



BSI Standards Publication

Micrographic examination of the non-metallic inclusion content of steels using standard pictures

National foreword

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Micrographic examination of the non-metallic inclusion content of steels using standard pictures

Détermination micrographique de la teneur en
inclusions non-métalliques des aciers à l'aide d'images-
types

Metallographische Prüfung des Gehaltes
nichtmetallischer Einschlüsse in Stählen mit Bildreihen

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European foreword

This document (EN 10247:2017) has been prepared by Technical Committee ECISS/TC 101 “Test methods for steel (other than chemical analysis)”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2018, and conflicting national standards shall be withdrawn at the latest by January 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 10247:2007.

The many changes in the current revision result from only a few basic adjustments. The length to width limit ratio for globular inclusions has been changed from 1,3 to 3 (Annex I), and the mathematical principles underlying the chart have been more clearly defined (Annex H). These two changes have led to many numerical changes in Table 2 and Figure 11, where moreover some classes have been deleted and others added. The rules of assessment have changed, most notably to allow stringer formation from two particles upward (Subclause 3.1.2, Annex B), to exclude stringer formation between a stringer and a single particle (Subclause 3.1.2), and to consistently define the classification of inclusions by shape, arrangement, and colour (Clause 3, Annexes A and B). Finally, the assessment and recording sheets have been redesigned to simplify manual use (Annexes K, L, and M).

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document establishes procedures for the assessment of inclusions in steels, based on their morphology using standard pictures.

These procedures include principles that yield results coherent with consolidated individual inclusion measurements and expressed in physical units.

The chart of standard pictures is derived from mathematical principles. In distinction to other inclusion rating standards, in this standard the order of the classification begins with the length (row index q).

The results may be directly computed from field assessments. The same precision level is achieved by using the same method in manual evaluation and computer controlled measurements.

The results are in physical units: length in $\mu\text{m}/\text{mm}^2$, number/ mm^2 , areas in $\mu\text{m}^2/\text{mm}^2$.

1 Scope

This European Standard defines a method of microscopic non-metallic endogenous inclusion assessment using picture charts.

The method does not apply to particles of a length or diameter less than 3,0 μm or a width smaller than 2,0 μm . If defined by a product standard or agreement between the involved parties for certain special products, inclusions with a width below 2,0 μm can be evaluated by length alone. Inclusions with dimensions exceeding the upper limits in Table 2 are evaluated as belonging to the maximum class and noted separately with their true dimensions (see 8.5.6).

It is assumed, if particles are elongated or if there are stringers of particles, that they are parallel to each other. Other arrangements are not covered by this draft standard. This draft European Standard applies to samples with a microscopic precipitation approaching random distribution.

From the data of measurements obtained by this method, evaluation according to other standards can be established.

This draft European Standard does not apply to free cutting steels.

NOTE The basic principle of this draft European Standard allows the determination of non-metallic inclusion content by image analysis techniques.

2 Normative references

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

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025)*

ISO 9042, *Steels — Manual point counting method for statistically estimating the volume fraction of a constituent with a point grid*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 General:

3.1.1

particle

single precipitate, in general non-metallic

3.1.2

stringer

arrangement of at least 2 particles, normally aligned, that meet the proximity conditions $e \leq 40 \mu\text{m}$ and $t \leq 10 \mu\text{m}$

Note 1 to entry: For formation of stringers particles with $L < 3 \mu\text{m}$ or $w < 2 \mu\text{m}$ are not taken into account (see Figure 5).

Note 2 to entry: See Figure 3 for proximity conditions, Figure 7 and Annex B and Annex C for examples

3.1.3

inclusion

general designation of a ratable feature composed of at least one particle, defined by the size and proximity of its constituents

Note 1 to entry: The inclusion can describe a single particle; a single stringer; or an agglomeration of stringers.

Note 2 to entry: Stringers that meet the proximity conditions $e \leq 40 \mu\text{m}$ and $t \leq 10 \mu\text{m}$ form an agglomeration of stringers (see Figure 4). Formation of inclusions by combining stringers and single particles is not permitted.

Note 3 to entry: If elongated and globular particles are combined (see Figure 6), in general the result is treated as one inclusion.

Note 4 to entry: For further examples see Figure 7.

3.1.4

test area

area on the polished surface of the specimen to be evaluated

3.2 Proximity:

3.2.1

distances between particles

distance e between the particles in the direction of main deformation and distance t in the direction perpendicular to it

Note 1 to entry: See Figure 3 for illustration.

