same as c) – Optical view – [DF] white light



e) Sample 2: surface of a ball, same as c) – Optical view – [BF] UV light

Figure 9 — Examples of star crack with missing material

5.3 Linear hollow indication

5.3.1 General

Linear hollow indication is a shallow imperfection defined by a linear shape (high aspect ratio, i.e. length/width >>1, typically start from an aspect ratio of 5:1) on the surface. The bottom of the imperfection is visible by optical inspection. See Figure 10 to Figure 13.

5.3.2 Scratch

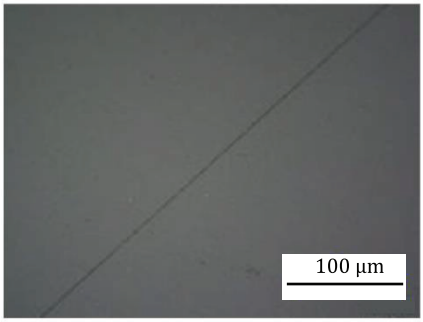
Scratch is a linear, narrow and shallow recession which appears shiny under lighting. Depending on the depth of the scratch it can appear and disappear with the light orientation. Length and width depend on the contact with the abrasive body that contributes to this type of pattern.

NOTE 1 A scratch can be isolated or in group of parallel scratches. When scratches are in group, this group can be seen as an irregular or rounded shape, but individual scratches are linear.

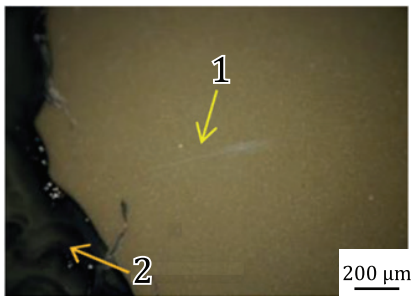
NOTE 2 Needle crystals are not observed in a scratch.

NOTE 3 The deprecated terms for "scratch" are “score”, “scoring” and “scratching”.

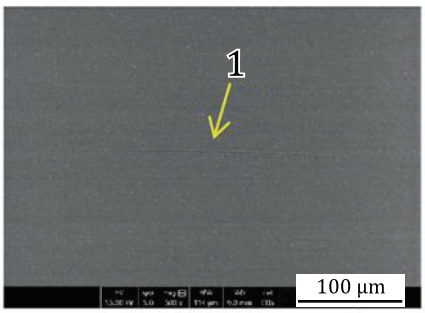
NOTE 4 The deprecated term for "severe scratch" is “groove”.



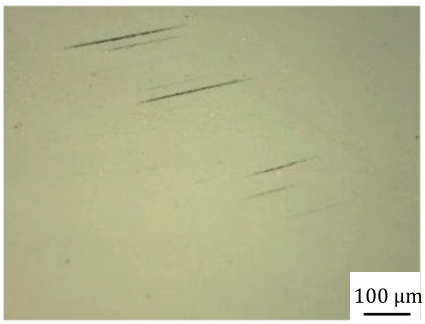
a) Sample 1: surface of a ball – Optical view – [BF] – single scratch



b) Sample 2: surface of a ball – Optical view – [DF] – single scratch



c) Sample 3: surface of a ball – Electronic view – [BSE] – single scratch



d) Sample 4: surface of a ball – Optical view – [BF] – parallel scratches

Key

1 scratch

2 marker line

Figure 10 — Examples of scratch

5.3.3 Cut

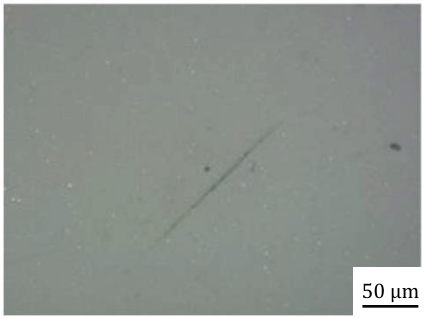
A cut is a linear, short and shallow depression, with a sharply defined matrix which appears shiny under lighting.

NOTE 1 Needle crystals are not observed in a cut.

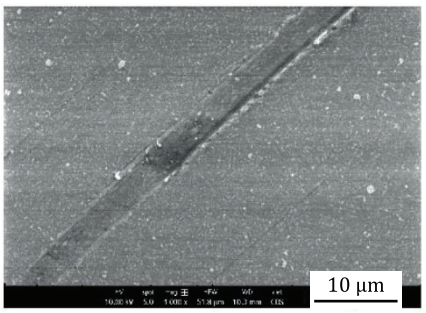
NOTE 2 Cut visibility does not depend on lighting angle.

NOTE 3 Depending on the condition in which the cut is created, width and depth of the cut can be different in terms of geometry and bulges beside the cut can or cannot be visible.

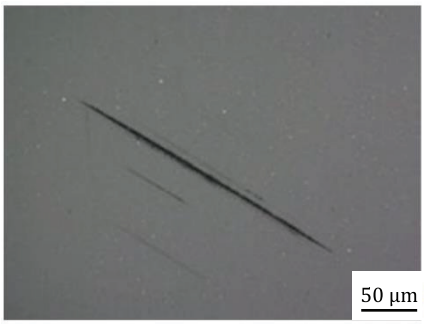
NOTE 4 The deprecated name for "cut" is "gouge".



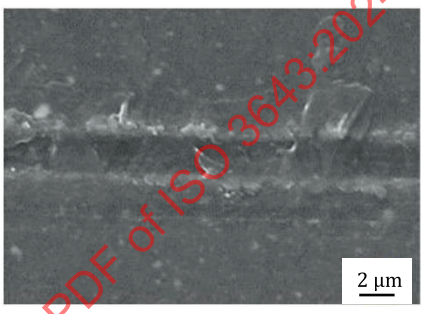
a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 2: surface of a ball – Electronic view – [BSE]



c) Sample 3: surface of a ball (multiple cuts) – Optical view – [BF]



d) Sample 4: surface of a ball (cut with visible bulges) – Electronic view – [BSE]

Figure 11 — Examples of cut

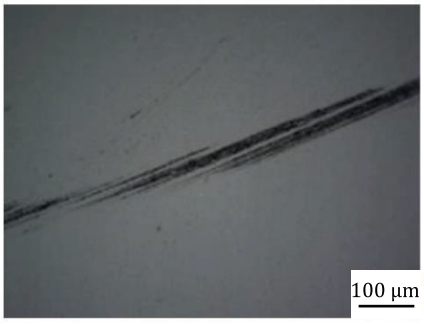
5.3.4 Contact mark

A contact mark is an aggregation of multiple scratches whose width, depth and length depend on the nature of contact surface which has generated this imperfection. Contact marks appear when sliding or rubbing occurs.

