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Metallic materials — Tensile testing —

Part 1:
Method of test at room temperature

Matériaux métalliques — Essai de traction —

Partie 1: Méthode d'essai à température ambiante

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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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This third edition cancels and replaces the second edition (ISO 6892-1:2016), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

- correction of the title of a standard in Clause 2;
- correction of the designation "coefficient of determination" ("coefficient of determination" instead of "coefficient of correlation");
- correction of Formula (1);
- wording in 10.3.2.1;
- wording in the key of Figure 9;
- wording in Table B.2;
- wording in Table D.3;
- correction of the references.

A list of all parts in the ISO 6892 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

During discussions concerning the speed of testing in the preparation of ISO 6892, it was decided to recommend the use of strain rate control in future revisions.

In this document, there are two methods of testing speeds available. The first, method A, is based on strain rates (including crosshead separation rate) and the second, method B, is based on stress rates. Method A is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results. Therefore, and out of the fact that often the strain rate sensitivity of the materials is not known, the use of method A is strongly recommended.

NOTE In what follows, the designations “force” and “stress” or “extension”, “percentage extension”, and “strain”, respectively, are used on various occasions (as figure axis labels or in explanations for the determination of different properties). However, for a general description or point on a curve, the designations “force” and “stress” or “extension”, “percentage extension”, and “strain”, respectively, can be interchanged.

Metallic materials — Tensile testing —

Part 1:
Method of test at room temperature

1 Scope

This document specifies the method for tensile testing of metallic materials and defines the mechanical properties which can be determined at room temperature.

NOTE Annex A contains further recommendations for computer controlled testing machines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7500-1, *Metallic materials — Calibration and 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 extensometer systems used in uniaxial testing*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
gauge length
L
length of the parallel portion of the test piece on which elongation is measured at any moment during the test

3.1.1
original gauge length
L_o
length between *gauge length* (3.1) marks on the test piece measured at room temperature before the test

3.1.2
final gauge length after fracture
L_u
length between *gauge length* (3.1) marks on the test piece measured after rupture, at room temperature, the two pieces having been carefully fitted back together so that their axes lie in a straight line

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

Note 1 to entry: The concept of parallel length is replaced by the concept of distance between grips for unmachined test pieces.

3.3
elongation
increase in the *original gauge length* (3.1.1) at any moment during the test

3.4
percentage elongation
elongation (3.3) expressed as a percentage of the *original gauge length* (3.1.1)

3.4.1
percentage permanent elongation
increase in the *original gauge length* (3.1.1) of a test piece after removal of a specified stress, expressed as a percentage of the *original gauge length* (3.1.1)

3.4.2
percentage elongation after fracture
A
permanent *elongation* (3.3) of the gauge length after fracture ($L_u - L_o$), expressed as a percentage of the *original gauge length* (3.1.1)

Note 1 to entry: For further information, see 8.1.

3.5
extensometer gauge length
L_e
initial gauge length of the extensometer used for measurement of *extension* (3.6)

Note 1 to entry: For the determination of several properties which are based (partly or complete) on extension, e. g. R_p, A_e or A_g, the use of an extensometer is mandatory.

Note 2 to entry: For further information, see 8.3.

3.6
extension
increase in the *extensometer gauge length* (3.5), at any moment during the test

3.6.1
percentage extension
strain
e
extension (3.6) expressed as a percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: e is commonly called engineering strain.

3.6.2
percentage permanent extension
increase in the *extensometer gauge length* (3.5), after removal of a specified *stress* (3.10) from the test piece, expressed as a percentage of the extensometer gauge length

3.6.3
percentage yield point extension
A_e
<discontinuous yielding materials> *extension* (3.6) between the start of yielding and the start of uniform work-hardening, expressed as a percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: See Figure 7.

3.6.4
percentage total extension at maximum force
A_{gt}
total *extension* (3.6) (elastic extension plus plastic extension) at maximum force, expressed as a percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: See Figure 1.

3.6.5
percentage plastic extension at maximum force
A_g
plastic *extension* (3.6) at maximum force, expressed as a percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: See Figure 1.