3.2.2

distance between stringers

similar to that for the distance between particles

Note 1 to entry: See Figure 4 for illustration.

3.2.3

scattered

random arrangement of particles

Note 1 to entry: For example see Annex C. This is defined in one field of view.

3.3 Parameters:

3.3.1

length

dimension of an inclusion in the main deformation direction, usually larger than the width

3.3.2

diameter

maximum dimension of inclusion classified according to column 6 (globular inclusion)

3.3.3**width**

dimension of inclusion perpendicular to the direction of principal deformation

Note 1 to entry: In particular for inclusions consisting of more than one particle, a subscript of “total” can be used to distinguish its width from the individual widths of the particles.

Note 2 to entry: For inclusions consisting of a single particle, the width is the maximum dimension perpendicular to the main deformation direction (see Figure 1).

For inclusions consisting of a single stringer, the width is the width of the confining rectangle (see Figure 2).

For inclusions consisting of an agglomeration of stringers, three cases apply:

- Case a) two stringers for which $0 \leq e \leq 40 \mu\text{m}$, $t \leq 10 \mu\text{m}$: the width of this inclusion is the width of the widest stringer ($w_{\text{total}} = w_1$; $w_1 > w_2$; see Figure 4 a)).
- Case b) two stringers for which $e < 0 \mu\text{m}$, $t \leq 10 \mu\text{m}$: the width of this inclusion is the sum of the stringers' widths and the distance t ($w_{\text{total}} = w_1 + w_2 + t$; see Figure 4 b)).
- Case c) an agglomeration of more than two stringers: the width of this inclusion is the widest width obtained by applying the rules in case a) and b) (see Figure 4 c)).

3.3.4**area**

area of the equivalent ellipse, calculated as

$$a = \frac{\pi}{4} \times L \times w_{\text{total}}, \quad (1)$$

or, in the case of globular particles,

$$a = \frac{\pi}{4} \times d^2 \quad (2)$$

Note 1 to entry: For details see 3.3.2 and Figures 1, 2, and 4.

3.3.5**shape factor**

exponent f in the formula:

$$\frac{\pi/4 \times L^2}{a} = \left(\frac{L}{1\mu\text{m}} \right)^f \quad (3)$$

Note 1 to entry: For details see Annex D.

3.4 Classes:**3.4.1****elongated particles**

particles with a ratio $L/w \geq 3$

Note 1 to entry: See Figure 1 for illustration.

3.4.2

globular particles

particles with a ratio $L/w < 3$

Note 1 to entry: See Figure 1 for illustration.

3.4.3

type

distinction of inclusions according to their shape, arrangement, and colour, and, if desired, by their apparent chemical composition

Note 1 to entry: See Annex A for illustration.

3.5 Others:

3.5.1

lot

unit of material processed at one time and subject to similar processing variables

3.5.2

restricted values

values of the average field assessment restricted to inclusions of a specified size range, or restricted to inclusions of specified types

Note 1 to entry: See Annex M.4 and Tables M.6 and M.7 for further detail.

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

Symbol	Unit	Designation
A	μm^2	area of field of view on the specimen
B	mm^2	polished surface
D		diameter of product
G		magnification
H	μm	length of measuring frame on the specimen
K	$\sim, \mu\text{m}, \mu\text{m}^2/\text{mm}^2$	average field assessment
L	μm	length of inclusions
M	$\sim, \mu\text{m}, \mu\text{m}^2/\text{mm}^2$	worst field assessment
MD		main deformation direction (e.g. rolling direction)
N_j		number of fields
N_s		number of specimens
P		worst inclusion assessment

Q		factor for K-assessment
R		restricted values
a	μm^2	area of inclusions
$\bar{a}$ or $\bar{a}$		average (mean) value of n, L, w, a
b	mm	width of the plate
b		black
c		coloured (pink or yellow) (typically nitrides)
d	μm	diameter of inclusions
e	μm	distance between the particles in the main deformation direction
f		shape factor
g		grey (typically sulphides)
i		inclusion index
j		field index
k		column number
m		type of inclusion index
$\max$		index of maximum value of n, L, w, d, a (in j or s)
n		number of assessed particles, inclusions
n_s		number of assessed inclusions per specimen
p		particle index
q		row number
s		specimen index
t	μm	distance between the particles perpendicular to the main deformation direction
u	μm	scale unit in microscope eyepiece
v	mm	width of polished surface
w	μm	width of inclusions
x		variable
α		scattered, elongated inclusion type
α_b		scattered, elongated, black inclusion type
α_c		scattered, elongated, coloured inclusion type
α_g		scattered, elongated, grey inclusion type
β		aligned, globular inclusion type
β_b		aligned, globular, black inclusion type,