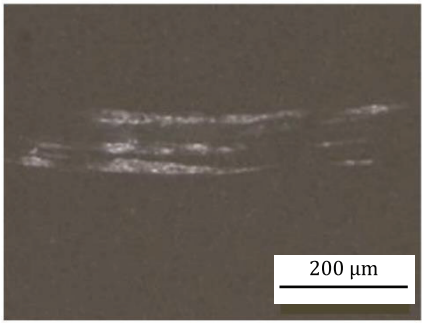
NOTE 1 In some cases, plastic deformation can be observed inside the contact mark.

NOTE 2 A contact mark can be associated with a smearing (5.5.5).

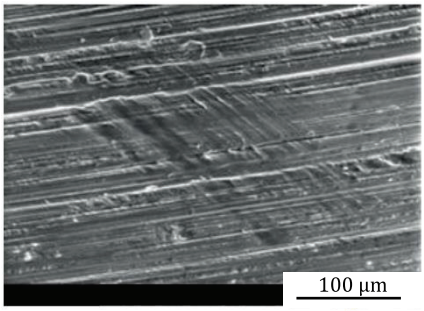
NOTE 3 The deprecated terms for "contact mark" are “scuff”, “scuffing” and "slippage".



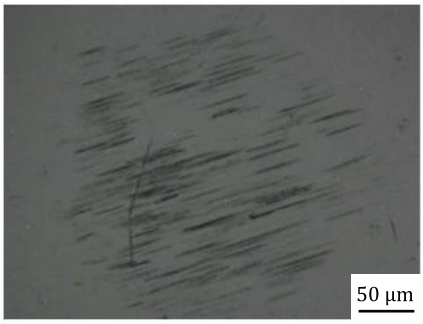
a) Sample 1: surface of a ball – Optical view – [BF]



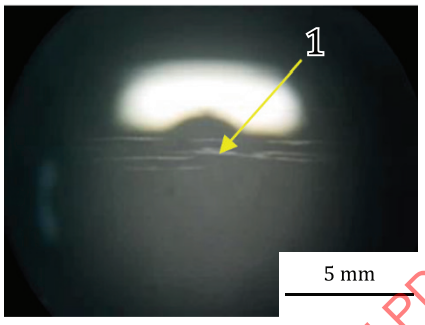
b) Sample 2: surface of a ball – Optical view – [DF]



c) Sample 3: surface of a roller – Electronic view – [BSE]



d) Sample 4: surface of a ball – Optical view – [BF]

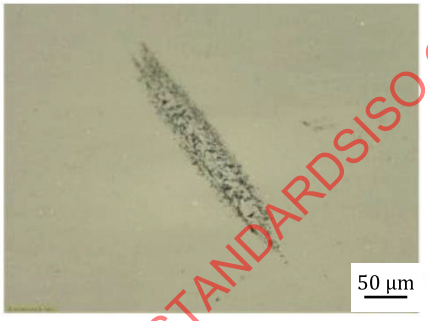


e) Sample 5: surface of a ball – Optical view – [DF]

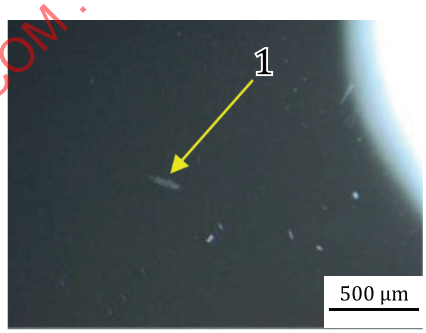
Key

1 contact mark

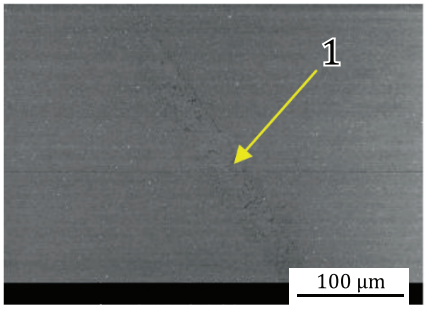
Figure 12 — Examples of contact mark without smearing or plastic deformation



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 2: surface of a ball – Optical view – [DF]



c) Sample 1: surface of a ball, same as a) – Electronic view – [BSE]

Key

1 contact mark

Figure 13 — Examples of contact mark with visible plastic deformation

5.4 Irregular or rounded shaped hollow indication

5.4.1 General

This imperfection is defined by a low aspect ratio, i.e. length/width ≈ 1, corresponding to a shallow rounded or more irregular shape. The bottom of the imperfection is visible by optical inspection. See Figure 14 to Figure 19.

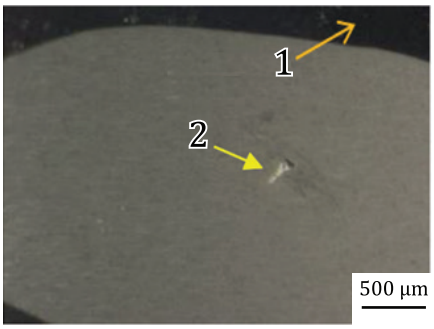
5.4.2 Pore

A pore is a well-defined surface cavity, often with a round aspect. Depth, shape and size can vary. Pores can be found isolated or in cluster.

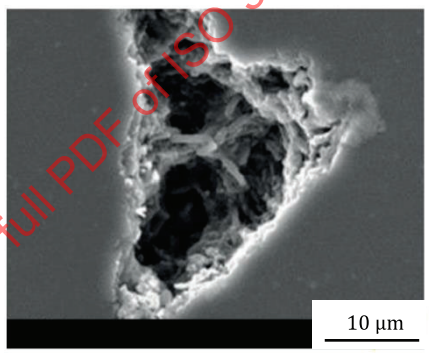
NOTE 1 Under SEM, needle shaped β-Si_3N_4 grains are visible.

NOTE 2 The deprecated terms for "pores" are “pit”, “hole”, “porosity "and “void”.

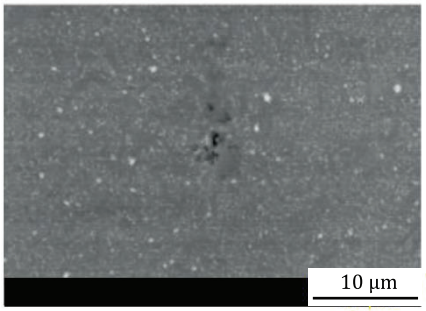
NOTE 3 The deprecated term for "cluster of pores" is “pitting”.



