TRUST
DESTRUCTIVE TESTING TECHNICIAN

Project number 2020-1-PL01-KA202-081820

European Destructive Testing Technician (EDTT)

Tensile Tests at Ambient Temperature

[Name of the Event & Date]

Co-funded by the Erasmus+ Programme of the European Union

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Introduction

The tensile test is one of the basic types of destructive tests.

It determine the basic properties of the materials like tensile strength, yield strength, and ductility of the material.

It measures the force required to break a specimen and the extent to which the specimen stretches or elongates to that breaking point.

It can be performed at both ambient and elevated temperatures.

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Standard

ISO 6892-1:2019

Metallic materials — Tensile testing — Part 1: Method of test at room temperature

This document defines a method for testing the tensile strength of metals and defines the mechanical properties determined at room temperature.

PRINCIPLE OF TESTING - stretching a specimen until it breaks and determining one or more mechanical properties:

- tensile strength – R_m,
- yield strength - R_e or $R_{0.2}$,
- elongation – A,
- percentage reduction of the area – Z.

Terms and definitions –
Percentage elongation after fracture – A

Permanent elongation of the gauge length after fracture expressed as a percentage of the original gauge length

$$A = \frac{L_u - L_0}{L_0} \cdot 100\%$$

where

L_u – final gauge length after fractur,

L_0 – original gauge length.

Terms and definitions –
Percentage elongation after fracture – A

A – percentage elongation after fracture,

Ag – percentage plastic extension at maximum force

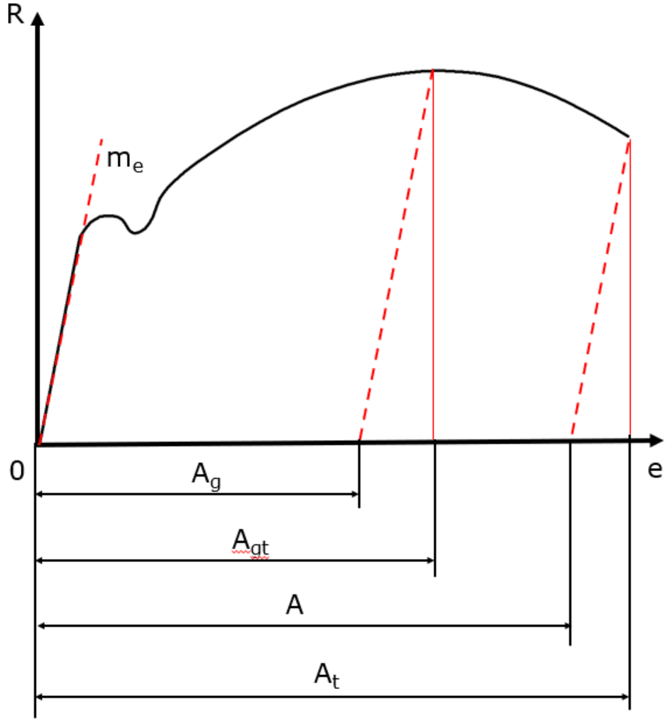
Agt – percentage total extension at maximum force

At – percentage total extension at fracture

R – stress

e – percentage extension

mE – slope of the elastic part of the stress-percentage extension curve



$$A = \frac{L_u - L_0}{L_0} \cdot 100\%$$

$$A_{gt} = \frac{\Delta L_m}{L_e} \cdot 100\%$$

$$A_t = \frac{\Delta L_t}{L_e} \cdot 100\%$$

L_0 – original gauge length,
L_u – final gauge length,
L_e – extensometer gauge length,
ΔL_m – extension at maximum force
ΔL_t – extension at fracture