3.6.6
percentage total extension at fracture
A_t
total *extension* (3.6) (elastic extension plus plastic extension) at the moment of fracture, expressed as a percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: See Figure 1.

3.7
testing rate
rate (resp. rates) used during the test

3.7.1
strain rate
$\dot{e}_{L_e}$
increase of strain, measured with an extensometer, in *extensometer gauge length* (3.5), per time

3.7.2
estimated strain rate over the parallel length
$\dot{e}_{L_c}$
value of the increase of strain over the *parallel length* (3.2) of the test piece per time based on the *crosshead separation rate* (3.7.3) and the parallel length of the test piece

3.7.3
crosshead separation rate
v_c
displacement of the crossheads per time

3.7.4
stress rate
$\dot{R}$
increase of *stress* (3.10) per time

Note 1 to entry: Stress rate is only used in the elastic part of the test (method B) (see also 10.3.3).

3.8
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 original cross-sectional area, S_o:

$$Z = \frac{S_o - S_u}{S_o} \cdot 100$$

3.9 Maximum force

3.9.1
maximum force
F_m
<materials displaying no discontinuous yielding> highest force that the test piece withstands during the test

3.9.2
maximum force
F_m
<materials displaying discontinuous yielding> highest force that the test piece withstands during the test after the beginning of work-hardening

Note 1 to entry: For materials which display discontinuous yielding, but where no work-hardening can be established, F_m is not defined in this document [see footnote to Figure 8 c)].

Note 2 to entry: See Figure 8 a) and b).

3.10
stress
R
at any moment during the test, force divided by the original cross-sectional area, S_o, of the test piece

Note 1 to entry: All references to stress in this document are to engineering stress.

3.10.1
tensile strength
R_m
stress (3.10) corresponding to the *maximum force* (3.9.2)

3.10.2
yield strength
when the metallic material exhibits a yield phenomenon, *stress* (3.10) corresponding to the point reached during the test at which plastic deformation occurs without any increase in the force

3.10.2.1
upper yield strength
R_{eH}
maximum value of *stress* (3.10) prior to the first decrease in force

Note 1 to entry: See Figure 2.

3.10.2.2
lower yield strength
R_{eL}
lowest value of *stress* (3.10) during plastic yielding, ignoring any initial transient effects

Note 1 to entry: See Figure 2.

3.10.3
proof strength, plastic extension
R_p
stress (3.10) at which the plastic *extension* (3.6) is equal to a specified percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: Adapted from ISO/TR 25679:2005, "proof strength, non-proportional extension".

Note 2 to entry: A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{p0,2}$.

Note 3 to entry: See Figure 3.

3.10.4
proof strength, total extension
R_t
stress (3.10) at which total *extension* (3.6) (elastic extension plus plastic extension) is equal to a specified percentage of the *extensometer gauge length* (3.5)

Note 1 to entry: A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{t0,5}$.

Note 2 to entry: See Figure 4.

3.10.5
permanent set strength
R_r
stress (3.10) at which, after removal of force, a specified permanent *elongation* (3.3) or *extension* (3.6), expressed respectively as a percentage of *original gauge length* (3.1.1), or *extensometer gauge length* (3.5), has not been exceeded

Note 1 to entry: A suffix is added to the subscript to indicate the specified percentage of the original gauge length, L_o, or of the extensometer gauge length, L_e, e.g. $R_{r0,2}$.

Note 2 to entry: See Figure 5.

3.11
fracture
phenomenon which is deemed to occur when total separation of the test piece occurs

Note 1 to entry: Criteria for fracture for computer controlled tests are given in Figure A.2.

3.12
computer-controlled tensile testing machine
machine for which the control and monitoring of the test, the measurements, and the data processing are undertaken by computer

3.13
modulus of elasticity
E
quotient of change of stress ΔR and change of percentage extension Δe in the range of evaluation, multiplied by 100 %

$$E = \frac{\Delta R}{\Delta e} \cdot 100\ \%$$

Note 1 to entry: It is recommended to report the value in GPa rounded to the nearest 0,1 GPa and according to ISO 80000-1.