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 2: surface of a ball – Electronic view – [SE]



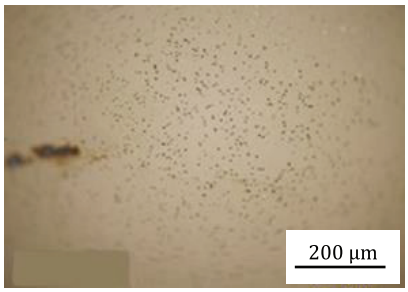
c) Sample 3: surface of a ball – Electronic view – [BSE]

Key

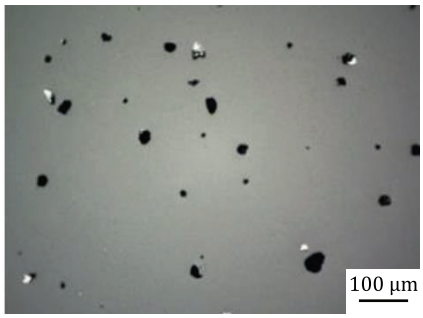
1 marker line

2 pore

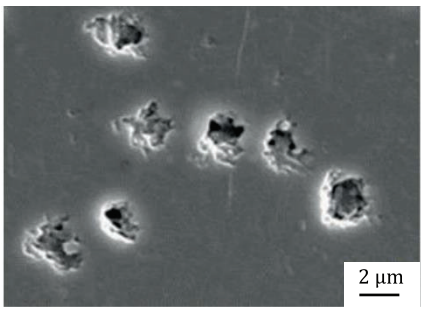
Figure 14 — Examples of isolated pore



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 2: surface of a ball – Optical view – [BF]



c) Sample 3: surface of a ball – Electronic view – [SE]

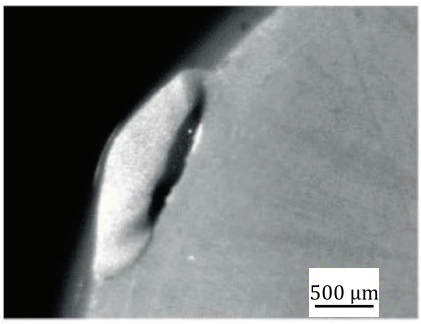
Figure 15 — Examples of pores in cluster

5.4.3 Missing material

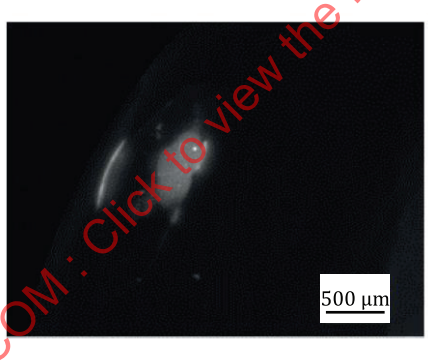
A missing material corresponds either to a depression or a removal of material from the surface. The size, shape and depth can vary. It can appear shiny or dark depending on light orientation.

NOTE 1 Under SEM, no needle shaped β-Si_3N_4 grains are visible, except if chipping occurred on the green body, in this case, needle shaped β-Si_3N_4 grains can be visible.

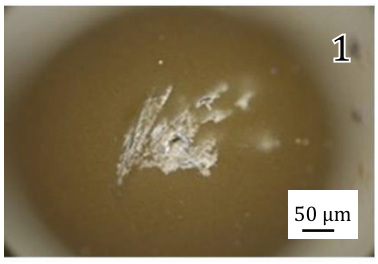
NOTE 2 The deprecated terms for "missing material" are “mark”, “pit”, “dent”, “nick "and “chip”.



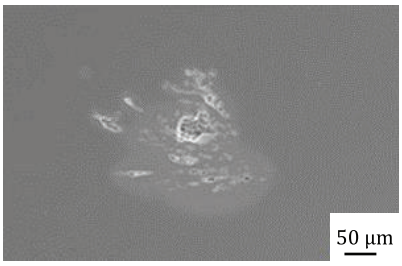
a) Sample 1: chamfer of a roller – Optical view – [BF]



b) Sample 1: chamfer of a roller, same as a) – Optical view – [DF]

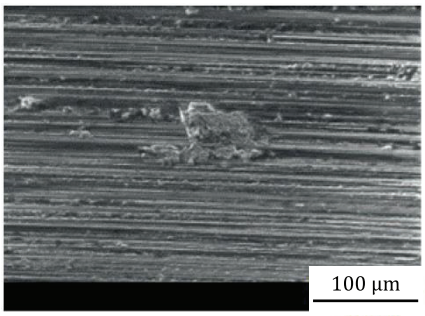


c) Sample 2: surface of a ball– Optical view – [DF]



d) Sample 2: surface of a ball, same as c) with zoom – Electronic view – [SE]

e) Sample 3: surface of a ball – Optical view – [DF]

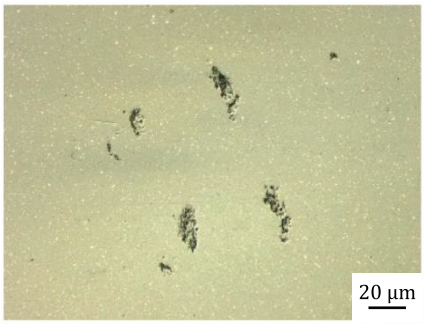


f) Sample 4: surface of a ground roller –Electronic view – [BSE]

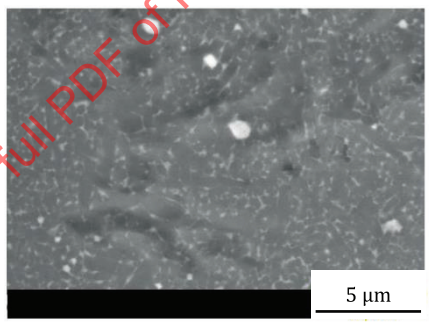
Key

1 lighter coloured area corresponds to reflected light on the surface of the ball

Figure 16 — Examples of missing material



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 1: surface of a ball, same as a) with zoom – Electronic view – [BSE]

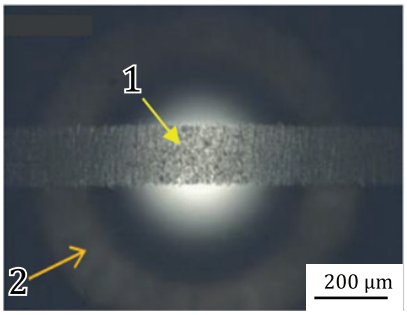
Figure 17 — Examples of missing material created by depression

5.4.4 Flat

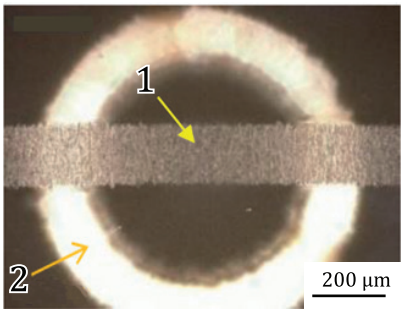
A flat corresponds to an area where machining marks are pronounced. It corresponds to non-appropriate rubbing or lapping against the grinding plates or wheel. It can be localized or extended in band shape.