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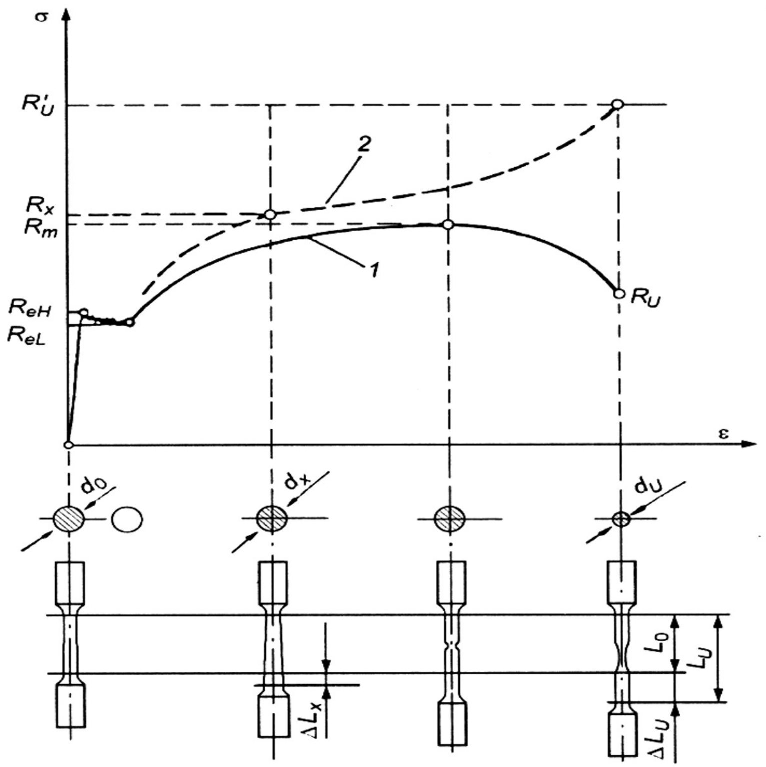
Terms and definitions –
Percentage reduction of the area – Z



$$Z = \frac{S_0 - S_u}{S_0} \cdot 100\%$$

S_0 – original cross-sectional area of the paralel length,

S_u – minimum cross-sectional area after fracture,

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Terms and definitions –
Proof strength, plastic R_p and total R_t extension

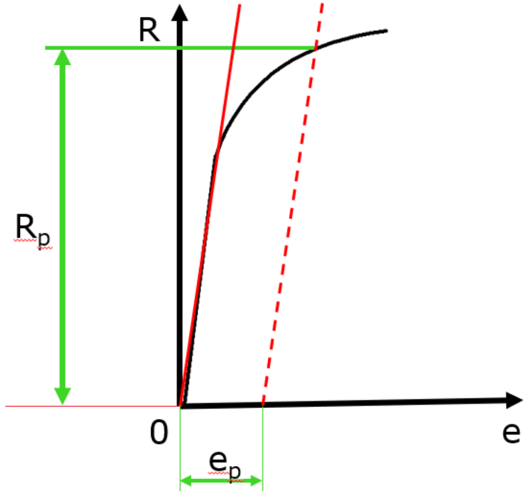
Proof strength, plastic extension, R_p

Stress at which the plastic extension is equal to a specified percentage of the extensometer gauge length.

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

For the determination of R_p, the use of extensometer is mandatory

e – percentage extension,
e_p – specified percentage plastic extension
R - stress,
R_p – proof strength, plastic extension,
a – initial transient effect.



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Terms and definitions –
Proof strength, plastic R_p and total R_t extension

Determination of proof strength, plastic extension, R_p

R_p is determined from the force-extension curve by drawing a line parallel to the linear portion of the curve and at a distance from it equivalent to the prescribed plastic percentage extension, e.g. 0.2 %.

The point which this line is intersect the curve gives the force corresponding to the desired proof strength plastic extension.

The latter is obtained by dividing this force by the original cross-sectional area of the test piece, S_0.

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Terms and definitions –
Proof strength, plastic R_p and total R_t extension

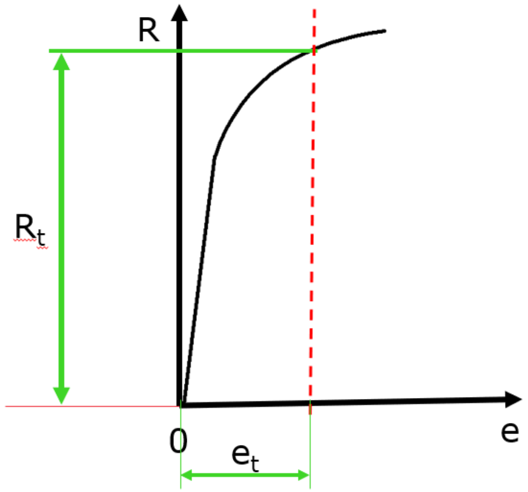
Proof strength, plastic extension, R_p

Stress at which total extension (elastic extension plus plastic extension) is equal to a specified percentage of the extensometer gauge length $L_{e.}$

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

For the determination of R_t, the use of extensometer is mandatory

e – percentage extension,
e_t – specified percentage total extension
R - stress,
R_t – proof strength, total extension,
a – initial transient effect.



Terms and definitions –
Proof strength, plastic R_p and total R_t extension

Determination of proof strength, total extension, R_t

R_t is determined from the force-extension curve by drawing a line parallel to the ordinate axis (force axis) and at a distance from this equivalent to the prescribed total percentage extension.

The point which this line is intersect the curve gives the force corresponding to the desired proof strength.

