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**Microscopic testing method for the
non-metallic inclusions in steel**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Iron and Steel Federation (JISF) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS G 0555:2015**), which has been technically revised.

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Microscopic testing method for the non-metallic inclusions in steel

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 4967:2013**, Edition 3 by adopting the microscopic testing method for the non-metallic inclusions in steel of the said **ISO** without any changes in the technical contents, and also adding the point counting method unique to **JIS**.

The vertical lines on both sides and dotted underlines indicate additions to the corresponding International Standard. A list of modifications with the explanations is given in Annex JB. Annex JA is unique to **JIS** and not given in the corresponding International Standard.

1 Scope

This Standard specifies a micrographic method of determining the non-metallic inclusions (hereafter referred to as inclusions) in rolled or forged steel products having a reduction ratio of at least 3 using standard diagrams and point counting method. This method is widely used to assess the suitability of a steel for a given use. However, since it is difficult to achieve reproducible results owing to the influence of the test operator, even with a large number of specimens, precautions should be taken when using the method.

NOTE 1 For certain types of steel (e.g. free cutting steels), the standardized diagrams described in this Standard may not be applicable.

This Standard also provides for the determination of non-metallic inclusions by image analysis technologies (see Annex D).

It also provides in Annex JA the method for assessing the cleanliness of steel by determining the type and number of inclusions in steel by means of a microscope.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 4967:2013 *Steel—Determination of content of nonmetallic inclusions—Micrographic method using standard diagrams* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standards and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

1A Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this Standard. The most recent edition of the standard (including amendments) indicated below shall be applied.

JIS G 0202 *Glossary of terms used in iron and steel (Testing)*

2 Principle

The method consists of comparing the observed field to the chart diagrams defined in this Standard and taking in consideration separately each type of inclusion. In the case of image analysis, fields will be rated according to the relationships given in Annex D.

The chart pictures correspond to square fields of view, each with an area of 0.50 mm², as obtained with a longitudinal plane-of-polish and as observed at 100 ×.

According to the shape and distribution of the inclusions, the standard diagrams are divided into five main groups, bearing the reference A, B, C, D and DS.

These five groups represent the most commonly observed inclusion types and morphologies:

- **Group A (sulfide type):** highly malleable, individual grey particles with a wide range of aspect ratios (length/width) and generally rounded ends;
- **Group B (aluminate type):** numerous non deformable, angular, low aspect ratio (generally < 3), black or bluish particles (at least three) aligned in the deformation direction;
- **Group C (silicate type):** highly malleable, individual black or dark grey particles with a wide range of aspect ratios (generally > 3) and generally sharp ends;
- **Group D (globular oxide type):** non deformable, angular or circular, low aspect ratio (generally < 3), black or bluish, randomly distributed particles;
- **Group DS (single globular type):** circular, or nearly circular, single particle with a diameter > 13 μm.

Non-traditional inclusion types may also be rated based on their morphology compared to the above five types and a statement about their chemical nature. As an example, globular sulfides would be rated as a D type and a descriptive subscript (e.g. D_{sulf}) defined in the test report. D_{cas} would indicate globular calcium sulfides; D_{RES} would indicate rare earth sulfides; D_{Dup} would indicate globular duplex inclusions, such as calcium sulfide surrounding an aluminate.

Types of precipitate such as borides, carbides, carbonitrides or nitrides may also be rated based on their morphology compared to the above five types and a statement about their chemical nature as described in the previous subclause.

Each main group on the chart consists of two subgroups, each made up of six diagrams representing increasing inclusion content. This division into subgroups is merely intended to give examples of different thicknesses of non-metallic particles.

The diagrams on the chart are given, by inclusion group, in Annex A.

These chart diagrams carry an index number, *i*, from 0.5 to 3, the numbers increasing with the inclusion or stringer lengths (Groups A, B, C) or by the number (Group D) or by the diameter (Group DS), as defined in Table 1, and by thickness, as defined in Table 2. For example, the diagram A2 indicates that the shape of the inclusions observed under the microscope is in accordance with group A and that their distribution and quantity are in accordance with number 2.