NOTE 1 Flats do not necessarily have machining marks. They can have been removed by further “machining”.

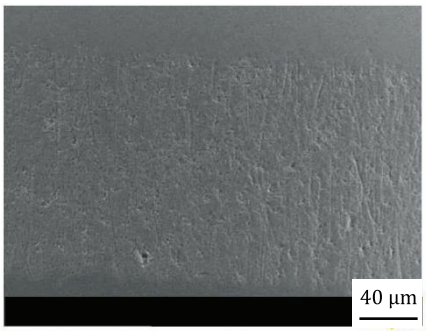
NOTE 2 On the two optical views [BF] and [DF], lighting is visible, reflected on the surface of the rolling element. This does not come from the imperfection.



a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 1: surface of a ball, same as a) – Optical view – [DF]



c) Sample 1: surface of a ball, same as a) with zoom – Electronic view – [SE]

Key

1 flat

2 lighting

Figure 18 — Example of flat in band shape

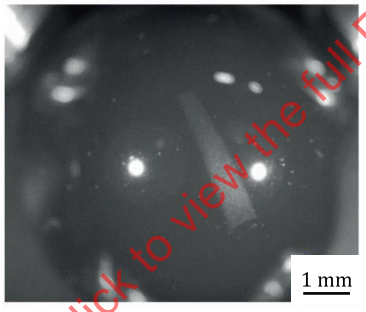


Figure 19 — Example of localized flat on the surface of a ball – Optical view – [BF]

5.5 Optically variable region

5.5.1 General

An optically variable region corresponds to an area where the light reflects in another way, darker or lighter than the rolling element surface, without topography variation of this surface. See Figure 20 to Figure 28.

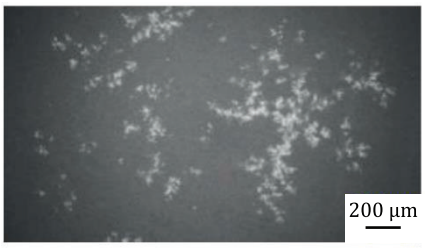
5.5.2 Snowflakes

Snowflakes correspond to patterns which can be distributed in different ways such as single isolated, in cluster, spotty, circular nested or widely present on the surface. They can be very small (submicrometres) or large (up to several tens of micrometres or even cover the whole surface of a part)[4].

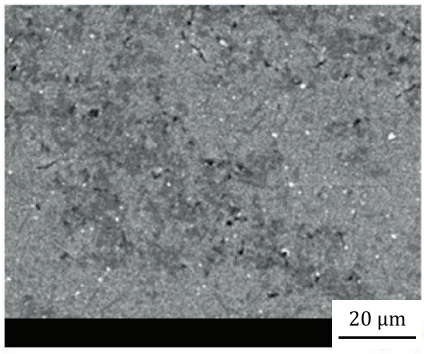
NOTE 1 High magnification SEM observation reveals this type of indications is an area of micro pores (around 1 µm) corresponding to non-filled triple junction (a triple junction is a point where three grains meet). There is no variation of composition associated with this indication, but tiny changes can be observed in the microstructure.

NOTE 2 Topographical variations can be detected on some snowflakes if they are large or in cluster for example.

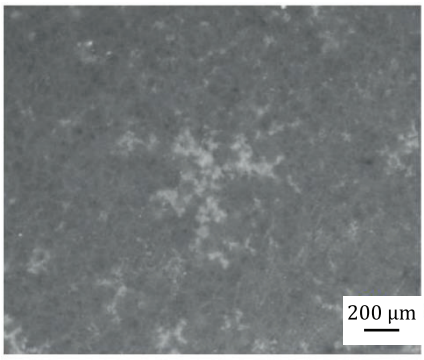
NOTE 3 The name for "snowflakes" comes from the fact that sometimes this indication appears with dendritic morphology.



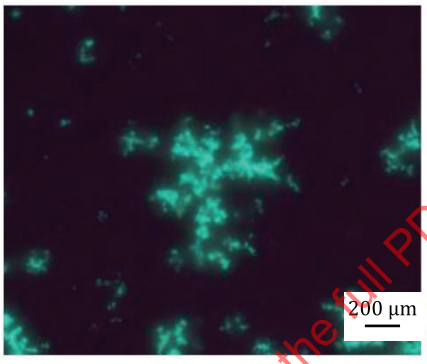
a) Sample 1: surface of a ball – Optical view – [DF]



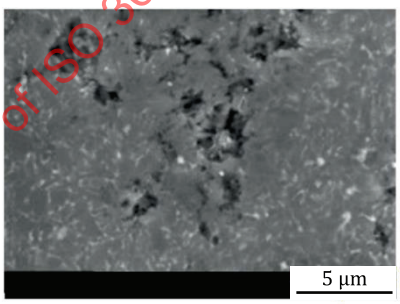
b) Sample 1: surface of a ball, same as a) with zoom – Electronic view – [BSE]



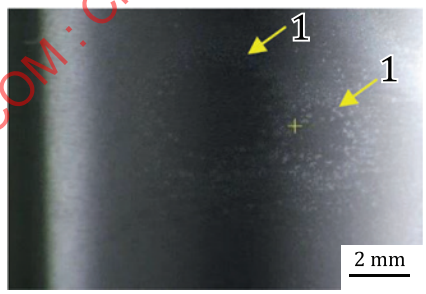
c) Sample 2: surface of a ball – Optical view – [BF] white light



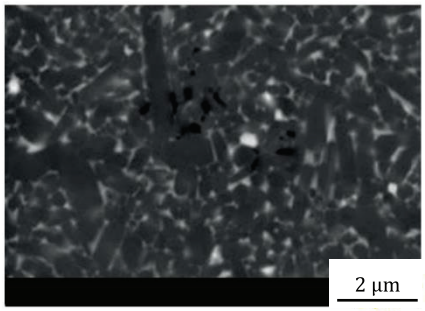
d) Sample 2: surface of a ball, same as c) –Optical view – [BF] UV light



e) Sample 3: surface of a ball – Electronic view – [BSE]



f) Sample 4: surface of a roller – Optical view – [DF]



g) Sample 4: surface of a roller, same as f) with zoom – Electronic view – [BSE]

Key

1 snowflake

Figure 20 — Examples of snowflake

5.5.3 Inclusion

5.5.3.1 General

An inclusion corresponds to endogenous or exogenous material detected inside the part. See ISO 26602:2017, 3.2. Depending on its origin, this type of imperfection appears differently on the surface of the rolling element.

