INTERNATIONAL STANDARD

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Metallic materials — Tensile testing at low temperature

Matériaux métalliques — Essai de traction à basse température

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15579 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of materials*, Subcommittee SC 1, *Uniaxial testing*.

Annex A of this International Standard is for information only.

Introduction

It was decided, at the ISO/TC 164/SC 1 meeting of 29th February and 1st March 1996, to define test rate by the strain rate of the parallel length of the test piece. The values taken into account correspond to testing steel products. If this International Standard is used for testing non-ferrous metallic materials, it should be verified that the test and rate values apply.

Metallic materials — Tensile testing at low temperature

1 Scope

This International Standard specifies the method of tensile testing of metallic materials at temperatures between + 10 °C and – 196 °C and defines the mechanical properties which can be determined.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing.*

3 Terms and definitions

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

3.1
gauge length
L
length of the cylindrical or prismatic portion of the test piece on which elongation shall be measured

NOTE In particular, a distinction is made between the lengths defined in 3.1.1 and 3.1.2.

3.1.1
original gauge length
L_o
gauge length before application of force measured at ambient temperature

3.1.2
final gauge length
L_u
gauge length after fracture of the test piece (see 9.3) measured at ambient temperature

3.2
parallel length
L_c
length of the parallel portion of the reduced section of the test piece

3.3
extensometer gauge length
L_e
length of the parallel portion of the test piece used for the measurement of elongation by means of an extensometer

NOTE This length may differ from L_o and has a value greater than b or d (see Table 1) but less than L_c.

3.4
elongation
increase in the original gauge length (L_o) at any moment during the test

3.5
percentage elongation
elongation expressed as a percentage of the original gauge length (L_o)

3.6
percentage permanent elongation
increase in the original gauge length of a test piece after removal of a specified stress (see 3.13), expressed as a percentage of the original gauge length (L_o)

3.7
percentage elongation after fracture
A
permanent elongation of the original gauge length after fracture ($L_u - L_o$), expressed as a percentage of the original gauge length (L_o)

NOTE In the case of proportional test pieces, only if the original gauge length is other than $5{,}65\sqrt{S_o}$ 1) where S_o is the original cross-sectional area of the parallel length should the symbol A be supplemented by an index indicating the coefficient of proportionality used, e.g.:

$A_{11,3}$ = percentage elongation of a gauge length (L_o) of $11{,}3\sqrt{S_o}$.

In the case of non-proportional test pieces, the symbol A should be supplemented by an index indicating the original gauge length used, expressed in millimetres, e.g.:

$A_{80\ mm}$ = percentage elongation of a gauge length (L_o) of 80 mm.

3.8
percentage total elongation at fracture
A_t
total elongation (elastic elongation plus plastic elongation) of the gauge length at the moment of fracture expressed as a percentage of the original gauge length (L_o)

3.9
extension
increase in the extensometer gauge length (L_e) at a given moment of the test

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1) $5{,}65\sqrt{S_o} = 5\sqrt{\frac{4\,S_o}{\pi}}$

3.10
percentage permanent extension
increase in the extensometer gauge length, after removal from the test piece of a specified stress, expressed as a percentage of the extensometer gauge length (L_e)

3.11
percentage reduction of area
Z
maximum change in cross-sectional area which has occurred during the test ($S_o - S_u$) expressed as a percentage of the orignal cross-sectional area (S_o)

3.12
maximum force
F_m
the maximum force which the test piece withstands during the test after any yielding has taken place

NOTE For brittle materials, it is the maximum value during the test.

3.13
stress
force at any moment during the test divided by the original cross-sectional area (S_o) of the test piece

3.13.1
tensile strength
R_m
stress corresponding to the maximum force (F_m)

3.13.2
yield strength
when the metallic material exhibits a yield phenomenon, a point during the test at which plastic deformation occurs without any increase in the force

3.13.2.1
upper yield strength
R_{eH}
value of stress at which the first decrease in force is observed

See Figure 1.

3.13.2.2
lower yield strength
R_{eL}
lowest value of stress during plastic yielding, ignoring any transient effects

See Figure 1.