Table 1 Rating limits

Chart diagram index <i>i</i>	Inclusion group ^{b)}				
	A ^{a)} total length μm	B ^{a)} total length μm	C ^{a)} total length μm	D count number	DS diameter μm
0.5	37 or over to and excl. 127	17 or over to and excl. 77	18 or over to and excl. 76	1 or over to and excl. 4	13 or over to and excl. 19
1	127 or over to and excl. 261	77 or over to and excl. 184	76 or over to and excl. 176	4 or over to and excl. 9	19 or over to and excl. 27
1.5	261 or over to and excl. 436	184 or over to and excl. 343	176 or over to and excl. 320	9 or over to and excl. 16	27 or over to and excl. 38
2	436 or over to and excl. 649	343 or over to and excl. 555	320 or over to and excl. 510	16 or over to and excl. 25	38 or over to and excl. 53
2.5	649 or over to and excl. 898	555 or over to and excl. 822	510 or over to and excl. 746	25 or over to and excl. 36	53 or over to and excl. 76
3	898 or over to and excl. 1 181	822 or over to and excl. 1 147	746 or over to and excl. 1 029	36 or over to and excl. 49	76 or over to and excl. 107
Notes ^{a)} The above length values for the A, B and C groups have been computed from the equations given in Annex D and then rounded off to the nearest whole number.					
^{b)} Inclusions outside the range of this table can be rated according to Annex D.					

Table 2 Inclusion thickness parametersUnit: μm

Group type	Fine Minimum width	Thick ^{b)} Minimum width
A	2 or over up to and incl. 4	Over 4 up to and incl. 12
B	2 or over up to and incl. 9	Over 9 up to and incl. 15
C	2 or over up to and incl. 5	Over 5 up to and incl. 12
D ^{a)}	2 or over up to and incl. 8	Over 8 up to and incl. 13
Notes ^{a)} For type D, the maximum dimension is defined as the diameter.		
^{b)} Inclusions having a width greater than the maximum width of the thick series in the table should be separately reported.		

Examination at a magnification greater than $100\times$ may be used to identify the nature of the non-traditional inclusions before performing the test.

3 Sampling

The shape of the inclusion depends to a large extent on the degree of reduction of the steel; therefore, comparative measurements may only be carried out on prepared sections taken from samples with a similar amount of deformation.

The polished surface of the specimen used to determine the content of inclusions shall be approximately 200 mm^2 ($20\text{ mm} \times 10\text{ mm}$). It shall be parallel to the longitudinal axis of the product and shall be located halfway between the outer surface and the centre.

The method of sampling shall be defined in the product standard or subject to agreement between the purchaser and the manufacturer. The test surface, in the case of plates, shall be approximately at a quarter of the width.

In the absence of such specifications, the sampling procedure shall be as follows:

- bar or billet with a diameter or length of side greater than 40 mm: the surface to be examined consists of a part of section located halfway between the outer surface and the centre (see Figure 1);
- bar or billet with a diameter or length of side greater than 25 mm and less than or equal to 40 mm: the surface to be examined consists of half the section (from the centre to the edge of the sample) (see Figure 2);
- bar with a diameter less than or equal to 25 mm: the surface to be examined consists of the full diametral section of length sufficient to obtain a surface of about 200 mm² (see Figure 3);
- plate with a thickness less than or equal to 25 mm: the surface to be examined consists of the whole thickness, and located at the quarter of the width (see Figure 4),
- plate with a thickness greater than 25 mm and less than or equal to 50 mm: the surface to be examined consists of half the thickness from the surface to the centre and is located at the quarter of the width (see Figure 5);
- plate with a thickness greater than 50 mm: the surface to be examined consists of quarter the thickness and is located halfway between the outer surface and the middle of the thickness and at the quarter of the width (see Figure 6).

The number of samples to be taken is defined in the product standard or by special agreement between the purchaser and the manufacturer.

For any other product, the sampling procedures shall be subject to agreement between the purchaser and the manufacturer.