5.5.3.2 Endogenous material inclusion

5.5.3.2.1 Overview

An endogenous material inclusion is a heterogeneity of the intergranular phase which has a different visual aspect depending on the type of heterogeneity, with well-defined or blurred aspect. It can be of three types depending on its appearance: ceramic second phase, high density of specific additives and low density of specific additives.

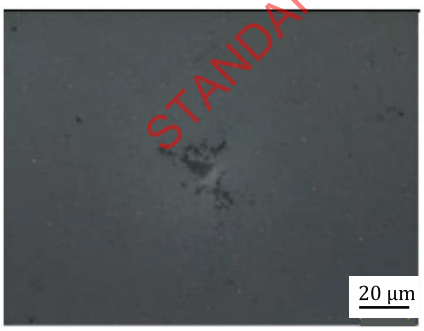
NOTE The deprecated terms for "endogenous material inclusion" are “additive agglomerate”, “black phase”, “black spot "and “segregation”.

5.5.3.2.2 Ceramic second phase

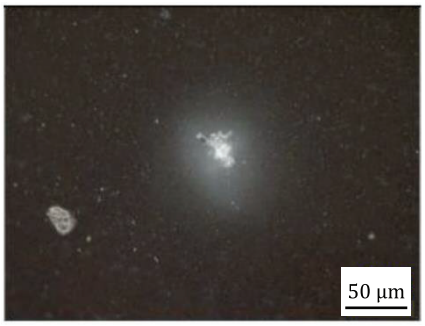
Ceramic second phase corresponds to inhomogeneous distributed mainly glassy, partly crystalline additive phase (such as Y_2O_3 and Al_2O_3) which appears darker or lighter than the silicon nitride matrix, with a well-defined aspect. Size ranges from few to several tens of micrometres. It can be combined with pores (5.4.2) or missing material (5.4.3).

a) Sample 1: surface of a ball – Optical view – [BF]

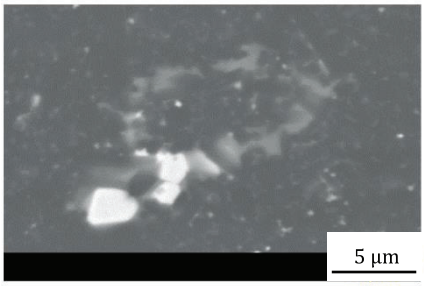
b) Sample 1: surface of a ball, same as a) – Optical view – [DF]



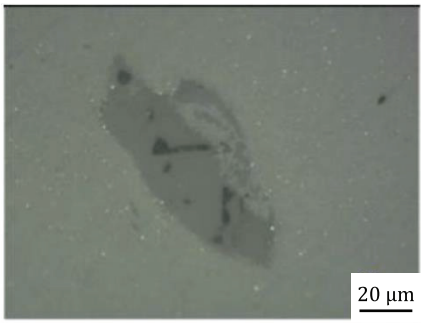
c) Sample 2: surface of a ball – Optical view – [BF]



d) Sample 2: surface of a ball, same as c) – Optical view – [DF]



e) Sample 3: surface of a ball – Electronic view – [BSE]

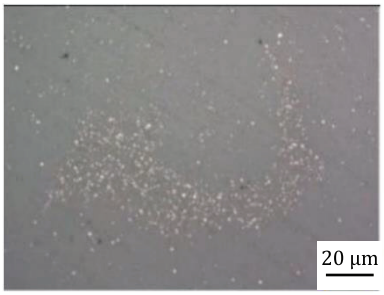


f) Sample 4: surface of a ball – Optical view – [BF]

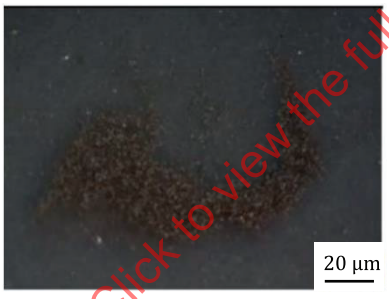
Figure 21 — Examples of ceramic second phase

5.5.3.2.3 High density of specific additives

A high density of specific additives corresponds to an accumulation of specific additives [such as Ti (titanium) or W (tungsten) compounds] which recombines to create other forms. It appears blurred and darker than the matrix under DF lighting, and highly reflective under BF lighting, but lighter under BSE.

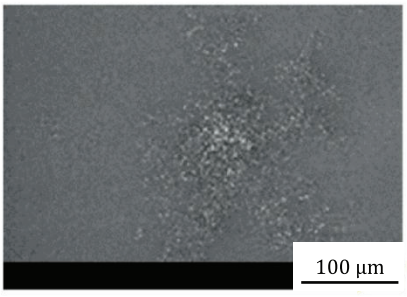


a) Sample 1: surface of a ball – Optical view – [BF]

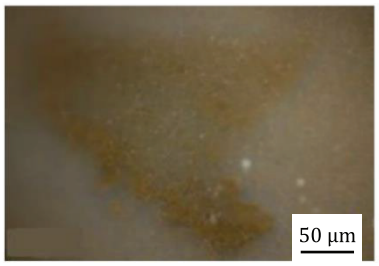


b) Sample 1: surface of a ball, same as a) – Optical view – [DF]

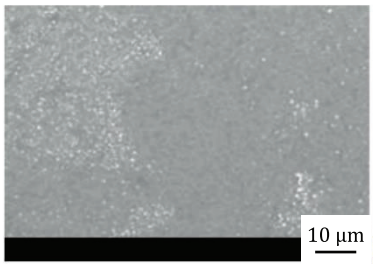
c) Sample 2 : surface of a ball – Optical view – [BF]



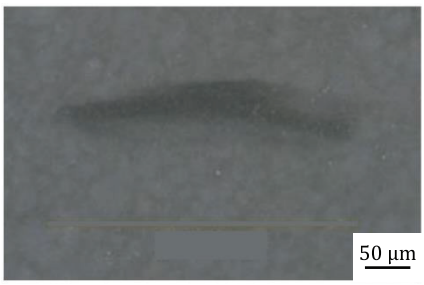
d) Sample 3: surface of a ball – Electronic view – [BSE]