3.14
default value
lower or upper value for *stress* (3.10), respectively *strain* (3.6.1), which is used for the description of the range where the *modulus of elasticity* (3.13) is calculated

3.15
coefficient of determination
R^2
additional result of the linear regression which describes the quality of the stress-strain curve in the evaluation range

Note 1 to entry: The used symbol R^2 is a mathematical representation of regression and is no expression for a squared stress value.

3.16
standard deviation of the slope
S_m
additional result of the linear regression which describes the difference of the *stress* (3.10) values from the best fit line for the given *extension* (3.6.1) values in the evaluation range

3.17
relative standard deviation of the slope
$S_{m(rel)}$
quotient of the *standard deviation of the slope* (3.16) and the slope in the evaluation range, multiplied by 100 %

$$S_{m(rel)} = \frac{S_m}{E} \cdot 100\ \%$$

4 Symbols

The symbols used in this document and corresponding designations are given in Table 1.

Table 1 — Symbols and designations

Symbol	Unit	Designation
		Test piece
a_o, T[a]	mm	original thickness of a flat test piece or wall thickness of a tube
b_o	mm	original 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_o	mm	original diameter of the parallel length of a circular test piece, or diameter of round wire or internal diameter of a tube
D_o	mm	original external diameter of a tube
L_o	mm	original gauge length
L'_o	mm	initial gauge length for determination of A_{wn} (see Annex J)
L_c	mm	parallel length
L_e	mm	extensometer gauge length
L_t	mm	total length of test piece
L_u	mm	final gauge length after fracture
L'_u	mm	final gauge length after fracture for determination of A_{wn} (see Annex J)

[a] Symbol used in steel tube product standards.

[b] 1 MPa = 1 N mm^{-2}.

[c] The calculation of the modulus of elasticity is described in Annex G. It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength.

[d] In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G).

CAUTION — The factor 100 is necessary if percentage values are used.

Table 1 *(continued)*

Symbol	Unit	Designation
S_o	mm^2	original cross-sectional area of the parallel length
S_u	mm^2	minimum cross-sectional area after fracture
k	—	coefficient of proportionality (see 6.1.1)
Z	%	percentage reduction of area
		Elongation
A	%	percentage elongation after fracture (see 3.4.2)
A_{wn}	%	percentage plastic elongation without necking (see Annex J)
		Extension
e	%	extension
A_e	%	percentage yield point extension
A_g	%	percentage plastic extension at maximum force, F_m
A_{gt}	%	percentage total extension at maximum force, F_m
A_t	%	percentage total extension at fracture
ΔL_m	mm	extension at maximum force
ΔL_f	mm	extension at fracture
		Rates
$\dot{e}_{L_e}$	s^{-1}	strain rate
$\dot{e}_{L_c}$	s^{-1}	estimated strain rate over the parallel length
$\dot{R}$	MPa s^{-1}	stress rate
v_c	mm s^{-1}	crosshead separation rate
		Force
F_m	N	maximum force
		Yield strength — Proof strength — Tensile strength
R	MPa[b]	stress
R_{eH}	MPa	upper yield strength
R_{eL}	MPa	lower yield strength
R_m	MPa	tensile strength
R_p	MPa	proof strength, plastic extension
R_r	MPa	specified permanent set strength
R_t	MPa	proof strength, total extension
		Modulus of elasticity — slope of the stress-percentage extension curve
E	GPa	modulus of elasticity[c]
m	MPa	slope of the stress-percentage extension curve at a given moment of the test
m_E	MPa	slope of the elastic part of the stress-percentage extension curve[d]
R_1	MPa	lower stress value
R_2	MPa	upper stress value

[a] Symbol used in steel tube product standards.

[b] 1 MPa = 1 N mm^{-2}.

[c] The calculation of the modulus of elasticity is described in Annex G. It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength.

[d] In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G).

CAUTION — The factor 100 is necessary if percentage values are used.

Table 1 *(continued)*

Symbol	Unit	Designation
e_1	%	lower strain value
e_2	%	upper strain value
R^2	—	coefficient of determination
S_m	MPa	standard deviation of the slope
$S_{m(rel)}$	%	relative standard deviation of the slope

[a] Symbol used in steel tube product standards.

[b] 1 MPa = 1 N mm^{-2}.

