INTERNATIONAL STANDARD

ISO 12986-2

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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
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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 226, *Materials for production of primary aluminium*.

This third edition cancels and replaces the second edition (ISO 12986-2:2009), 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 strength by the 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 This part of ISO 12986 is based on DIN 51944.

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.

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*

ISO 8007-1, *Carbonaceous materials used in the production of aluminium — Sampling plans and sampling from individual units — Part 1: Cathode blocks*

ISO 8007-2, *Carbonaceous materials used in the production of aluminium — Sampling plans and sampling from individual units — Part 2: Prebaked anodes*

ISO 8007-3, *Carbonaceous materials used in the production of aluminium — Sampling plans and sampling from individual units — Part 3: Sidewall blocks*

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 to entry: The flexural strength is calculated as the quotient of the bending moment at maximum force, before or at rupture of the specimen under the conditions of the four-point method and its section modulus.

$$\sigma_b = \frac{M_b}{Z}$$

where

M_b is the bending moment at maximum force, in newton millimetres;

Z is the section modulus, in cubic millimetres.

Note 2 to entry: The flexural strength is expressed in megapascals (MPa).

Note 3 to entry: Generally, the maximum force displayed on the test machine and the force at fracture are similar; if they are different, the term refers to the maximum force displayed

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

Note 1 to entry: M_b is the maximum moment at fracture, calculated from the maximum force displayed by the testing machine and the geometry of the test specimen. Generally, the maximum force displayed on the test machine and the force at fracture are similar; if they are different, the term refers to the maximum force 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 to entry: The section modulus can be expressed mathematically as shown in the following formula.

$$Z = I_a / r_{Q,max}$$

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 to entry: 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 a force is applied to its centre until the test specimen ruptures; the force is equally distributed on two points. The flexural strength is calculated from the maximum force, the distance between the load-bearing edges and the 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.

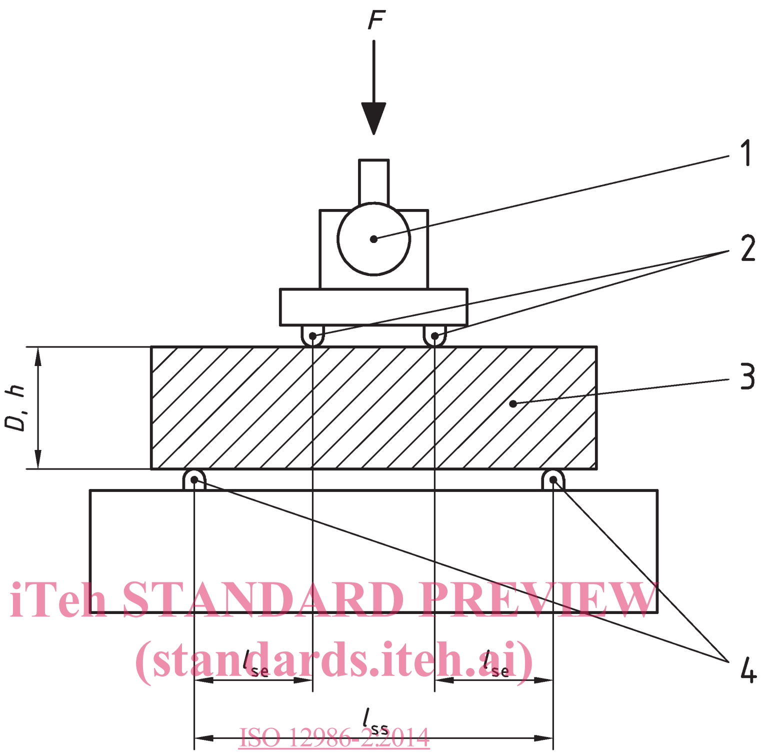
5.2 Measuring device, with two bearing blocks and two force edges.

The device shall ensure a symmetrical force 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 force edges shall be in the range 2 mm to 5 mm.

The distance between the support and between the force 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 13385-1) 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 force edges

3 test specimen

4 support

D diameter of test specimen

F force, in newtons

h height of test specimen

l_{ss} distance between supports

l_{se} distance between support and force edge

Figure 1 — Example of a measuring device and test setup

6 Test specimen

6.1 Sampling and sample preparation

Sampling shall be in accordance with the appropriate method i.e. ISO 8007-1, ISO 8007-2, ISO 8007-3, or be agreed with the applicant. The number of specimens shall be defined with respect to the homogeneity of the material to be tested.

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

8 Calculation and expression of results

8.1 Bending moment, M_b

The bending moment, M_b, is calculated according to Formula (1).

$$M_b = \frac{l_{se}}{2} \cdot F_{max} \tag{1}$$

where

l_{se} is the distance between the support and the force edge (leverage of force, see Figure 1), in mm;

F_{max} is the maximum force, in N.

8.2 Flexural strength, σ_b

The flexural strength, σ_b, in MPa is calculated using the formula in 3.1 and Formula (2).

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

where

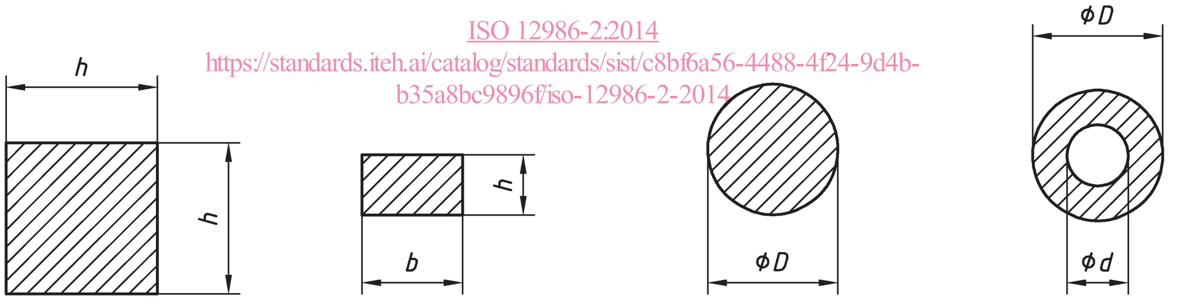
Z	is the section modulus, in mm^3 (see Figure 2);
l_{se}	is the distance between the support and the force-bearing edge (leverage of force, see Figure 1), in mm;
F_{max}	is the maximum force, in N.

In the case of test specimens with square cross-section and $l_{se} = h$, the flexural strength σ_b in MPa is calculated according to Formula (3):

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

In the case of cylindrical test specimens and $l_{se} = D$, the flexural strength in MPa squared is calculated according to Formula (4):

$$\sigma_b = 16 \cdot \frac{F_{max}}{\pi \cdot D^2} \qquad (4)$$



a) Square	b) Rectangle	c) Circle	d) Ring
$Z = \frac{h^3}{6}$	$Z = \frac{b \cdot h^2}{6}$	$Z = \frac{\pi \cdot D^3}{32}$	$Z = \frac{\pi}{32} \cdot \frac{(D^4 - d^4)}{D}$

Key

Z section moment, in mm^3

h height of a rectangular cross-section, in mm

b breadth of a rectangular cross-section, in mm

D external diameter of a circular cross-section, in mm

d internal diameter of a ring cross-section, in mm

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