β_c	aligned, globular, coloured inclusion type
β_g	aligned, globular, grey inclusion type
γ	aligned, elongated inclusion type
γ_b	aligned, elongated, black inclusion type
γ_c	aligned, elongated, coloured inclusion type
γ_g	aligned, elongated, grey inclusion type
δ	scattered, globular inclusion type
δ_b	scattered, globular, black inclusion type
δ_c	scattered, globular, coloured inclusion type
δ_g	scattered, globular grey inclusion type

Combined symbols shall be written with indices.

EXAMPLE	K_L	average field assessment for length;
	n_j	number of inclusions in a field;
	$\overline{n_j}$	average number of inclusions per field.

5 Principles

This standard consists of a comparison between inclusions observed in a field of view and chart pictures. The chart classifies inclusions into four different types according to their shape (8.4 / Annex H). The minimum requirements for applying this method are a square measuring frame of 0,71 mm x 0,71 mm overlaid on the viewfield at a magnification of 100:1 (see Figure 9), along with the chart – or alternatively a measuring scale and Table 2 of this draft standard.

An inclusion according to this standard can consist of a single particle, a stringer of particles, or an agglomeration of stringers. All inclusions are treated as ellipses (see Figure 1), with special rules for agglomerations of stringers (3.1.3 / Figure 4). Inclusions are classified according to shape, arrangement, and size (Annex A). A classification by colour is also permissible in order to differentiate apparent chemical composition (Annex A), although this classification provides no information on crystal structure or actual chemical composition.

The length and width of an inclusion are estimated by the class values of its corresponding row and column in the picture chart. The chart pictures depict the upper class boundaries. Upon classification, all further calculations refer to the class values in Table 2.

This standard yields different results depending on the chosen method: the largest inclusions (worst inclusion method), the largest inclusion parameters per field of view (worst field method), and an averaged inclusion content (average field method). If not determined by product standards, the involved parties shall agree on the preferred method for their steel grade. The default rating methods are the worst inclusion method ($P_{L/d}$) and the average field method (K_n , $K_{L/d}$). All results have physical dimensions, regardless of the method.

Annexes M, N, and P include examples for recording and for calculating results. The following section contains a brief practical guide to the evaluation specified in this standard.

6 Brief practical guide

6.1 Basic rules for evaluation

a) Preparing the measurement:

- 1) Take and prepare specimens according to Clause 7, Sampling.
- 2) Define the test area and a starting point for the measurement.

b) Examining the test area:

- 1) Scan the entire test area at the selected magnification (usually 100:1).
- 2) Evaluate all inclusions using the measurement frame or a measuring scale, or image analysis.

c) Exclusion of particles outside of the scope:

- 1) Exclude from evaluation all particles with a length or diameter $< 3 \mu\text{m}$ or a width $< 2 \mu\text{m}$.

d) Rules for ascertaining inclusions:

- 1) Distinguish globular from elongated particles using the length-to-width ratio. According to 3.4 Classes, particles with $L/w < 3$ are globular and particles with $L/w \geq 3$ are elongated.
- 2) Inclusions can consist of a single particle, a stringer of particles, or an agglomeration of stringers.
- 3) The proximity conditions for joining together particles or stringers are $e \leq 40 \mu\text{m}$ and $t \leq 10 \mu\text{m}$ (see 3.1.2, stringer, and Note 2 to 3.1.3, inclusion).
- 4) Particles that do not meet the proximity conditions are rated as individual inclusions.
- 5) A stringer is formed and rated as an inclusion when at least two particles meet the proximity conditions.
- 6) Stringers that meet the proximity conditions are joined to form an agglomeration of stringers. The agglomeration (and not the individual stringers) is rated as an inclusion.
- 7) Inclusions consisting of different types of particles are classified according to the areally predominant shape and subsequently, if necessary, according to the areally predominant colour.
- 8) Inclusions longer than the field of view are rated according to their total dimensions and only rated once.
- 9) Inclusions longer or wider than the classes in the scope of this standard (oversized) are rated as belonging to the largest possible class and reported separately with their actual dimensions.