[c] The calculation of the modulus of elasticity is described in Annex G. It is not required to use Annex G to determine the slope of the elastic part of the stress-percentage extension curve for the determination of proof strength.

[d] In the elastic part of the stress-percentage extension curve, the value of the slope may not necessarily represent the modulus of elasticity. This value may closely agree with the value of the modulus of elasticity if optimal conditions are used (see Annex G).

CAUTION — The factor 100 is necessary if percentage values are used.

5 Principle

The test involves straining a test piece by tensile force, generally to fracture, for the determination of one or more of the mechanical properties defined in Clause 3.

The test shall be carried out at room temperature between 10 °C and 35 °C, unless otherwise specified. For laboratory environments outside the stated requirement, it is the responsibility of the testing laboratory to assess the impact on testing and/or calibration data produced with and for testing machines operated in such environments. When testing and calibration activities are performed outside the temperature limits of 10 °C and 35 °C, the temperature shall be recorded and reported. If significant temperature gradients are present during testing and/or calibration, measurement uncertainty may increase and out of tolerance conditions may occur.

Tests carried out under controlled conditions shall be made at a temperature of 23 °C ± 5 °C.

If the determination of the modulus of elasticity is requested in the tensile test, this shall be done in accordance with Annex G.

6 Test pieces

6.1 Shape and dimensions

6.1.1 General

The shape and dimensions of the test pieces may be constrained by the shape and dimensions of the metallic product from which the test pieces are taken.

The test piece is usually obtained by machining a sample from the product or a pressed blank or casting. However, products of uniform cross-section (sections, bars, wires, etc.) and also as-cast test pieces (i.e. for cast iron and non-ferrous alloys) may be tested without being machined.

The cross-section of the test pieces may be circular, square, rectangular, annular or, in special cases, some other uniform cross-section.

Preferred test pieces have a direct relationship between the original gauge length, L_o, and the original cross-sectional area, S_o, expressed by the formula $L_o = k\sqrt{S_o}$, where k is a coefficient of proportionality, and are called proportional test pieces. The internationally adopted value for k is 5,65. The original gauge length shall be not less than 15 mm. When the cross-sectional area of the test piece is too small for this requirement to be met with k = 5,65, a higher value (preferably 11,3) or a non-proportional test piece may be used.

NOTE By using an original gauge length smaller than 20 mm, the uncertainty of the result "elongation after fracture" will be increased.

For non-proportional test pieces, the original gauge length, L_o, is independent of the original cross-sectional area, S_o.

The dimensional tolerances of the test pieces shall be in accordance with Annexes B to E (see 6.2).

Other test pieces such as those specified in relevant product standards or national standards may be used by agreement with the customer, e.g. ISO 3183[1] (API 5L), ISO 11960[2] (API 5CT), ASTM A370[6], ASTM E8M[7], DIN 50125[10], IACS W2[13], and JIS Z 2241[14].

6.1.2 Machined test pieces

Machined test pieces shall incorporate a transition radius between the gripped ends and the parallel length if these have different dimensions. The dimensions of the transition radius are important and it is recommended that they be defined in the material specification if they are not given in the appropriate annex (see 6.2).

The gripped ends may be of any shape to suit the grips of the testing machine. The axis of the test piece shall coincide with the axis of application of the force.

The parallel length, L_c, or, in the case where the test piece has no transition radii, the free length between the grips, shall always be greater than the original gauge length, L_o.

6.1.3 Unmachined test pieces

If the test piece consists of an unmachined length of the product or of an unmachined test bar, the free length between the grips shall be sufficient for gauge marks to be at a reasonable distance from the grips (see Annexes B to E).

As-cast test pieces shall incorporate a transition radius between the gripped ends and the parallel length. The dimensions of this transition radius are important and it is recommended that they be defined in the product standard. The gripped ends may be of any shape to suit the grips of the testing machine provided that they enable the centre of the test piece to coincide with the axis of application of force. The parallel length, L_c, shall always be greater than the original gauge length, L_o.

6.2 Types

The main types of test pieces are defined in Annexes B to E according to the shape and type of product, as shown in Table 2. Other types of test pieces can be specified in product standards.