INTERNATIONAL STANDARD 3763

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Wrought steels — Macroscopic methods for assessing the content of non-metallic inclusions

Aciers corroyés — Méthodes macroscopiques de détermination de la teneur en inclusions non métalliques

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3763 was drawn up by Technical Committee ISO/TC 17, *Steel*, and was circulated to the Member Bodies in May 1975.

It has been approved by the Member Bodies of the following countries :

Australia	Iran	South Africa, Rep. of
Austria	Ireland	Spain
Belgium	Italy	Sweden
Canada	Korea, Dem. P. Rep. of	Switzerland
Czechoslovakia	Netherlands	Turkey
Denmark	New Zealand	United Kingdom
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Hungary	Romania	Yugoslavia

The Member Body of the following country expressed disapproval of the document on technical grounds :

Japan

Wrought steels — Macroscopic methods for assessing the content of non-metallic inclusions

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard describes the macroscopic methods used in current practice for assessing the content of non-metallic inclusions in wrought steel products.

1.2 Macroscopic methods are those dealing with non-metallic inclusions visible to the naked eye or with the aid of a magnifying glass with a magnification of not more than × 10. Only inclusions equal to or greater than 1 mm long are taken into consideration.

1.3 The methods usually applied and defined in this International Standard are :

- the blue fracture test method;
- the step machined test method;
- the magnetic particle inspection method.

2 GENERAL

2.1 Characteristics of non-metallic inclusions

Non-metallic inclusions, shown by the macroscopic methods given in clauses 3, 4 and 5, appear as stringers.

The parameters characterizing non-metallic inclusions shall be their total number and their length or thickness. No distinction is made concerning the type of inclusion.

2.2 Sampling

It should be noted that the shape of the inclusion as well as the number of inclusions and their distribution depend on the grade of steel, the method of production, the conditions of killing, the shape of the ingot and the rolling reduction. These various factors should be taken into consideration when selecting the sample.

For these reasons it is not possible to formulate a universal method of sampling and accordingly general rules are given in the case of each method.

3 BLUE FRACTURE TEST METHOD

3.1 Principle

The blue fracture test method consists in detemining the total number and distribution of non-metallic inclusions visible on the surface of a fracture which has undergone blue tempering. This fracture is in the longitudinal direction of the product and the inclusions normally appear as white stringers.

3.2 Field of application

The blue fracture test method is applicable to forged or rolled products and can be used for a wide range of products. In general, the test is carried out on semi-finished products.

3.3 Sampling and preparation of test piece

3.3.1 *Sampling*

The test piece shall consist of a slice the thickness (for example between 5 and 20 mm) of which depends on the dimensions of the product, the thickness being measured parallel to the longitudinal direction, and the slice being taken by hot or cold sawing or by flame cutting. In general a thickness of 10 mm is recommended.

When flame cutting is used, care shall be taken to ensure that the fracture takes place outside the heat-affected zone.

The number and position of the test pieces shall be the subject of an agreement between the parties concerned.

3.3.2 *Preparation*

The test piece may contain a groove in the middle of one of the principal sides (i.e. perpendicular to the longitudinal axis of the product). Its shape is variable and its depth shall be such that the thickness of the remaining slice complies with the conditions defined above. The purpose of this groove is to facilitate the fracture of the test piece.

3.4 Procedure

After undergoing normalizing treatment if necessary, the test piece shall be either

- heated in air so that at the moment of starting the test, the metal is at the blue brittleness temperature (300 to 350 °C), or
- fractured at the ambient temperature and the two pieces subsequently heated to blue the fractures.

In certain cases, which may be subject to agreement between the parties concerned, the test piece may be hardened, possibly followed by tempering.

The fracture produced on one of the two broken parts of the test piece shall be examined with the naked eye or with the aid of a magnifying glass with a magnification less than or equal to X 10.

3.5 Results

The examination may be carried out qualitatively or, by special agreement between the parties concerned, quantitatively.

3.5.1 *Qualitative examination*

Qualitative examination shall be carried out by comparison with the series of ten reference diagrams included in annex A. When interpreting in conjunction with that annex, account shall be taken of the positions of the inclusions within the section, for example core, surface or uniform distribution.

3.5.2 *Quantitative examination*

Quantitative examination shall be carried out by counting the inclusions and using one (or both) of the following parameters of the inclusions :

— length;

— thickness.