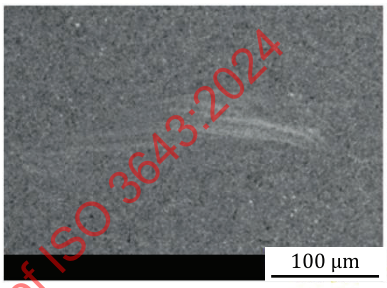
e) Sample 4: surface of a ball – Optical view – [DF]



f) Sample 5: surface of a ball – Electronic view – [SE]



g) Sample 6: surface of a ball – Optical view – [DF]

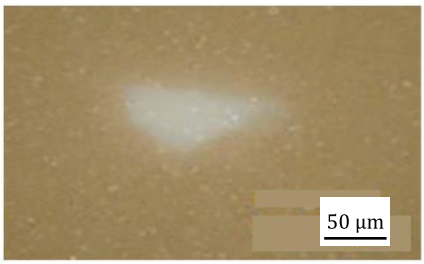


h) Sample 6: surface of a ball, same as g) – Electronic view – [BSE]

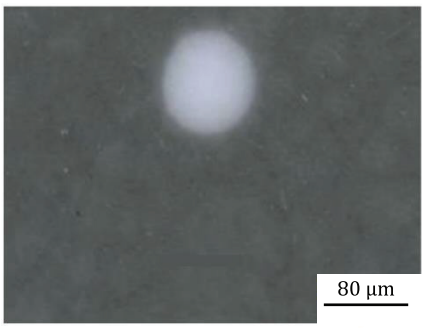
Figure 22 — Examples of high density of specific additives

5.5.3.2.4 Low density of specific additives

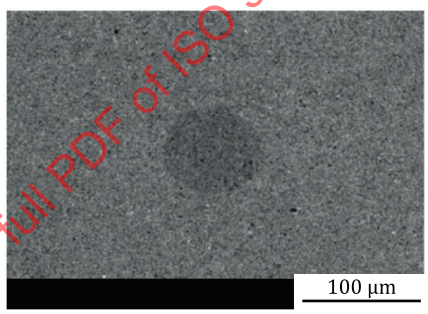
A low density of specific additives corresponds to a depletion of specific additives [such as Ti (titanium) or W (tungsten) compounds]. It often appears blurred and lighter than the matrix under DF lighting, but darker under BSE. Low density of specific additives area is inconspicuous under BF lighting.



a) Sample 1: surface of a ball – Optical view – [DF]



b) Sample 2: surface of a ball – Optical view – [DF]



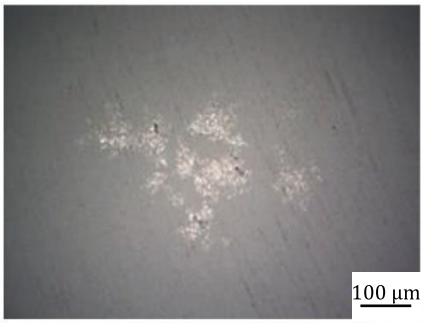
c) Sample 2: surface of a ball, same as b) – Electronic view – [BSE]

Figure 23 — Examples of low density of specific additives

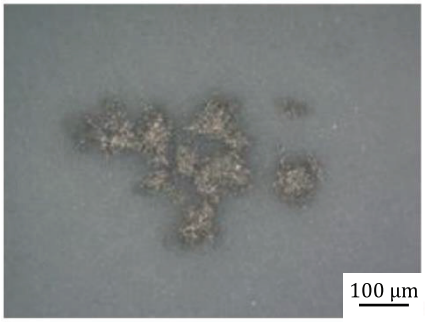
5.5.3.3 Exogenous material inclusion

An exogenous material inclusion can be of metallic nature, ceramic or a mix. It appears as well-delimited phase. Size and shape can vary depending on the contamination. Under BF lighting, metallic inclusions appear shiny, whereas non-metallic inclusions appear non-shiny.

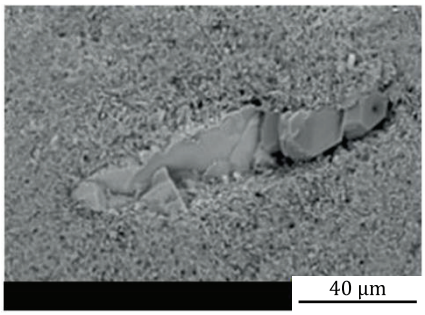
Sometimes, decohesion with Si_3N_4 matrix can be observed in association. Nature of the inclusion can be identified by energy dispersive X-ray (EDX) spectrometer analysis.



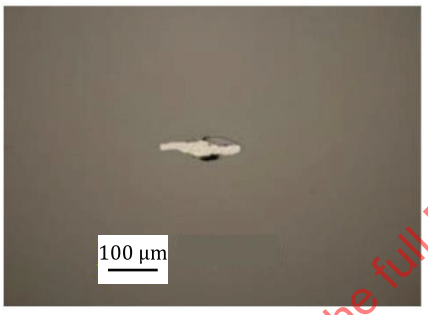
a) Sample 1: surface of a ball – Optical view – [BF]



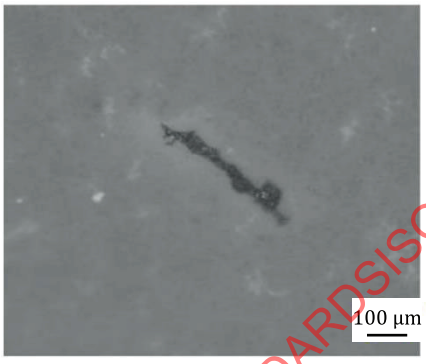
b) Sample 1: surface of a ball, same as a) – Optical view – [DF]



c) Sample 2: surface of roller (before grinding) – Electronic view – [BSE]

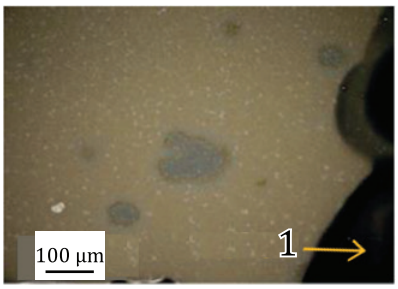


d) Sample 3: surface of a ball – Optical view – [DF]



e) Sample 4: surface of a ball – Optical view – [BF]

f) Sample 4: surface of a ball, same as e) – Optical view – [DF]



g) Sample 5: surface of a ball – Optical view – [DF]

Key

1 marker line

Figure 24 — Examples of exogeneous material inclusion

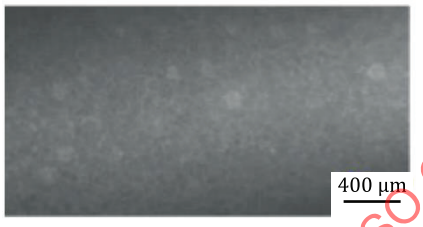
5.5.4 Colour variation

A colour variation is a grey shade variation of different shape and size, darker or lighter of the matrix depending on the exact composition, with blurred appearance, most often visible without magnification but not detected by SEM in BSE mode[5].

