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Steels — Determination of depth of decarburization

Aciers — Détermination de la profondeur de décarburation

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 3887 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 7, *Methods of testing (other than mechanical tests and chemical analysis)*.

This second edition cancels and replaces the first edition (ISO 3887:1976), which has been technically revised.

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Steels — Determination of depth of decarburization

1 Scope

This International Standard defines decarburization and specifies three methods of measuring the depth of decarburization of non-alloy and low-alloy steels.

2 Normative references

The following referenced documents are indispensable for the application 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 4545, *Metallic materials — Hardness test — Knoop test*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 9556, *Steel and iron — Determination of total carbon content — Infrared absorption method after combustion in an induction furnace*

ISO 15349-2, *Unalloyed steel — Determination of low carbon content — Part 2: Infrared absorption method after combustion in an induction furnace (with preheating)*

3 Terms and definitions

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

3.1
decarburization
loss of carbon from the surface zone of the steel where the loss is:

a) either partial decarburization, d_3;

b) or complete decarburization, d_1, measured as the distance between the surface of the product and the point at which carbon is detectable

NOTE The depth of complete decarburization as described in b) is determined by examination of the microstructure.

3.2
depth of functional decarburization
d_2
distance between the surface of the product and the point at which the carbon content or hardness is at the level where the performance of the product would be unaffected by a reduction in carbon (i.e., at the minimum level specified in the product standard)

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3.3
depth of total decarburization
d_4
distance between the surface of the product and the point at which the carbon content is that of the unaffected core, the sum of the partial and the complete decarburization $d_3 + d_1$ being designated by the letters DD and expressed in millimetres, e.g., DD = 0,08 mm

NOTE The various bands of decarburization are shown diagrammatically in Figure 1. The boundaries separating the various types of decarburization are shown as hatched bands with the width of the band illustrating the practical variability in measurements due to uncertainty of interpretation.

3.4
depth of ferrite decarburization
depth of complete decarburization in the surface layer

NOTE The depth of ferrite decarburization is determined by examination of the microstructure.

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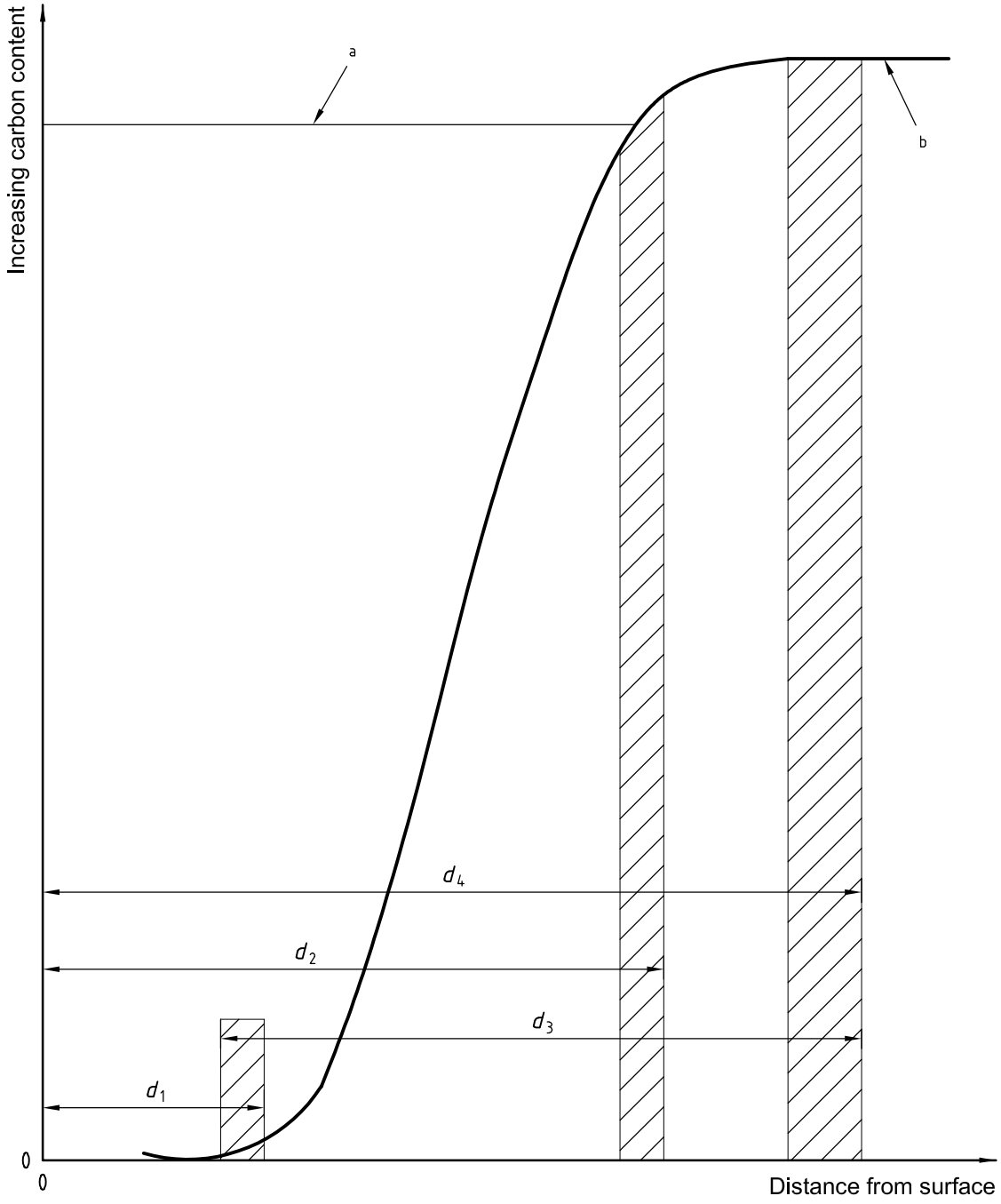