The distribution of the inclusions according to the parameter(s) chosen shall be established according to table 1 and/or 2.

TABLE 1 — **Inclusion distribution based on length**

Symbol	Length *l* mm
L_0	no macroscopic inclusion
L_1	$1{,}0 \leqslant l \leqslant 2{,}5$
L_2	$2{,}5 < l \leqslant 5{,}0$
L_3	$5{,}0 < l \leqslant 10$
L_4	$l > 10$

TABLE 2 — **Inclusion distribution based on thickness**

Symbol	Thickness *e* mm
T_0	no macroscopic inclusion
T_1	$0{,}1 \leqslant e \leqslant 0{,}25$
T_2	$0{,}25 < e \leqslant 0{,}50$
T_3	$0{,}50 < e \leqslant 1{,}00$
T_4	$e > 1$

NOTE — The presence of inclusions less than 1 mm in length should be noted.

3.5.3 *Interpretation of the results*

The way in which results obtained are evaluated shall be the subject of special agreement.

3.6 Comments

Comparative tests shall be carried out on products which have undergone similar hot-working reductions.

In addition, it should be noted that inclusions appear clearly for one hardness range. Thus, for mild steel, previous treatment (hardening without tempering) of the test piece is often preferable.

Care shall be taken when examining steels with ferrite lines or carbide stringers, as these may be confused with inclusion stringers.

4 STEP MACHINED TEST METHOD

4.1 Principle

The step machined test method consists in determining the total number and the distribution of non-metallic inclusions revealed by machining and visible on the longitudinal surfaces of a cylindrical stepped test piece.

4.2 Field of application

The test is applicable to rolled and forged products of simple shape. The test piece is generally machined from samples of bars or billets.

4.3 Sampling and preparation of test piece

4.3.1 *Sampling*

The number of test pieces and their positions shall be subject to agreement between the parties concerned.

4.3.2 *Preparation*

According to the type of product and the purposes of the examination, the cylindrical test piece shall contain one or more concentric steps. Products with non-circular sections may be forged into the round bars beforehand.

The test piece in common usage comprises three steps the dimensions of which are as given in table 3.

TABLE 3 — **Dimensions of steps on test piece**

Step	Diameter	Length mm
1	0,90 *D*	60
2	0,75 *D*	72
3	0,60 *D*	90

D = diameter or side of the product.

In the test piece dimensioned as in table 3, the lengths of the steps are such that the surface area of each step is identical. Other dimensions of steps may be used subject to agreement between the parties concerned.

The test piece shall be carefully centred. Where it is necessary to have a greater area for examination, each step shall be machined successively along the whole length of the test piece, after establishing the number of inclusions for each step.

The test piece shall be turned so that the depth of the last cut is less than 0,2 mm. The machined surface shall be smooth and shall not show a relief which is too pronounced.

4.4 Procedure

The test piece shall be examined with the naked eye or with the help of a magnifying glass (maximum magnification X 10).

To facilitate examination, the test piece may be retained in the lathe, so that it can be rotated. A reference line should be marked along the entire length of the test piece. Similarly, the inclusions counted should also be marked (by putting a circle round them, for example) to avoid double counting.

When, in certain cases, it is difficult to observe inclusions, the magnetic particle inspection method may be used. (See clause 5.)

Special precautions shall be taken when examining, so that only lines relating to non-metallic inclusions are taken into consideration, as machining of the test piece surface may also reveal macroscopic irregularities such as cracks, pipe seams, metallic inclusions, etc.

4.5 Results

For each step, the number of inclusions and their lengths shall be determined.

The distribution of inclusions in terms of their size may be obtained by using the classification given in table 4.

TABLE 4 – **Inclusion distribution based on length**

Dimensions in millimetres

Length l of the inclusions	Approximate mean length
$1 \leqslant l \leqslant 2{,}5$	2
$2{,}5 < l \leqslant 5$	4
$5 < l \leqslant 10$	8
$10 < l \leqslant 20$	16
$l > 20$	individual length

The assessment of the results shall be subject to special agreement between the parties concerned.

4.6 Comments

For comparative tests, care should be taken that test pieces are of the same type and that products have the same degree of reduction.

