INTERNATIONAL STANDARD

ISO 12986-2

Second edition
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Carbonaceous materials used in the production of aluminium — Prebaked anodes and cathode blocks —

Part 2:
Determination of flexural strength by the four-point method

Produits carbonés utilisés pour la production de l'aluminium — Anodes précuites et blocs cathodiques —

Partie 2: Détermination de la résistance à la flexion par la méthode quatre points

Reference number
ISO 12986-2:2009(E)

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Foreword

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

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 12986-2 was prepared by Technical Committee ISO/TC 226, *Materials for the production of primary aluminium*.

This second edition cancels and replaces the first edition (ISO 12986-2:2005), which has been technically revised.

ISO 12986 consists of the following parts, under the general title *Carbonaceous materials used in the production of aluminium — Prebaked anodes and cathode blocks*:

— *Part 1: Determination of bending/shear strength by a three-point method*

— *Part 2: Determination of flexural strength by the four-point method*

Carbonaceous materials used in the production of aluminium — Prebaked anodes and cathode blocks —

Part 2: Determination of flexural strength by the four-point method

1 Scope

This part of ISO 12986 specifies a four-point method to determine the flexural strength of carbon and solid graphite materials at room temperature.

NOTE ISO 12986 is based on DIN 51944.

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 4288, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

3 Terms and definitions

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

3.1
flexural strength
σ_b
maximum flexural stress developed in a specimen during a flexural test to rupture

NOTE 1 Adapted from ISO 472:1999. The definition is identical to that in ISO 472:1999; the symbol has been added.

NOTE 2 The flexural strength is calculated as the quotient of the bending moment at fracture of the specimen under the conditions of the four-point method and its section modulus.

$$\sigma_b = \frac{M_b}{Z} \qquad (1)$$

where

M_b is the bending moment at rupture, in newton millimetres;

Z is the section modulus, in millimetres cubed.

NOTE 3 The flexural strength is expressed in newtons per millimetre squared.

NOTE 4 Generally, the maximum load displayed on the test machine and the load at fracture are similar; if they are different, the term refers to the maximum load displayed.

3.2
bending moment
M_b
component of moment of force perpendicular to the longitudinal axis of a beam or a shaft

[ISO 80000-4:2006, 4-13.3]

NOTE M_b is the maximum moment at fracture, calculated from the maximum load displayed by the testing machine and the geometry of the test specimen. Generally, the maximum load displayed on the test machine and the load at fracture are similar; if they are different, the term refers to the maximum load displayed.

3.3
section modulus
Z
ratio of the second axial moment of area to the maximum radial distance of any point in the surface considered from the Q-axis with respect to which the second axial moment of area is defined

NOTE 1 The section modulus can be expressed mathematically as $Z = I_a/r_{Q,max}$

where

I_a is the second axial moment of area;

$r_{Q,max}$ is the maximum radial distance considered from the Q-axis with respect to which I_a is defined.

NOTE 2 Adapted from ISO 80000-4:2006.

NOTE 3 The section modulus is calculated for the most common cross sections in Figure 2.

4 Principle

A bar-shaped test specimen is placed on two bearing blocks and its centre is loaded until the test specimen ruptures; the load is equally distributed on two points. The flexural strength is calculated from the load at fracture, the distance between the load-bearing edges and the points of support, and the dimensions of the cross-section of the test specimen.

5 Apparatus

5.1 Compression-testing machine, which meets at least the demands of class 2 in accordance with ISO 7500-1.

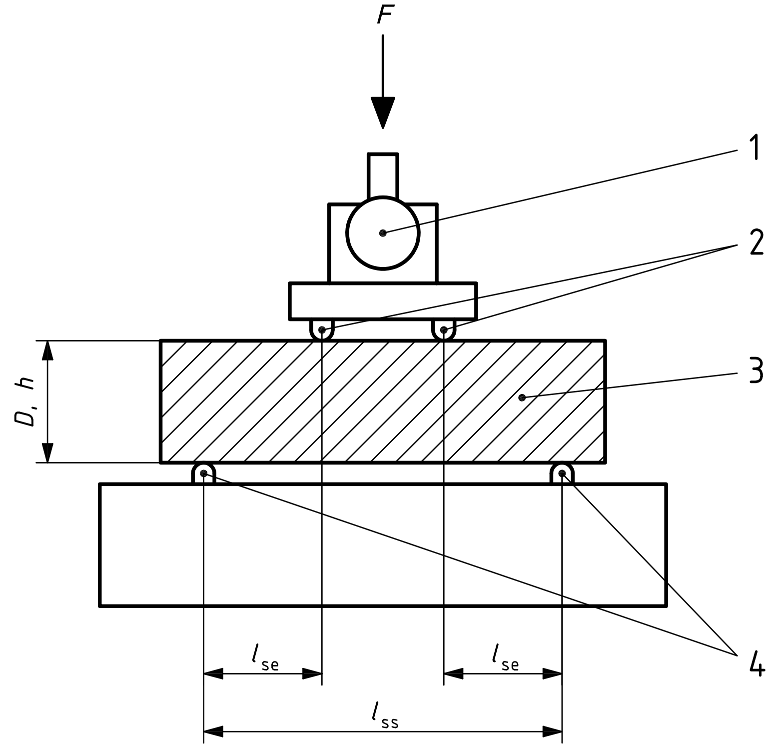
5.2 Measuring device with two bearing blocks and two loading edges.

The device shall guarantee a symmetrical load over the whole test length by means of an appropriate self-adjusting system such as a cardanic suspension and movable support blocks; see Figure 1. The radius of curvature of the bearing blocks and of the loading edges shall be in the range 2 mm to 5 mm.

The distance between the points of support and between the loading edges should be variable in order to adjust the measuring device to different sample geometries.

