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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

Reference number
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Foreword

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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 6892-1 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This first edition of ISO 6892-1 cancels and replaces ISO 6892:1998.

ISO 6892 consists of the following parts, under the general title *Metallic materials — Tensile testing*:

— *Part 1: Method of test at room temperature*

The following parts are under preparation:

— *Part 2: Method of test at elevated temperature*

— *Part 3: Method of test at low temperature*

The following part is planned:

— *Part 4: Method of test in liquid helium*

Introduction

During discussions concerning the speed of testing in the preparation of ISO 6892:1998, it was decided to recommend the use of strain rate control in future revisions.

In this part of ISO 6892, 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.

Metallic materials — Tensile testing —

Part 1:
Method of test at room temperature

1 Scope

This part of ISO 6892 specifies the method for tensile testing of metallic materials and defines the mechanical properties which can be determined at room temperature.

NOTE Annex A indicates complementary recommendations for computer controlled testing machines.

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 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

ISO 2566-2, *Steel — Conversion of elongation values — Part 2: Austenitic steels*

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 document, the following terms and definitions apply.

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

[ISO/TR 25679:2005[3]]

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

NOTE Adapted from ISO/TR 25679:2005[3].

3.1.2
final gauge length after rupture
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

NOTE Adapted from ISO/TR 25679:2005[3].

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

[ISO/TR 25679:2005[3]]

NOTE 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

NOTE Adapted from ISO/TR 25679:2005[3].

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

[ISO/TR 25679:2005[3]]

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, L_o

[ISO/TR 25679:2005[3]]

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

[ISO/TR 25679:2005[3]]

NOTE For proportional test pieces, if the original gauge length is not equivalent to $5{,}65\sqrt{S_o}$ 1) where S_o is the original cross-sectional area of the parallel length, the symbol A should be supplemented by a subscript indicating the coefficient of proportionality used, e.g. $A_{11,3}$ indicates a percentage elongation of the gauge length, L_o, of

$$A_{11,3} = 11{,}3\sqrt{S_o}$$

For non-proportional test pieces (see Annex B), the symbol A should be supplemented by a subscript indicating the original gauge length used, expressed in millimetres, e.g. $A_{80\ \text{mm}}$ indicates a percentage elongation of a gauge length, L_o, of 80 mm.

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1) $5{,}65\sqrt{S_o} = 5\sqrt{(4S_o/\pi)}$.

3.5
extensometer gauge length
L_e
initial extensometer gauge length used for measurement of extension by means of an extensometer

NOTE 1 Adapted from ISO/TR 25679:2005[3].

NOTE 2 For measurement of yield and proof strength parameters, L_e should span as much of the parallel length of the test piece as possible. Ideally, as a minimum, L_e should be greater than 0,50L_o but less than approximately 0,9L_c. This should ensure that the extensometer detects all yielding events that occur in the test piece. Further, for measurement of parameters "at" or "after reaching" maximum force, L_e should be approximately equal to L_o.

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

[ISO/TR 25679:2005[3]]

3.6.1
percentage extension
"strain"
extension expressed as a percentage of the **extensometer gauge length**, L_e (3.5)

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

[ISO/TR 25679:2005[3]]

3.6.3
percentage yield point extension
A_e
in discontinuous yielding materials, the extension between the start of yielding and the start of uniform workhardening, expressed as a percentage of the **extensometer gauge length**, L_e (3.5)

NOTE Adapted from ISO/TR 25679:2005[3].

See Figure 7.

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

See Figure 1.

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

See Figure 1.

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

See Figure 1.

3.7 Testing rate

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

NOTE See 3.5.

3.7.2
estimated strain rate over the parallel length
$\dot{e}_{L_c}$
value of the increase of strain over the **parallel length**, L_c (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 per time

NOTE Stress rate should only be used in the elastic part of the test (method B).

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:

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

3.9 Maximum force

NOTE For materials which display discontinuous yielding, but where no workhardening can be established, F_m is not defined in this part of ISO 6892 [see footnote to Figure 8 c)].

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 workhardening

NOTE See Figure 8 a) and b).

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

NOTE 1 Adapted from ISO/TR 25679:2005[3].

NOTE 2 All references to stress in this part of ISO 6892 are to engineering stress.

NOTE 3 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 definition of a well-defined point on a curve, the designations “force” and “stress” or “extension”, “percentage extension” and “strain”, respectively, are interchangeable.

3.10.1
tensile strength
R_m
stress corresponding to the **maximum force**, F_m (3.9)

[ISO/TR 25679:2005[3]]

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

NOTE Adapted from ISO/TR 25679:2005[3].

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

NOTE Adapted from ISO/TR 25679:2005[3].

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

[ISO/TR 25679:2005[3]]

See Figure 2.

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

NOTE 1 Adapted from ISO/TR 25679:2005, “proof strength, non-proportional extension”.

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

See Figure 3.

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

NOTE 1 Adapted from ISO/TR 25679:2005[3].

NOTE 2 A suffix is added to the subscript to indicate the prescribed percentage, e.g. $R_{t0,5}$.

See Figure 4.

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

[ISO/TR 25679:2005[3]]

See Figure 5.

NOTE 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. $R_{r0,2}$.

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

NOTE Criteria for fracture which may be used for computer controlled tests are given in Figure A.2.

4 Terms and symbols

The symbols used in this part of ISO 6892 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 I)
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 I)
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 I)
		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

Table 1 — Symbols and designations *(continued)*

Symbol	Unit	Designation
Force		
F_m	N	maximum force
Yield strength — Proof strength — Tensile strength		
E	MPa [b]	modulus of elasticity
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 [c]
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

[a] Symbol used in steel tube product standards.

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

[c] 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 can closely agree with the value of the modulus of elasticity if optimal conditions (high resolution, double sided, averaging extensometers, perfect alignment of the test piece, etc.) are used.

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 is carried out at room temperature between 10 °C and 35 °C, unless otherwise specified. Tests carried out under controlled conditions shall be made at a temperature of 23 °C ± 5 °C.

6 Test piece

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 equation $L_o = k\sqrt{S_o}$, 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 measurement uncertainty is 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 the 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 Z2201[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. 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.