5 MAGNETIC PARTICLE INSPECTION METHOD

5.1 Principle

The test consists in examining the machined surface of a test piece or product submitted to a magnetic field and coated with a liquid containing a ferromagnetic powder suspension[1].

Non-metallic inclusions cause a distortion in the induced magnetic field. This distortion attracts and holds the ferromagnetic powder, giving visible indication.

NOTE – It should be noted that other irregularities in the metal such as cracks, blow-holes, shrinkage cracks, etc. also give an indication under magnetic particle inspection. Precautions should be taken to ensure that the readings obtained correspond properly to the non-metallic inclusions by means of a supplementary examination such as a dye penetrant test.

5.2 Field of application

Magnetic particle inspection is only valid for ferromagnetic steels. It is generally used for products such as slabs, bars, billets and tube rounds.

5.3 Method of operation

5.3.1 *Preparation of the surface*

The surface which is to be examined shall be in the longitudinal plane of the product. The nature of the test piece used may vary greatly according to the shape of the product and depending on the examination carried out.

The methods of sampling, the number of samples and their positions shall be subject to agreement between the parties concerned.

In the case of bars, billets and rounds, various examination surfaces may be chosen :

– the surface of the product after a fine grinding;

– an axial section of the product;

– the step test piece defined in clause 4;

– cylindrical test pieces obtained by machining or forging and taken from a quarter of the section of the product, machining being carried out so that the axis of the product is included on the surface of the test piece; this should be marked (see the figure).

1) Magnetic particle inspection may be carried out by the dry method, by special agreement between the parties concerned.

The first three types of examination surface are generally used for products of diameter or side less than 100 mm. The last type of examination surface is used for products having a larger section.

Preparation of the surface to be examined or of the test piece shall be carried out by fine grinding, perpendicular to the direction of rolling, in order to be able to distinguish any machining marks and to avoid tearing out the whole of the inclusions.

It should be noted that preparation should be more carefully carried out, the smaller the inclusions which it is wished to reveal. The ends of the test piece shall also be machined to facilitate magnetization.

In certain cases of heterogeneous structure it may be necessary to carry out heat treatment of test pieces.

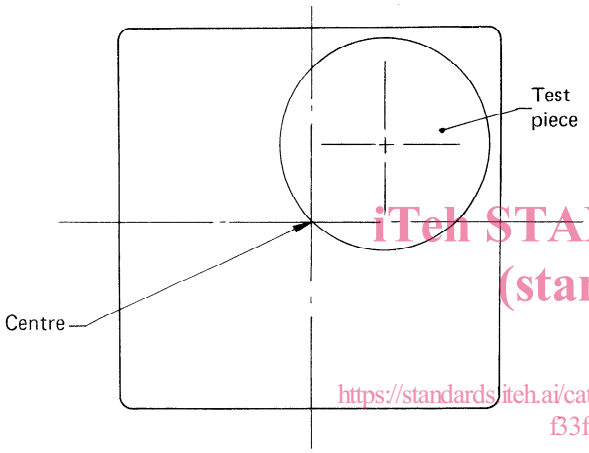


FIGURE – **Sampling**

5.3.2 *Procedure*

The procedure for magnetic particle inspection will be described in a separate International Standard. Until that is available, the method of operation given in annex B of this International Standard shall apply.

5.4 Results

The magnetic image shall be examined under well-diffused light. Fluorescent white light is satisfactory in the majority of cases.

Instead of measuring directly on the surface under observation, it is possible to measure a replica of the surface. This method has the advantage of producing a record of the image. For this, a piece of transparent cellulose adhesive tape is placed in contact with the surface, the adhesive side being towards the sample. This tape is then pressed against the sample so that the magnetic powder adheres to it. These operations are carried out preferably with the current flowing in order to avoid an alteration in the magnetic image. After switching off the current, the tape is then removed from the sample and stuck either on white paper or on a transparent plastic sheet.

The number of inclusion stringers and their length shall be determined either directly on the surface or on the replica.

The distribution of inclusions in terms of their size may be obtained according to the same classification as the one given for the step test piece method (clause 4).

The assessment of the results shall be subject to special agreement between the parties concerned.