a Minimum carbon content specified in the product standard

b Core carbon content

If the product has undergone a process involving carburization, the definition of the “core” shall form the subject of an agreement between the parties concerned.

The permissible depth of decarburization shall be specified in the appropriate standard covering the product or shall be the subject of an agreement between the parties concerned.

Figure 1 — Carbon content as a function of distance from the surface: schematic representation for a typical decarburized steel

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4 Measuring methods

4.1 General

The choice of the method and its accuracy depend on the degree of decarburization, the microstructure, the carbon content of the product examined and the shape of the component.

The usual methods employed on finished products are:

— a micrographic method (see 4.2);

— a method for measuring the microindentation hardness (Vickers or Knoop) for steels in the hardened or quenched and tempered condition (see 4.3);

— a method for the determination of the carbon content by chemical or spectrographic analysis (see 4.4).

The inclusion of several methods of measurement, each having its own sphere of application, avoids the necessity for further heat treatment. The sample shall be examined in the condition of delivery. Nevertheless if, by agreement between the parties concerned, a supplementary heat treatment is applied, every precaution shall be taken to prevent changes in mass percentage and/or in the distribution of carbon, i.e., a small sample, a short austenitization time, a neutral atmosphere.

In the absence of an indication of the choice of method in the product standard, this shall form the subject of an agreement between the parties concerned.

4.2 Micrographic method

4.2.1 General

Unless otherwise specified, this method shall only be applied in situations where changes in carbon content are reflected by resulting variations in microstructure.

This method is especially valid for steels showing an annealed or normalized (ferrite-pearlite) structure. It may apply, with reservations, for products showing a hardened, or tempered, or as-rolled, or forged structure where the interpretation of the structural variations becomes difficult.

4.2.2 Selection and preparation of the sample

The sample selected shall consist of a section perpendicular to the longitudinal axis of the product. For products with no longitudinal axis, selection of the sample shall form the subject of an agreement between the parties concerned.

Wherever possible, small samples (section area less than 4 cm^2) shall be examined over their entire periphery. If this is impractical, e.g. for large samples, several sections shall be taken in order to ensure that the sampling is representative. The number and the relative positions of the various samples shall be specified by agreement between the parties concerned.

The micrographic polishing, carried out by applying the usual methods, shall not round the edges. In order to achieve this, the sample may be mounted or held in a clamp, and the surface of the product may, if necessary, be protected by a metallic deposit obtained by electroless or electrolytic plating. Automatic/semi-automatic preparation techniques are recommended, where possible.

Etching in a solution of 1,5 % to 4 % nitric acid in ethanol (nital) or 2 % to 5 % picral will reveal the structure of the steel.

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4.2.3 Measurement proper

As a rule, the reduction in carbon content can be determined for:

a) ferrite and pearlite: from the decrease in the amount of pearlite;

b) pearlite and carbides developing hypereutectoidally: from the decrease in the amount of carbides developing hypereutectoidally and/or of pearlite;

c) ferrite matrix with dispersed carbides: from the decrease in the amount of carbides in the ferrite matrix.

Hardened or quenched and tempered microstructures can be assessed by this method if the change in carbon content leads to clear changes in the microstructure.