e) Rating the inclusions:

- 1) Using a measuring scale and the chart (or Table 2), the observed inclusions are classified according to shape, arrangement, and size, and rated according to the parameters of the chosen method (see Clause 9, Types of assessment).
- 2) The inclusions are assigned to the types α , β , γ and δ according to their shape and arrangement. Where a differentiation by colour is required, inclusions are assigned to the types EA, EC, EAB, EB, EAD, and ED (see Annex A).
- 3) The inclusions are rated according to Table 2 or the picture chart. The chart pictures and values in Table 2 represent the upper class boundaries.
- 4) An inclusion is classified in row q if for its length L_x :

$$L_{q-1} < L_x \leq L_q \text{ } [\mu\text{m}]$$

- 5) An inclusion is classified in column k if for its width w_x :

$$w_{q,k-1} < w_x \leq w_{q,k} \text{ } [\mu\text{m}]$$

Upon classification by length and width, all further calculations (e.g. for inclusion area) refer to the class values in Table 2.

6.2 Evaluation according to the default rating methods

— **Method P_L , P_d – Ascertaining the largest inclusions by length and diameter (see Subclause 9.1, method P):**

For every inclusion type (α , β , γ , δ or EA, EAD, EB, EAB, EC, ED), rate and record the inclusion with the largest value for the chosen parameter (L or d). The recording sheet K.1 can be used for documentation (see Annex K).

The result is the average of the individual values for each specimen.

— **Method K_n , K_L and K_n , K_d – Ascertaining the mean inclusion content by number, as well as by length and diameter (see Subclause 9.3 and Annex M):**

Rate and record every inclusion of the chosen types (e.g.: α , β , γ , δ or EA, EAD, EB, EAB, EC, ED) according to the chosen parameter (L or d). Take care that each inclusion is recorded once and only once. Record the examined area. The recording sheet M.2 can be used for documentation (see Annex M).

The result is an averaged inclusion content. The computation sheet M.3 can be used to obtain this result (see Annex M).

7 Sampling**7.1 General**

Unless otherwise specified in the technical delivery conditions, the following requirements apply.

7.2 Degree of reduction

The shape of the inclusions depends, to a large extent, on the degree of reduction of the steel. The chart can only be used if the shape of inclusions in the specimen can be compared with that given in the pictures of the chart.

NOTE The lower the degree of reduction, the likelier it is that porosities remain in the steel. Failing to properly differentiate them from inclusions will affect the final result. Too high a degree of reduction will lead to inappropriate statistical representation of the longest inclusions.

7.3 Size and location of test area

The polished surface of the specimen used to determine the content of inclusions should cover a minimum of 200 mm² (e.g. 20 mm x 10 mm) and shall be parallel to the direction of the main deformation direction (e.g. rolling direction).

The sampling and the number of specimens shall be specified in the product standard or shall be subject to agreement between parties.

In the absence of an agreement, the sampling procedure shall be as follows, see Figure 8:

- a) bar or billets with a diameter above 50 mm: the test area shall be located halfway between the outer surface and the centre. The longer side shall be perpendicular and the shorter side parallel to the main deformation direction (see Figure 8 a));
- b) bar with a diameter greater than 25 mm and less than or equal to 50 mm: the surface to be examined consists of half the diametric section (from the centre to the edge of the specimen) (see Figure 8 b));
- c) bar with a diameter less than or equal to 25 mm: the surface to be examined consists of the full diametric section (see Figure 8 c));
- d) plates with a thickness less than 25 mm: the specimen contains the whole thickness (see Figure 8 d));
- e) plates with a thickness between 25 mm and 50 mm: the specimen contains half the thickness, position between surface and centre;
- f) plates with a thickness greater than 50 mm: the specimen contains one quarter of the thickness. The position is not defined.

The positions of the measuring planes for tubes are given in Figure 8 e).

For thin products one sample could comprise several specimens. In this case the test area is smaller than 200 mm² per specimen.

For any other product, the sampling procedures shall be subject to agreement between parties.

7.4 Number of specimens

Single specimens do not provide a representative index of the content of inclusions of a cast or a batch and therefore the test shall be carried out on a number of specimens. If the number of specimens taken is not defined in the product standard or by special agreement, the content of inclusions shall be determined on not less than six specimens.