5.5 Comments

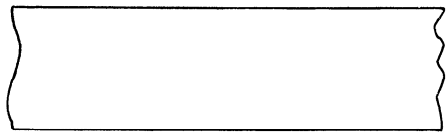
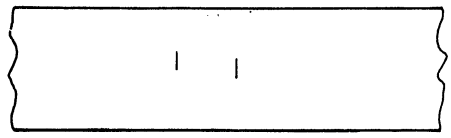
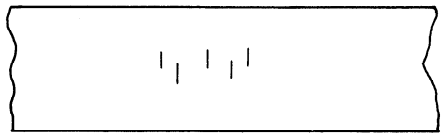
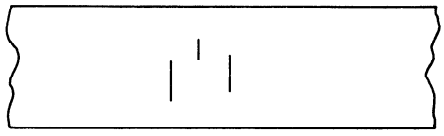
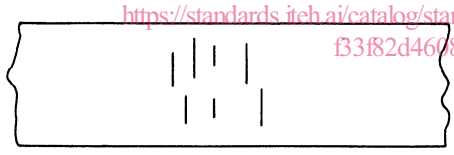
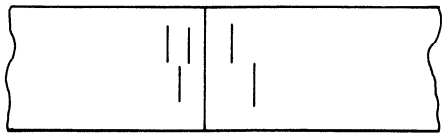
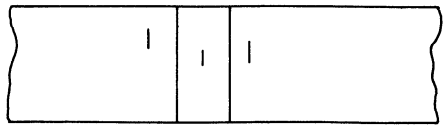
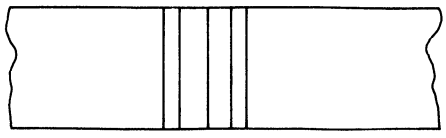
The results of counting after treatment with the magnetic powder may differ from those obtained by examination of the surface after machining only. In fact, when they are traced with magnetic powder, inclusion stringers are indicated with their maximum length, even if a large part of the inclusion lies below the surface examined.

Similarly, inclusions which lie entirely below the surface may give a poorly defined indication.

It should be noted that certain structural constituents, such as carbide stringers, may give misleading results.

ANNEX A

STANDARD DIAGRAMS FOR THE BLUE FRACTURE TEST METHOD

0		No inclusions with a length > 1 mm
1		Few very short stringers
2		Several very short stringers
3		Few very short stringers and short stringers
4		Several short stringers
5		Several short stringers and very short stringers
6		Several short stringers and one long stringer
7		Few long stringers and very short stringers
8		Several long stringers
9		Several long thick stringers

Explanation of terms

Very short stringers : 1 to 2,5 mm
Short stringers : > 2,5 mm, ⩽ 5 mm
Long stringers : > 5 mm

Few : ⩽ 3
Several : > 3
Thick : > 0,5 mm

ANNEX B

PROCEDURE FOR MAGNETIC PARTICLE INSPECTION

B.1 MAGNETIC FLUID

The magnetic fluid consists of a fine-grain ferromagnetic powder in suspension in a liquid.

The liquid used may be water (with anticorrosive additive), paraffin or a transparent light mineral oil, its viscosity being in general less than 3 mm^2/s*.

The magnetic powder should be magnetic iron oxide, of particle size 0,5 to 1 μm, all capable of being attracted by the magnet.

The concentration of the fluid should be from 5 to 10 g of magnetic powder per litre and should be checked during use.

Fluorescent pastes or liquids may also be used.

B.2 MAGNETIZATION

The magnetization method used shall be that involving direct passage of current, the test piece acting as a conductor. The type of current and the current intensity shall be subject to special agreement between the parties. In general a current intensity of 200 A/cm of the test piece diameter is appropriate.

B.3 OPERATING TECHNIQUE

Before the test, the surface shall be carefully cleaned with a solvent so that no trace of grease or any contamination remains.

In the case of a cylindrical test piece this may be placed such that it is able to rotate about its own axis.

The magnetizing current shall then be passed and the liquid immediately poured over the entire surface, the current being maintained.

The surface shall then be carefully dried with an air jet. For drying, a volatile solvent may also be used. The current being maintained, the solvent shall be poured over the surface and drying shall be carried out by means of an air jet. In this case, it is recommended that any excess solvent be collected in order to avoid contamination of the indicator fluid.

In the case of high-hardness steels (greater than 50 HRC or 515 HV) application of the indicator shall be made after magnetization of the sample.

It is recommended that the apparatus be checked by means of control samples, to ensure that the control is sufficiently sensitive.

* 1 mm^2 = 1 cSt (centistokes).