This method can also be applied for other structural conditions, e.g., for hardened or quenched and tempered microstructures, but only if a distinct boundary exists within the structure characteristic, which is decisive for the depth of decarburization.

The distance from the surface to the point at which the structure does not differ from that of the core shall be measured (total decarburization). The measurement shall be conducted using suitably calibrated equipment.

The choice of magnification depends on the depth of decarburization and shall be chosen by the assessor unless specifically agreed upon between the parties. It is recommended that the maximum magnification that allows the full extent of decarburization to be viewed is adopted. A magnification of $\times$ 100 is recommended as a useful magnification for the majority of instances.

A preliminary examination of the whole surface at low magnification ensures that any great variation in the depth of decarburization along the periphery will be observed for further evaluation.

The point of the maximum depth of decarburization, uninfluenced by surface defects and corner effects, is determined by preliminary examination of the surface of the section. Beginning at this point, the first measurement point, the surface is divided into parts of equal size, at the ends of which the depth of decarburization shall also be measured. Unless agreed otherwise, four individual measured values shall be determined. The depth of total decarburization of the sample (see 3.3) is defined as the average of these measurements. Measuring points that are affected by surface defects shall not be taken into account when determining the average.

4.3 Methods for measuring the microindentation hardness

4.3.1 General

The methods under consideration are that of Vickers, in accordance with ISO 6507-1, and of Knoop, in accordance with ISO 4545.

Each method consists of determining the gradient of the microindentation hardness on a cross-section of the product along a line perpendicular to the surface.

This technique applies only to hypoeutectoid steels in the hardened, tempered or heat-treated condition, and to decarburized zones that are within a hardened zone, in order to avoid the occurrence of variations in hardness due to imperfect penetration. The technique becomes inaccurate for low-carbon steels.

4.3.2 Selection and preparation of the sample

The selection and preparation of the sample shall be identical to that used in the micrographic method (see 4.2.2) although, in general, the sample shall not be etched, in order to facilitate the measurement of the size of the impression. Precautions shall be taken to avoid overheating the sample.

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4.3.3 Measurement proper

The load shall be as high as possible, in order to minimize the scatter of the measurements. In principle, this load shall be in the range of HV 0,1 to HV 2,5 or in an appropriate range for the Knoop test. The distance between impressions shall be at least 2,5 times the length of the diagonal of the impression.

The depth of total decarburization is defined by the distance from the surface to the point at which the core hardness is attained.

At least two series of measurements shall be carried out in locations as remote as possible from each other. The average of the two depth measurements defines the depth of the total decarburization (see 3.3).

4.4 Methods of determination of carbon content

4.4.1 General

The methods consist of determining the gradient of the carbon content in a direction perpendicular to the surface. They are applicable whatever the structure of the steel.

4.4.2 Chemical analysis

4.4.2.1 General

This applies only to products with a simple geometry (round base cylinder or plain faced polyhedron) and of a size consistent with machining facilities, and when decarburization is over the complete surface. Unless otherwise agreed this method does not apply to products with partial decarburization.

4.4.2.2 Selection of samples and test

Successive layers 0,1 mm thick, parallel to the surface of the piece, shall be removed by dry machining, avoiding all contamination. Any oxide films shall be removed beforehand.

The metal collected at each level shall be submitted for carbon determination by chemical means, in accordance with ISO 9556 and ISO 15349-2.

4.4.3 Spectrographic analysis

4.4.3.1 General

This applies only to products with flat faces of adequate size.

4.4.3.2 Selection of samples and test

The flat sample shall be subjected to successive grinding operations to different levels 0,1 mm apart. Spectrographic determination of the carbon shall be carried out at each level in such a way that successive sparkings are not superimposed.

4.4.4 Interpretation of the results (chemical and spectrographic methods)

The methods described in 4.4.2 (chemical analysis) and 4.4.3 (spectrographic analysis) permit the determination of the depth of functional decarburization, by measuring the distance from the surface to the point where the carbon content reaches the minimum specified value. Alternatively, the depth of total decarburization can be determined by measuring the distance from the surface to the point where the carbon content values become consistent, i.e., the core carbon content.

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5 Test report

The test report shall contain the following information.

a) the number and the location of the samples taken from the test piece;

b) the method used;

c) all measured values, averaged values such as DD and, if given, the thickness of a ferritic layer as complete decarburization.

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Bibliography

[1] ISO 437, *Steel and cast iron — Determination of total carbon content — Combustion gravimetric method*

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