7.5 Preparation of specimens

The specimen shall be cut so as to obtain a surface for examination. In order to achieve a flat surface and to avoid rounding the edges of the specimen when polishing, the specimen may be held mechanically or may be mounted.

When polishing specimens, it is important to avoid any tearing out or deformation of the inclusions or contamination of the polished surface, so that the surface is as clean as possible and the appearance of the inclusions is not affected. These precautions are of particular importance when the inclusions are small. It is advisable to use diamond paste for polishing. The kind of lubricant can depend on the inclusion type (water may not be an acceptable lubricant for certain types of inclusions, e.g. sulfides). No particles of a grinding or polishing agent shall be pressed into the polished surface. In certain cases it may be necessary for the specimen to be hardened before polishing in order to retain inclusions.

8 Test method

8.1 Magnification

The measuring frame length of 710 μm shall be used if nothing else is specified. If it is not possible to use this value, other magnifications can be used and shall be recorded. The magnification shall not be changed during one measurement.

When analyzing images, the resolution of the picture shall be higher than the shortest length to be determined. Magnifying hundredfold (10x lens), the calibration factor should be 1 μm / pixel or finer and adapted to the optical resolution of the complete system, which ranges up to 0,3 μm in the ideal case. The smallest particles to be determined should be mapped at at least 10 pixels.

The magnification G is defined only by the size of the measuring frame on the specimen. To use the chart with different magnifications, the length H of the side of the measuring frame on the specimen will have one of the three following values: $H = 355 \mu\text{m}$, $H = 710 \mu\text{m}$, $H = 1\,420 \mu\text{m}$.

These values shall be used with an accuracy of $\pm 0,02 \text{ mm}$ for manual evaluation. The area A of one measuring frame on the specimen is given in Table 1.

Table 1 — Area A in function of the measuring frame

H μm	A mm^2	<i>Magnification</i>
355	0,13 (0,126)	200:1
710	0,50 (0,504)	100:1
1 420	2,0 (2,016)	50:1

EXAMPLE See Annex E.

8.2 Microscope settings for image analysis and manual analysis

For automated particle detection the full dynamic range of 8 bit gray values and/or colour values should be used. To achieve the maximum possible image dynamics, settings of the microscope and of the digital image source should be set according to the manufacturer's recommendations. The image source, provided it has an adjustable Gamma (gamma correction), should be set to a gamma correction value of 1.

The matrix should be located at the top of the gray level scale (>200) as an approximate normal distribution. Everything outside this matrix normal distribution in the direction of gray level 0 (black)

should be considered as particles. In the case of the distinction between gray and black particles, this area may again be divided. As a general rule, black is defined as the range from 0 - 130 and gray as the range from 131 to about 180. These ranges are not absolute or normative. The segmentation should be checked in the gray scale image. The flicker method is a recognized method for this purpose.

Colour image analyses should be handled similarly.

8.3 Field of view

At a magnification corresponding to $H = 710 \mu\text{m}$ the square frame is given by an etched glass in the eyepiece graticule, as defined in Figure 9. For broad field microscopes, the etched glass defined in Figure 10 may be used.

Additional information is drawn on the etched glass (see Annex F), and information concerning the manufacturing of the graticules is given in Annex G.

One scale unit in the eyepiece is $10 \mu\text{m}$ for $H = 710 \mu\text{m}$. The correct value shall be checked by calibration.

When analyzing images the field of view can take up the entire image area of the camera when applying the analyzing method K (see 9.3). If this is the case, an appropriate margin correction shall be provided.

8.4 Definition of the pictures of the chart

8.4.1 Size and Shape

The shape of the inclusions is assumed to be an ellipse, see Figures 1 and 2. From this ideal shape the actual pictures are drawn to have an appearance as realistic as possible with a variation of size and shape (see Figure 11).

NOTE Small inclusions are only visible in pictures of original size in the official chart, but not in Figure 11.

8.4.2 Parameters

Inclusions can be described using the parameters number n , length L , width w , and area a . The parameters n , L , and w are measured or estimated directly, whereas a is calculated using the data in Table 2.

8.4.3 Arrangement of the pictures

The pictures of the chart are arranged in horizontal rows q and vertical columns k (see Figure 11). Columns 1 to 5 contain ellipses with different widths representing elongated inclusions. Column 6 utilizes circles for describing globular inclusions. Columns 7 to 11 present globular particles arranged as stringers. The dimensions correspond to the values given for Columns 1 to 5. Column 12 shows different numbers of inclusions per field to replace counting by estimation (see 8.5.2).