5.3 Measuring device (e.g. vernier calliper in accordance with ISO 6906) capable of measuring the linear dimensions of the test specimens with an accuracy of ± 0,5.

5.4 Measuring device capable of measuring the surface roughness (peak-to-valley height) of test specimens.



Key

1 cardanic suspension
2 load bearings
3 test specimen
4 points of support

D diameter of a cylindrical test specimen
F load, in newtons
h height of a rectangular test specimen
l_{se} distance between the support and the load-bearing edge
l_{ss} distance between the supports

Figure 1 — Example of a measuring device and test set-up

6 Test specimen

6.1 Sampling and sample preparation

The sampling method used to determine the location and number of test specimens shall be agreed by the users of this part of ISO 12986. Five specimens shall be tested unless agreed otherwise.

All specimens shall be tested in air-dry condition unless agreed otherwise.

The side faces of the specimens shall be machined such that the surface roughness in terms of the peak-to-valley height Ra, when measured in accordance with ISO 4288, is smaller than 15 µm. Depressions that can clearly be regarded as surface pores are not considered.

6.2 Size and geometry

Cylindrical or prismatic specimens may be used, provided that the smallest dimension be at least twice the diameter of the largest structural constituent (e.g. maximum particle size) of the material to be tested, but not smaller than 4 mm. The length of the specimens shall be at least 3,5 times their width or diameter.

7 Procedure

7.1 Perform all measurements at room temperature, i.e. in the range 10 °C to 35 °C.

7.2 Choose the measuring range of the testing machine such that the expected load at failure is at least 1/10 of full scale. Centre the test specimen on the support, with the longitudinal axis perpendicular to the support edges. The width between supports shall be at least three times the width or diameter of the specimen. The distance between the load edges shall be equal to the width or diameter of the test specimen.

In the case of prismatic specimens, ensure that the specimens rest entirely on the support edges, that at least one loading edge is movable and that the loading edges transmit the force uniformly over the whole width to the test specimens. In the case of cylindrical specimens, it is recommended that support edges be used with a diameter about 2 mm larger than the diameter of the test specimens to prevent the specimens from rolling away.

Increase the load uniformly and shock-free at a rate (velocity of the load bearing) of about 5 mm/min or about 0,5 N/mm^2/s until the test specimen fractures. Determine the load at fracture.

8 Calculation and expression of results

8.1 Bending moment, M_b

The bending moment, M_b, is calculated according to Equation (2):

$$M_b = \frac{l_{se}}{2} \cdot F_{max} \qquad (2)$$

where

l_{se} is the distance, in millimetres, between the support and the load-bearing edge (leverage of load, see Figure 1);

F_{max} is the maximum load, in newtons.

8.2 Flexural strength, σ_b

The flexural strength, σ_b, in newtons per millimetre squared, is calculated using Equations (1) and (2):

$$\sigma_b = \frac{l_{se}}{2} \cdot \frac{F_{max}}{Z} \qquad (3)$$

where

Z is the section modulus, in cubic millimetres (see Figure 2);

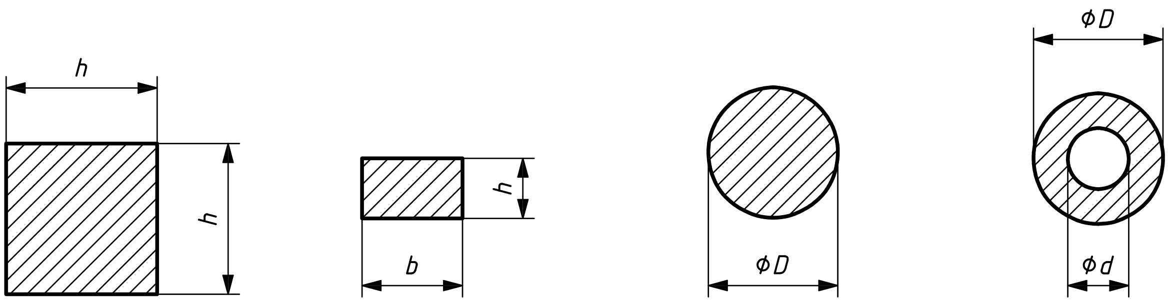
F_{max} and l_{se} are as in Equation (2).

In the case of test specimens with square cross-section and $l_{se} = h$, the flexural strength σ_b in newtons per millimetre squared is calculated according to Equation (4):

$$\sigma_b = 3 \cdot \frac{F_{max}}{h^2} \quad (4)$$

In the case of cylindrical test specimens and $l_{se} = D$, the flexural strength in newtons per millimetre squared is calculated according to Equation (5):

$$\sigma_b = 16 \cdot \frac{F_{max}}{\pi \cdot D^2} \quad (5)$$



a) Square $Z = \frac{h^3}{6}$

b) Rectangle $Z = \frac{b \cdot h^2}{6}$

c) Circle $Z = \frac{\pi \cdot D^3}{32}$

d) Ring $Z = \frac{\pi}{32} \cdot \frac{(D^4 - d^4)}{D}$

Key

Z section moment, in cubic millimetres
h height of a rectangular cross-section, in millimetres
b breadth of a rectangular cross-section, in millimetres
D external diameter of a circular cross-section, in millimetres
d internal diameter of a ring cross-section, in millimetres

Figure 2 — Calculation of section moments for cross-sections of the most common geometries

9 Precision

The uncertainty of measurement when testing with this method of testing is approximately 5 % for a confidence level of 95 % under repeatability conditions for test pieces with dimensions of 30 mm × 110 mm.

10 Test report

The test report shall contain the following information:

a) type, position and orientation of test specimens during the sampling procedure;

b) designation of the test specimens;

c) number of test specimens;

d) linear dimensions of test specimens, in millimetres;