Unit: mm

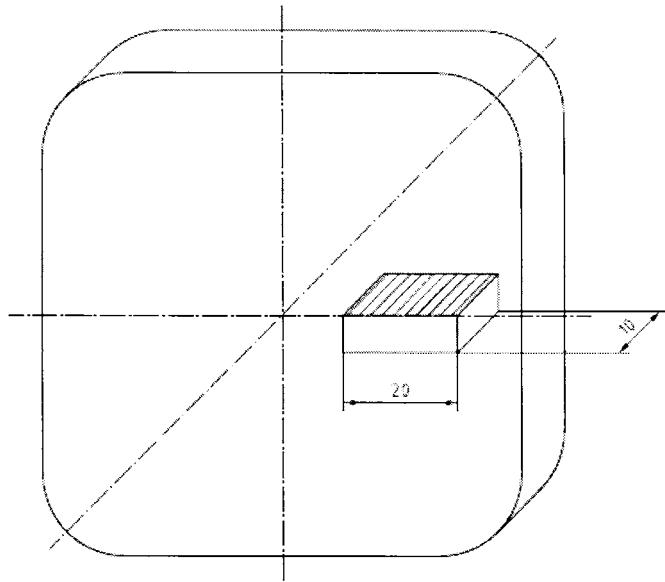


Figure 1 Sample from bar or billet with a diameter or length of side > 40 mm

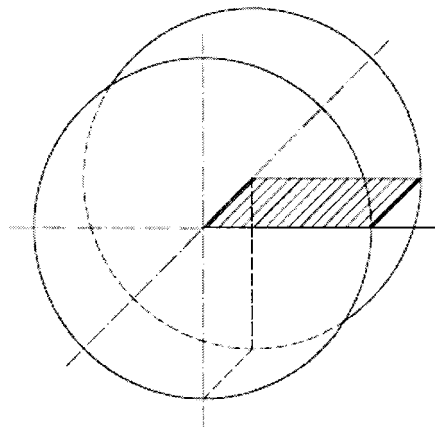


Figure 2 Sample from bar or billet with a diameter or length of side > 25 mm and ≤ 40 mm