The column to the left of Column 1 shows inclusions with a width of $2 \mu\text{m}$ and a length corresponding to the maximum length for its row. Above the pictures, the types of the inclusions according to Annex A are indicated.

The pictures represent upper limits of classes. The class is denoted by the number of row q and the Column k in this sequence.

EXAMPLE The designation of class 3.4 denotes the class row 3, Column 4.

For details see Annex I.

8.5 Procedure

8.5.1 General

The prepared sample is placed under the microscope, usually at a magnification of 100 : 1. For ease of use, eyepiece graticules as described in Figures 9 and 10 may be used. In each field of view the inclusions are classified by shape, arrangement, and size by comparison with the pictures of the chart, determining first the row and then the column of the class corresponding to the inclusion. A chart in original size shall be used for this comparison, not the pictures in Figure 11. Inclusions may additionally be classified by colour.

Whether evaluating manually or with image analysis, inclusions may equally be rated by measuring them and comparing them to values of Table 2, instead of using the chart.

8.5.2 Several inclusions of mixed sizes in one field

8.5.2.1 General

To simplify the manual evaluation where many inclusions occur in one field of view, the following approximations for length, width or area (indirectly) can be employed.

8.5.2.2 Elongated inclusions

Up to 3 stretched inclusions; these are evaluated separately. If there are more than three inclusions in one field of view, evaluation shall be carried out in three steps:

- a) inclusions with a length greater than a quarter of the length of the longest inclusion present are evaluated as individuals according to the chart;
- b) for the rest of the inclusions, the average length of all inclusions and the average width are estimated. Chart classification (row, column and number) is established using these parameters;
- c) the number of inclusions is recorded for the class defined in b). This number can be estimated using Column 12 (see Figure 11).

8.5.2.3 Globular inclusions

If the inclusions are greater or equal to 11 µm, then each shall be evaluated separately. In other cases, evaluation shall be carried out in three steps:

- a) inclusions with a diameter greater than half the diameter of the largest inclusions in the field are evaluated as individuals according to the chart;
- b) for the rest of the inclusions the average diameter is estimated and chart classification is carried out by comparison with the pictures of Column 6;
- c) the number of inclusions is determined and recorded for that class. This number can be estimated using Column 12 (see Figure 11).

8.5.3 Scanning

For all assessments the whole test area shall be scanned.

8.5.4 Assessment and evaluation

Three types of assessments are defined and used in agreement with the customer or the product standard:

- a) worst inclusion assessment (see 9.1);
- b) worst field assessment (see 9.2);
- c) average field assessment (see 9.3).

For average field assessment, the evaluation can be restricted according to 3.5.2 or made separately for each column. These restrictions shall be specified in the product standards.

8.5.5 Evaluation of different types of inclusions

This draft European Standard refers only to size, shape and arrangement of inclusions. As additional elements, colours can be taken into account (see Annex A). More information and examples are given in Annex C.

Classes of inclusion types and arrangement can be compared with those of other standards (see Annex J).

8.5.6 Recording of results

For recording and final calculations of results it is recommended to use the sheets of Annex K, Annex L and Annex M, or derived arrangements adapted to the needs of the laboratory.

As a default, heterogeneous inclusions, partly or completely encapsulated, shall be considered as one inclusion.

The product standard or agreement between the parties shall establish for inclusions with mixed particles such as Figure 6, Example 2, whether the two different types are one particle or two types of particles mixed. Without an agreement, if an inclusion consists of both stretched and globular particles, it shall be analyzed according to the areally predominant shape and subsequently, if necessary, according to the areally predominant colour.

Unless otherwise agreed, numbers lower than 10 should be exactly quoted with two digits after the comma, all other values should be rounded to integers.

If no special arrangements are made, inclusions greater in length and/or width than the max. value of the class, are assigned to the max. possible class. During subsequent assessment they are taken into account using the parameters of the class to which they were assigned. In addition, they are noted separately in the test report as oversized inclusions with indication of their true length and width.

Instead of the type designations α , γ , β , δ (grey/black, coloured) the group designations EA, EB, EC, ED, EAB, EAD, and EF (EFB, EFD) can be used. Using the group designations can lead to a loss of information regarding inclusion arrangement (scattered vs. aligned).