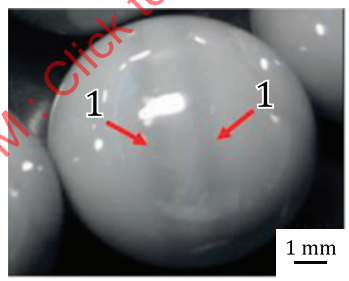
NOTE 1 The deprecated terms for "colour variation" are “discoloration” and "discolouration”.

NOTE 2 No modification of microstructure or indentation is detectable in the area of colour variation under high magnification SEM observation.

NOTE 3 Colour variation is not detected by SEM in BSE or EDX analysis (See Figure 25 d)).

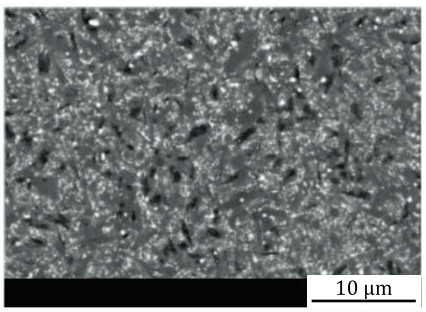


a) Sample 1: surface of a ball – Optical view – [BF]



b) Sample 2: surface of a ball – Optical view – [DF]

c) Sample 3: surface of a ball – Optical view – [BF]



d) Sample 4: surface of a ball – Electronic view – [BSE]

Key

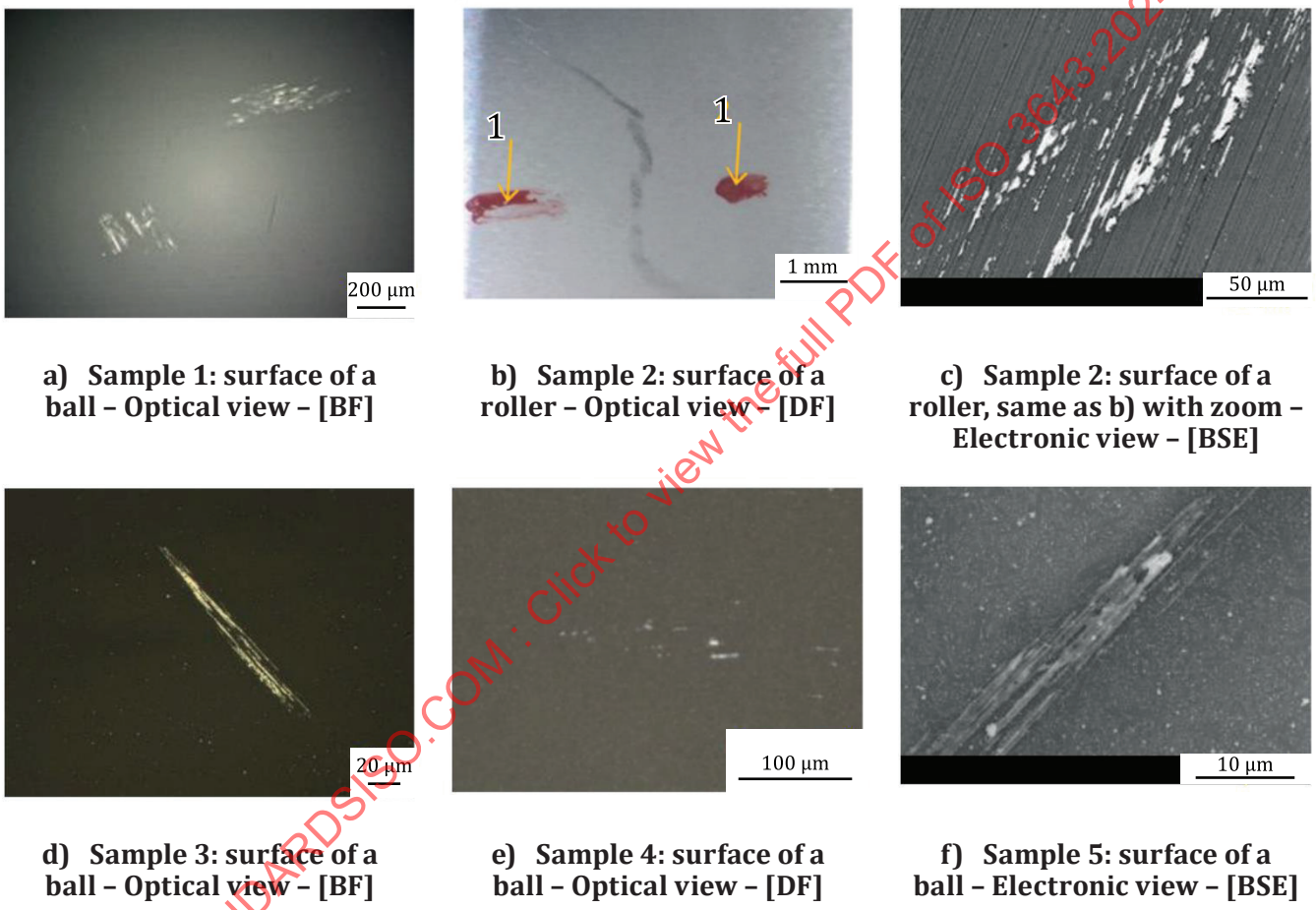
1 colour variation

Figure 25 — Examples of colour variation

5.5.5 Smearing

A smearing is a localized shiny or mat area depending on the type of foreign material transferred on the surface, caused by contact (rubbing) with another material, softer than ceramic, which creates a deposit on the surface. Shape and size of this imperfection depend on the contact.

NOTE Smearing is not detectable by dimensional measurement.



a) Sample 1: surface of a ball – Optical view – [BF]

b) Sample 2: surface of a roller – Optical view – [DF]

c) Sample 2: surface of a roller, same as b) with zoom – Electronic view – [BSE]

d) Sample 3: surface of a ball – Optical view – [BF]

e) Sample 4: surface of a ball – Optical view – [DF]

f) Sample 5: surface of a ball – Electronic view – [BSE]

Key

1 marker line

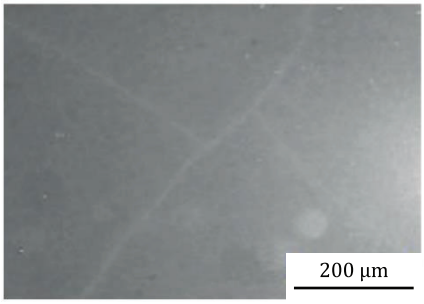
Figure 26 — Examples of smearing

5.5.6 Healed crack

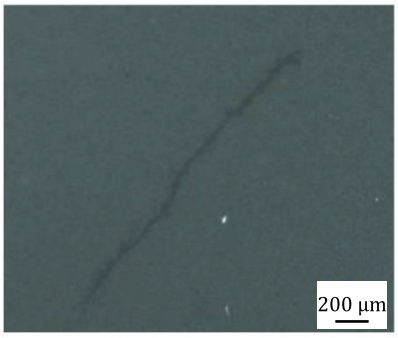
A healed crack is an irregular, narrow, closed break in the surface of the element, with shiny white reflect inside the crack under DF lighting, due to the presence of glassy phase. This type of crack can be linear or branched.