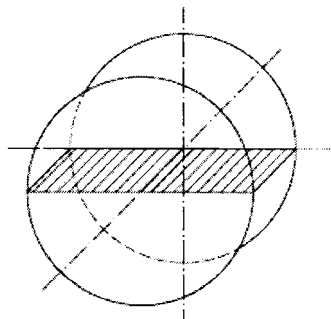


Figure 3 Sample from bar with a diameter ≤ 25 mm

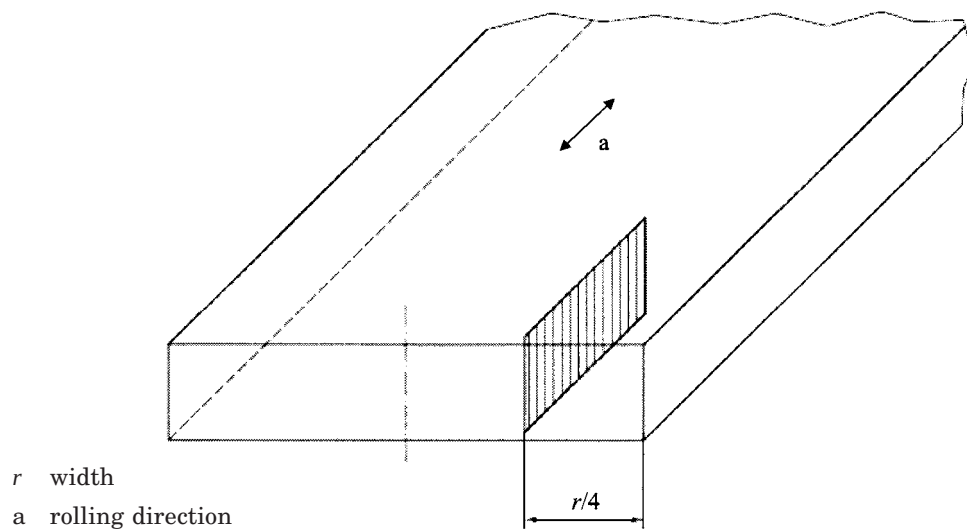


Figure 4 Sample from plate with thickness ≤ 25 mm

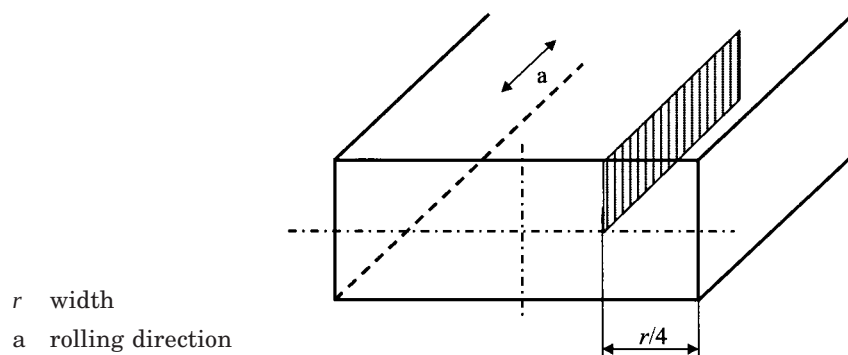


Figure 5 Sample from plate with thickness > 25 mm and ≤ 50 mm

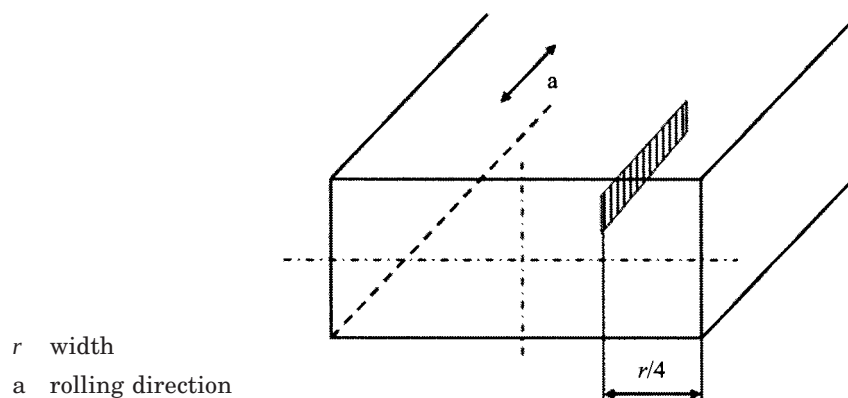


Figure 6 Sample from plate with thickness > 50 mm

4 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 shape 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. In certain cases it may be necessary for the specimen to be heat treated before polishing in order to give it the maximum possible hardness.

5 Determination of the content of inclusions

5.1 Method of observation

Examination with the microscope may be by one of two methods:

- by projection on to ground glass,
- by observation by means of an eyepiece.

The method of observation chosen shall be maintained throughout the test.

If the image is projected onto a ground glass or similar device, the magnification shall be $100 \times \pm 2 \times$ on the ground glass. Place a clear plastic overlay (Figure 7) of a 71 mm square (0.50 mm^2 true area) over or behind the ground glass projection screen. The image within the test square is compared to the standard pictures on the chart (Annex A).

If the inclusions are examined through the microscope eyepieces, insert a reticle with the test pattern shown in Figure 7 in the microscope at the appropriate location so that the test grid area is 0.50 mm^2 at the image plane.

Automatic image analysis can be used to assess inclusions of applicable materials providing that the accuracy of the methods has previously been proven by an extensive cross correlation.

In special cases, a magnification greater than $100 \times$ may be used, provided that the same magnification is applied for the standard diagrams, and shall be recorded in the test report.