9 Types of assessment

9.1 Worst inclusion method: method P

9.1.1 Principle

The whole test area shall be scanned field by field. The field size is $H = 710 \mu\text{m}$ for any case, see 8.1. On each test area, for each type of inclusion, only the inclusion having the greatest value of the selected parameter (L , d or a) is evaluated by comparison with the chart and recorded.

The result of the evaluation is the average of the individual values of the N_S assessed specimens.

The formulae for this method are given in Annex N.

Assessment and computation sheets with comments and examples are given in Annex K.

9.1.2 Evaluation of P_L (worst length)

Evaluation can be made as a rating according to the length method P_L . In this case just the row number of the greatest inclusion in the test area is recorded following the pictures of the chart. The final result P_L is the average of the N_S samples.

9.1.3 Evaluation of P_d (worst diameter)

This evaluation is valid for globular inclusions. The assessment is similar to that of P_L , but restricted to Column 6.

9.1.4 Evaluation of P_a (worst area)

Evaluation can be made as a rating according to area, method P_a . Only the inclusion with the greatest area is recorded. This is realized by classification according to length and width and using the appropriate row and column number to pick up the area from Table 2.

9.2 Worst field method: method M

9.2.1 Principle

The value according to method M is determined by scanning the complete measurement area. The field size is $H = 710 \mu\text{m}$ (100 : 1), for any case (see 8.1).

Each specimen is inspected in a search for the field containing the greatest value of the selected parameter (n , L , d , or a) for each type of inclusion. The corresponding row and column are recorded for these fields alone.

The result of the evaluation is the average of the individual values of the N_S assessed specimens.

Assessment and computation sheets are given with comments and examples in Annex L. The formulae this method is based on are given in Annex N.

9.2.2 Evaluation of M_n (rating according to number)

For each specimen, only the greatest number of inclusions per field M_{ns} is recorded per inclusion type.

If there are few inclusions, they are counted. If not, their number can be estimated by using Figure 11, column 12. For N_S specimens, M_n is the average of the individual values M_{ns} .

9.2.3 Evaluation of M_L (rating according to length)

For the test areas of each specimen s , the worst field is the one with the maximum cumulated length of a particular inclusion type. For one specimen this value is M_{Ls} .

The lengths of all inclusions shall be taken into account.

For N_S specimens, M_L is the average of the individual values M_{Ls} .

9.2.4 Evaluation of M_d (rating according to diameter)

For N_S specimens, M_d is the average of the individual values M_{ds} evaluated like the values of M_{Ls} .

9.2.5 Evaluation of M_a (rating according to area)

The worst field is the one with the maximum cumulated area of a particular inclusion type. For one specimen this value is M_{as} .

9.3 Average field method: method K

9.3.1 Principle

The K value is an average of a parameter for the entire test area. The K value is evaluated on scanning the entire test area.

The K value can be calculated:

- for number (K_n), or number and length (K_n , K_L), or number and area (K_n , K_a) for elongated inclusions;
- for number (K_n), or number and diameter (K_n , K_d), or number and area (K_n , K_a) for globular inclusions.

The total number of assessed fields N_i , including empty fields, shall be counted.

The formulae this method is based on are given in Annex N, Annex P and Annex Q. Assessment and computation sheets are given with comments and examples in Annex M.

9.3.2 Scanning of a specimen for average field assessment

The test area is scanned field by field. For any evaluation of size values an edge error correction shall be made to make sure that inclusions are counted only once (see Annex O).

9.3.3 Evaluation

9.3.3.1 Complete evaluation

Parameter values (see Table 2) as defined for the classification are upper values (see Annex I). For the evaluation of the average values the parameters are averaged for each class using the averaging factor Q (see Table Q.1). Regardless of the magnification used, the procedure detailed in Annex I applied with Table 2 always produces the correct classification. For classification by chart comparison, a magnification of 100:1 is recommended.

9.3.3.2 Restricted evaluation

Before evaluation it may be decided to record only inclusions in a specified size range. Details are given in Annex M, Tables M.6 and M.7.

9.3.4 Evaluation of K_n , K_L for elongated and K_n , K_d for globular inclusions

For each specimen the number of inclusions is recorded for each type of inclusion according to the rows of the chart. An example is given in Table M.2.

After finishing the scan, the total number of inclusions per row is recorded as in Table M.2 and the total scanned area is determined.