3.13.3
proof strength, non-proportional extension
R_p
stress at which the non-proportional extension is equal to a specified percentage of the extensometer gauge length (L_e)

See Figure 2.

NOTE The symbol used is followed by a suffix giving the prescribed percentage, e.g.: $R_{p0,2}$.

4 Symbols and designations

Symbols and corresponding designations are given in Table 1.

Table 1 — Symbols and designations

Symbol	Unit	Designation
a	mm	Thickness of a flat test piece or wall thickness of a tube
b	mm	Width of the parallel length of a flat test piece or average width of the longitudinal strip taken from a tube or width of flat wire
d	mm	Diameter of the parallel length of a cylindrical test piece or diameter of a circular wire
L_o	mm	Original gauge length
L_u	mm	Final gauge length after fracture
L_c	mm	Parallel length
L_e	mm	Extensometer gauge length
S_o	mm^2	Original cross-sectional area of the parallel length
S_u	mm^2	Minimum cross-sectional area after fracture (final cross-sectional area)
Z	%	Percentage reduction of area: $\frac{S_o - S_u}{S_o} \times 100$
A	%	Percentage elongation after fracture: $\frac{L_u - L_o}{L_o} \times 100$
A_t	%	Percentage total elongation at fracture
F_m	N	Maximum force
R_{eH}	N/mm^2	Upper yield strength
R_{eL}	N/mm^2	Lower yield strength
R_m	N/mm^2	Tensile strength
R_p	N/mm^2	Proof strength, non-proportional extension
θ	°C	Specified temperature
θ_i	°C	Indicated temperature

5 Principle

The test consists of straining a test piece by a tensile force, generally to fracture, for the purpose of determining one or more of the mechanical properties defined in clause 3.

The test is carried out at a specified temperature which is between + 10 °C and – 196 °C.

6 Apparatus

6.1 Testing machine

The testing machine shall be verified in accordance with ISO 7500-1 and shall be of at least class 1, unless otherwise specified in the product standard.

6.2 Extensometer

When using an extensometer to measure the extension, the extensometer shall be of class 1 (see ISO 9513) for the determination of the proof stress for non-proportional elongation; for the determination of other properties (corresponding to higher elongations) an extensometer of class 2 (see ISO 9513) can be used.

The extensometer gauge length shall be not less than 10 mm and shall be centrally located in the mid-region of the parallel length and along the centre axis. The extensometer should preferably be of the type that is capable of measuring extension on both sides of a test piece thus enabling the operator to determine the mean of the two readings.

Any part of the extensometer projecting beyond the cooling device shall be protected from air currents so that fluctuations in the ambient temperature have only a minimal effect on the readings. It is recommended that reasonable stability of the temperature and speed of the air surrounding the testing machine be maintained.

6.3 Cooling device

6.3.1 General

The cooling device shall be capable of cooling the test piece to the specified temperature θ.

The means of cooling can be, for example:

— by refrigeration unit;

— by expansion of compressed gas (e.g. CO_2 or N_2);

— by immersion in a liquid maintained at its boiling point (e.g. N_2) or in a refrigerated liquid (e.g. alcohol).

WARNING — Test personnel should use proper personal protective equipment when handling the cooling medium. Precautions should be taken to avoid damage to the test equipment or test piece.

6.3.2 Measurement of temperature

The temperature of the cooling medium or the test piece shall be measured by thermocouples or other suitable devices.

The temperature of the test piece shall be measured at the surface of the parallel length of the test piece.

NOTE 1 Use of the proper type and class of thermocouple is important to ensure accuracy of the measured temperature.

NOTE 2 When the gauge length is less than 50 mm, one thermocouple should be placed at each end of the parallel length. When the gauge length is equal to or greater than 50 mm, a third thermocouple should be placed near the centre of the parallel length.

If the test piece is in a liquid medium which can be assumed to be homogeneous, the temperature measurement may be done at a point away from the test piece.

If testing is carried out in liquid nitrogen, no temperature measurement is needed. In this case, it shall be recorded in the test report.