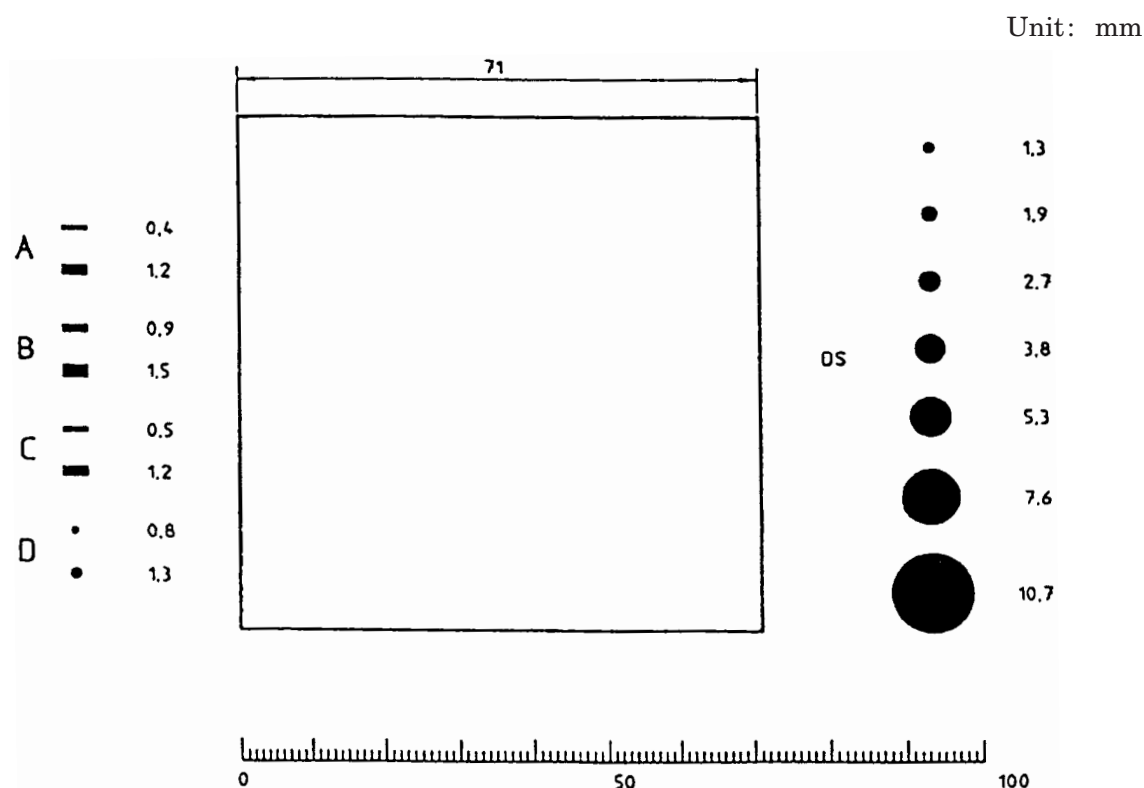


Figure 7 Test pattern for grid overlays or reticles

5.2 Actual examination

5.2.0A General

Two methods are defined as described in **5.2.1** and **5.2.2**.

5.2.1 Method A

The entire polished surface is examined and, for each type of inclusion, a note is made of the reference number¹⁾ of the standard diagram which corresponds to the worst field examined, in the fine and thick series.

Note ¹⁾ The reference number lies to the side of the standard diagram.

5.2.2 Method B

The entire polished surface is examined and each field of the specimen is compared with the standard diagrams. The reference number of the field which best corresponds to the field examined for each type of inclusion is noted, in the fine and thick series.

It may be agreed upon to make a partial examination of the specimen by studying a reduced number of fields, distributed in accordance with a fixed scheme. Both the number of fields examined and their distribution shall be arranged by prior agreement between the purchaser and the manufacturer.

5.2.3 General rules for methods A and B

Each field observed is compared with the standard diagrams. If a field of inclusions falls between two standard diagrams, it is rated following the lower diagram.

Individual inclusions or stringers that have a length greater than the field width (0.710 mm) or a width or diameter greater than the thick series maximum (see Table 2) will be rated as oversized by length, width or diameter. The oversized dimensions of the inclusion or stringer shall be noted separately. However, these inclusions shall still be part of the overall rating of that field.

Reproducibility of measurements is improved if actual measurements (stringer lengths of A, B or C types, diameter of DS type) and counts (D types) are made. Use a grid overlay or reticle, as shown in Figure 7, the measurement limits in Tables 1 and 2, and the morphological descriptions in Clause 2, as illustrated in the chart in Annex A.

Non-traditional inclusion types are rated according to the chart group (A, B, C, D, DS) that best corresponds to their morphology. Compare the length, number, thickness or diameter of the inclusions to each group shown in Annex A or use Tables 1 and 2 to assign the appropriate inclusion content number and thickness class (fine, thick or over-size). Then indicate the nature of the non-traditional inclusion with a subscript to the group type. Define the subscript in the test report.