The results can be calculated using a second sheet, e.g. as in Table M.3.

This second sheet gives all the information to calculate K_n and K_L for α , γ , and β elongated inclusions as well as K_n and K_d for δ globular inclusions. These sheets enable the calculation of the average inclusion size per type.

9.3.5 Evaluation of K_n and K_a

Each specimen is rated counting the number of inclusions for each row and column value.

Details of the evaluation can be derived from Annex M or the formulae given in Annex N, Annex P, and Annex Q.

The method of K_a cannot be used to measure true volume fraction. This is defined in ISO 9042.

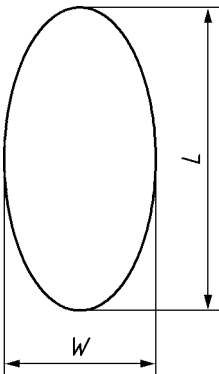
10 Test report

The test results shall be given in accordance with the requirements for reporting results set forth in EN ISO/IEC 17025 and the test report shall contain the following information:

- a) reference to this draft European Standard;
- b) steel grade and when applicable, the symbol identifying the steelmaking process;
- c) form and dimension of product from which the specimens have been taken;
- d) method used as described in Clause 9, together with any special condition;
- e) result of the evaluation according to the requirement of the product standard or by special agreements between the parties;
- f) any abnormalities that may have occurred during the test;
- g) magnification used if other than 100:1;
- h) reference to image analysis.

Table 2 — Length L , width w , and area a for the pictures of the chart

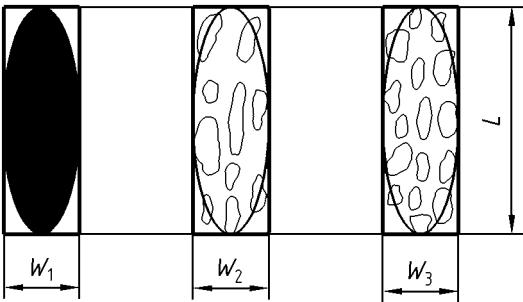
			Single and aligned elongated inclusions and stringers of globular inclusions columns 1 to 5 and 7 to 11 Length $L \geq 3 \mu\text{m}$ and width $w \geq 2 \mu\text{m}$					Globular inclusions column 6 $d \geq 3 \mu\text{m}$
Row q	$L \mu\text{m}$		1 or 7	2 or 8	3 or 9	4 or 10	5 or 11	6
1	5,5	$w \mu\text{m}$						5,5
		$a \mu\text{m}^2$						24
2	11	$w \mu\text{m}$			3,0	8,0		11
		$a \mu\text{m}^2$			25	70		97
3	22	$w \mu\text{m}$			4,0	11		22
		$a \mu\text{m}^2$			70	197		387
4	44	$w \mu\text{m}$			6,0	16		44
		$a \mu\text{m}^2$			197	558		1 547
5	89	$w \mu\text{m}$		3,0	8,0	23	64	89
		$a \mu\text{m}^2$		197	558	1 577	4 461	6 186
6	178	$w \mu\text{m}$		4,0	11	32	91	178
		$a \mu\text{m}^2$		558	1 577	4 461	12 618	24 745
7	355	$w \mu\text{m}$		6,0	16	45	128	355
		$a \mu\text{m}^2$		1 577	4 461	12 618	35 688	98 980
8	710	$w \mu\text{m}$	3,0	8,0	23	64	181	
		$a \mu\text{m}^2$	1 577	4 461	12 618	35 688	100 942	
9	1 420	$w \mu\text{m}$	4,0	11	32	91	256	
		$a \mu\text{m}^2$	4 461	12 618	35 688	100 942	285 508	
NOTE Inclusions with a ratio $L/w < 3,0$ are considered as a globular inclusion (see Figure 1). The values in Table 2 are binding for all evaluations (see Clause 5).								



Key

<i>L/w</i>	Shape	<i>a</i>
< 3	globular	$\frac{\pi}{4} L^2$
≥ 3	elongated	$\frac{\pi}{4} Lw$

Figure 1 — Definition of standard shapes



Key

$w_1 = w_2 = w_3 = w \quad a_1 = a_2 = a_3 = a = L \times w \times \frac{\pi}{4} \approx 0,8 \times L \times w$

Figure 2 — Three different inclusions with the same length *L*, width *w* and area *a* of involved material