NOTE 1 Healed crack has the same microstructure and composition as the matrix.

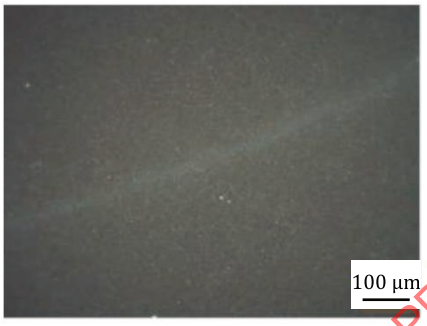
NOTE 2 The deprecated terms for "healed crack" are “pressing defects” and “green crack”.



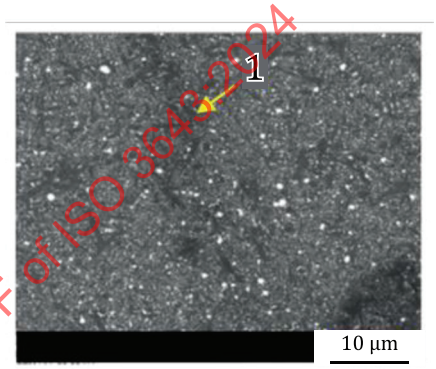
a) Sample 1: surface of a ball – Optical view – [DF]



b) Sample 2: surface of a ball – Optical view – [BF]



c) Sample 3: surface of a ball – Optical view – [DF]



d) Sample 4: surface of a ball – Electronic view – [BSE]

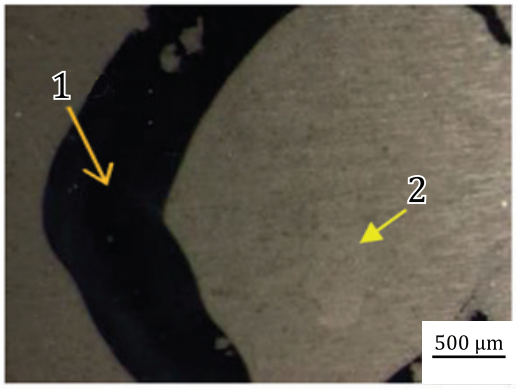
Key

1 healed crack

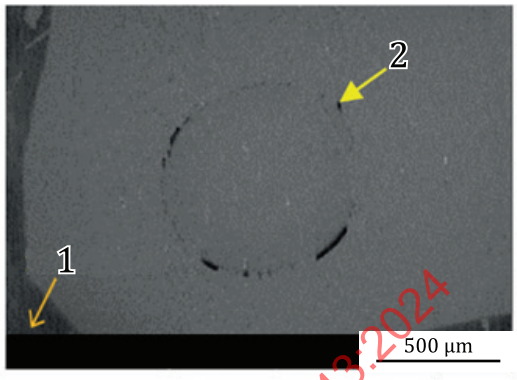
Figure 27 — Examples of healed crack

5.5.7 Non cleaned-up area

A non cleaned-up area is a shiny or mat area which can be removed by cleaning (mechanically or chemically), which is caused by dust, stain or dried residues.



a) Sample 1: surface of a ball – Optical view – [DF]



b) Sample 2: surface of a ball – Electronic view – [BSE]

Key

1 marker line

2 non cleaned-up area

Figure 28 — Examples of non cleaned-up area

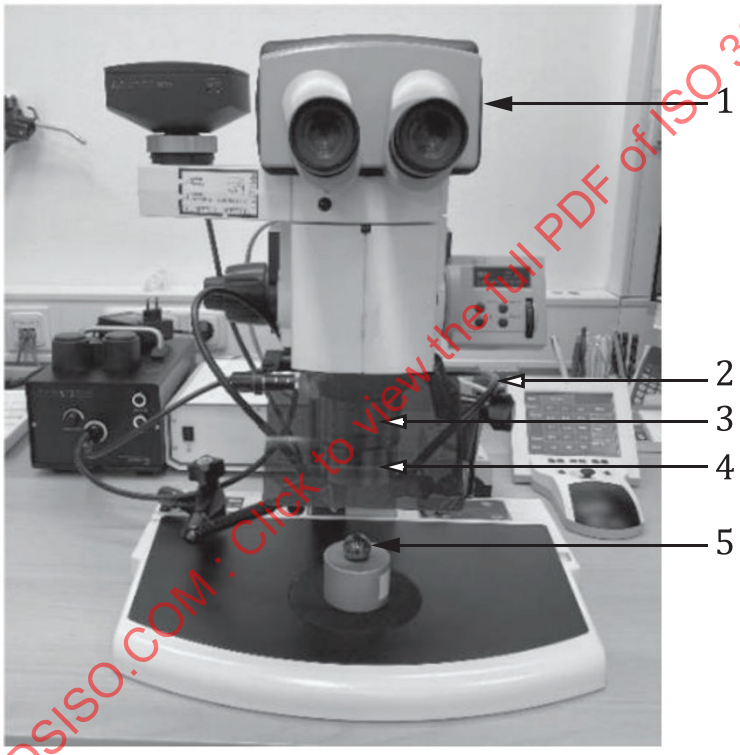
Annex A
(informative)

Explanations for the terms used in inspection means

A.1 Optical microscopy

A.1.1 General

Inspection by optical microscopy of ceramic rolling elements is typically performed with a stereo microscope, also named binocular. See Figure A.1 for an example.



Key

1 ocular lens
2 lighting (coaxial)
3 objective lens
4 lighting (ocular)
5 sample

Figure A.1 — Example of stereo microscope

A stereo microscope is a type of microscope that commonly uses visible light (see A.1.2) and a system of lenses to generate magnified images of small objects. It is possible to equip such a microscope with an additional UV-light source for fluorescent penetrant inspection (FPI) in form of a “gooseneck” light guide.

Usual magnification for this device is between 6× to 200×, but some binoculars can reach higher resolution and magnification.