For type A, B and C inclusions, two individual inclusions or stringers of lengths l_1 and l_2 and which are, or are not, in line are considered as one inclusion or stringer if the distance d is lower than or equal to $40\text{ }\mu\text{m}$ and if the distance s , (the distance between centres of inclusions/stringers) is lower than or equal to $10\text{ }\mu\text{m}$ (see Figures 8 and 9).

In the case of a stringer with inclusions of different width, the width to be considered is the width of the biggest inclusion.

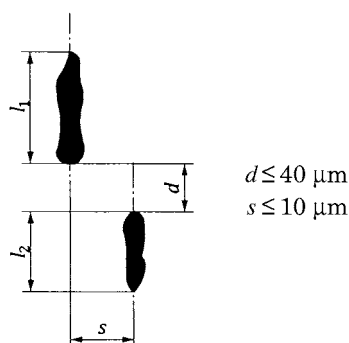


Figure 8 Type A and C inclusions

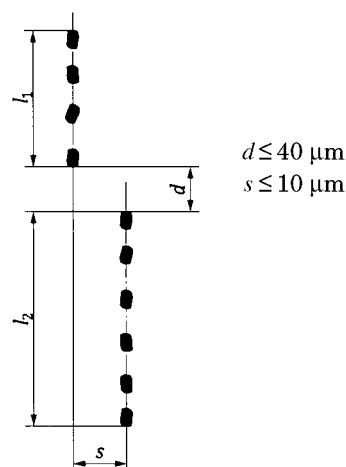


Figure 9 Type B inclusions

6 Expression of results

6.1 General

Unless otherwise stated in the product standard, the results may be expressed as described in 6.2 and 6.3 depending on the method used (method A or method B).

6.2 Case of method A

For each type of inclusion and for each thickness series (see Annex B), the reference symbol for the group of inclusions shall be followed by the reference number of the worst field among the observed number of fields, N , the presence of thick inclusions being indicated by the letter e, the presence of inclusion oversized being indicated by the letter s.

Example A2, B1e, C3, D1, B2s, DS0.5

Any subscripts used to identify non-traditional inclusion types shall be defined.

On the basis of the index numbers relating to each specimen and on their basis, an arithmetic mean may be assessed per cast for each type of inclusion and for each thickness series.

6.3 Case of method B

The total number of fields shall be indicated for a given index, per type of inclusion and per thickness series for a given number of fields observed (N).

The full set of total numbers of fields for a given index relative to the various types of inclusions may be used in special methods for expressing results, such as total index, i_{tot} , or mean index, i_{moy} , subject to agreement between the purchaser and the manufacturer.

Example For type A inclusions taking: n_1 as the number of fields of index 0.5
 n_2 as the number of fields of index 1.0
 n_3 as the number of fields of index 1.5
 n_4 as the number of fields of index 2.0
 n_5 as the number of fields of index 2.5
 n_6 as the number of fields of index 3.0,

$$i_{\text{tot}} = (n_1 \times 0.5) + (n_2 \times 1.0) + (n_3 \times 1.5) + (n_4 \times 2.0) + (n_5 \times 2.5) + (n_6 \times 3.0)$$

$$i_{\text{moy}} = \frac{i_{\text{tot}}}{N}$$

where, N : total number of fields observed.

A typical result is given in Annex C.

7 Test report

Where required, a test report shall be prepared including the items of information chosen among the following by agreement between the purchaser and the manufacturer:

- a) a reference to this Standard;

Example **JIS G 0555**

- b) the steel grade or its symbol, and the cast number;
- c) the symbol of the product and its dimensions;
- d) the type of sampling and position of the area examined;
- e) the method selected (method of observation, method of examination, standard chart used, method of expressing results);
- f) the magnification if greater than 100 ×;
- g) the number of observed fields or the total area examined;
- h) the results of the examination (including the number, size and type of oversize inclusions or stringers);
- i) statement of subscripts used to define any non-traditional inclusion type;
- j) report number and date;
- k) name of operator.

Annex A (normative)
Chart diagrams for inclusion groups A, B, C, D and DS

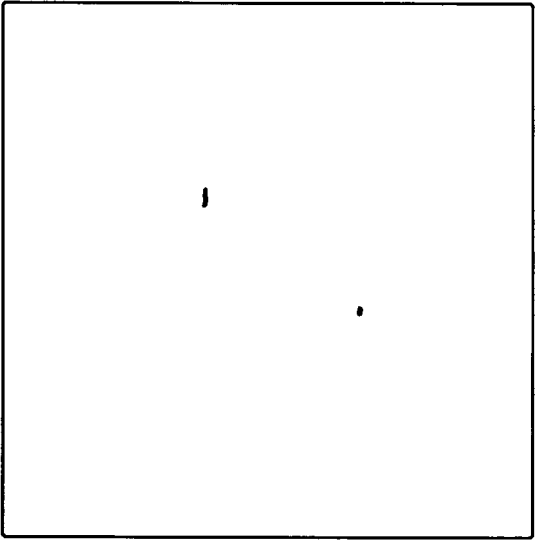
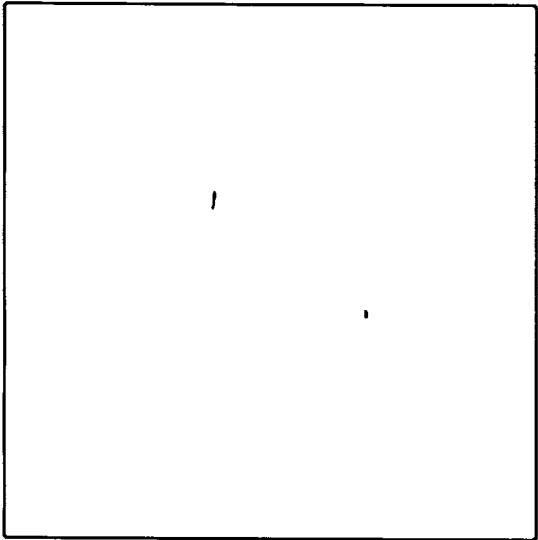
A
(Sulfide type)

Fine series
Thickness $\geq 2 \mu\text{m}$ to $4 \mu\text{m}$

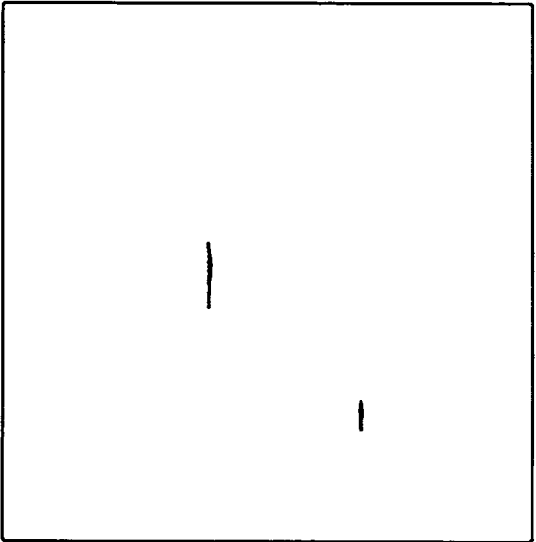
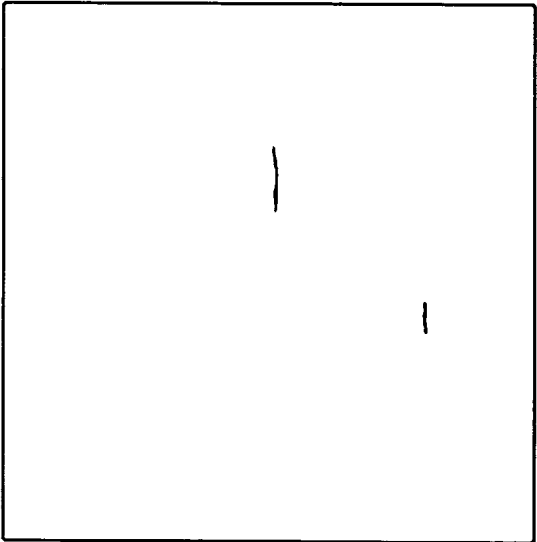
Minimum
total
length

Thick series
Thickness $\geq 4 \mu\text{m}$ to $12 \mu\text{m}$

$i=0.5$



$i=1$



Magnification: 100 ×