The value is calculated by dividing this force by the original cross-sectional area of the test piece, S_0.

Terms and definitions –
Upper and lower yield strength, R_{eH}, R_{eL}

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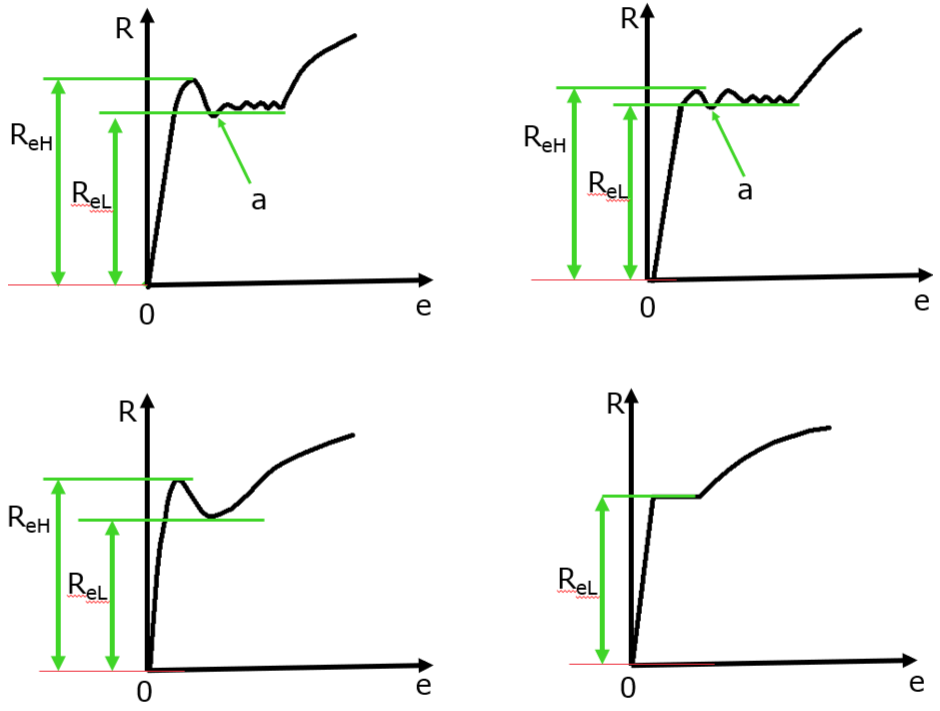
Upper yield strength, R_{eH}

Maximum value of stress prior to the first decrease in force

Lower yield strength, R_{eL}

Lowest value of stress during plastic yielding, ignoring any initial transient effects.



e – percentage extension,
R – stress,
R_{eH} – upper yield strength,
R_{eL} – lower yield strength,
a – initial transient effect.

Terms and definitions –
Proof strength, plastic R_p and total R_t extension

Determination of the upper and lower yield strength, R_{eH}, R_{eL}

R_{eH}, R_{eL} may be determined from the force-extension curve or peak load indicator according to figure.

The value is calculated by dividing the force by original cross-sectional area of the test piece, S_0.

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Principle of the method - Temperature

Unless otherwise specified, the test should be carried out at an ambient temperature of **10 °C to 35 °C**.

If the environmental conditions in the laboratory exceed the specified requirements, it is the responsibility of the test laboratory to assess the impact on test and or calibration data obtained with and for test equipment operating in such environments.

When test and calibration operations are performed outside the recommended temperature limits of 10 °C and 35 °C the temperature should be recorded and its value reported. If significant temperature gradients occur during test and or calibration, measurement uncertainty may increase and out-of-tolerance conditions may occur.

Tests carried out under controlled conditions should be performed at **23 °C ± 5 °C**

Principle of the method – Test Samples

The shape and dimensions of the test samples may depend on the shape and dimensions of the products from which they are taken.

Test specimens have a defined ratio between the initial gauge length L_0 and the initial cross-sectional area S_0

$$L_0 = k \cdot \sqrt{S_0}$$

Where, k is the coefficient of proportionality.

Generally, k = 5.65 is most common value, but if the cross-sectional area of the test specimen is too small (measuring length less than 15 mm), a higher value of the coefficient can be adopted (e.g. 11.3), or a non-proportional test specimen can be used.

Principle of the method – Test Samples

For proportional test specimens, if the measuring length is other than $5.65\sqrt{(S_0)}$, symbol A should be supplemented by a subscript indicating the proportionality factor used, e.g. $A_{5.65}$.

For non-proportional test specimens, symbol A should be supplemented with a subscript indicating the applied initial measurement length, expressed in minimetres, e.g. A_{80}

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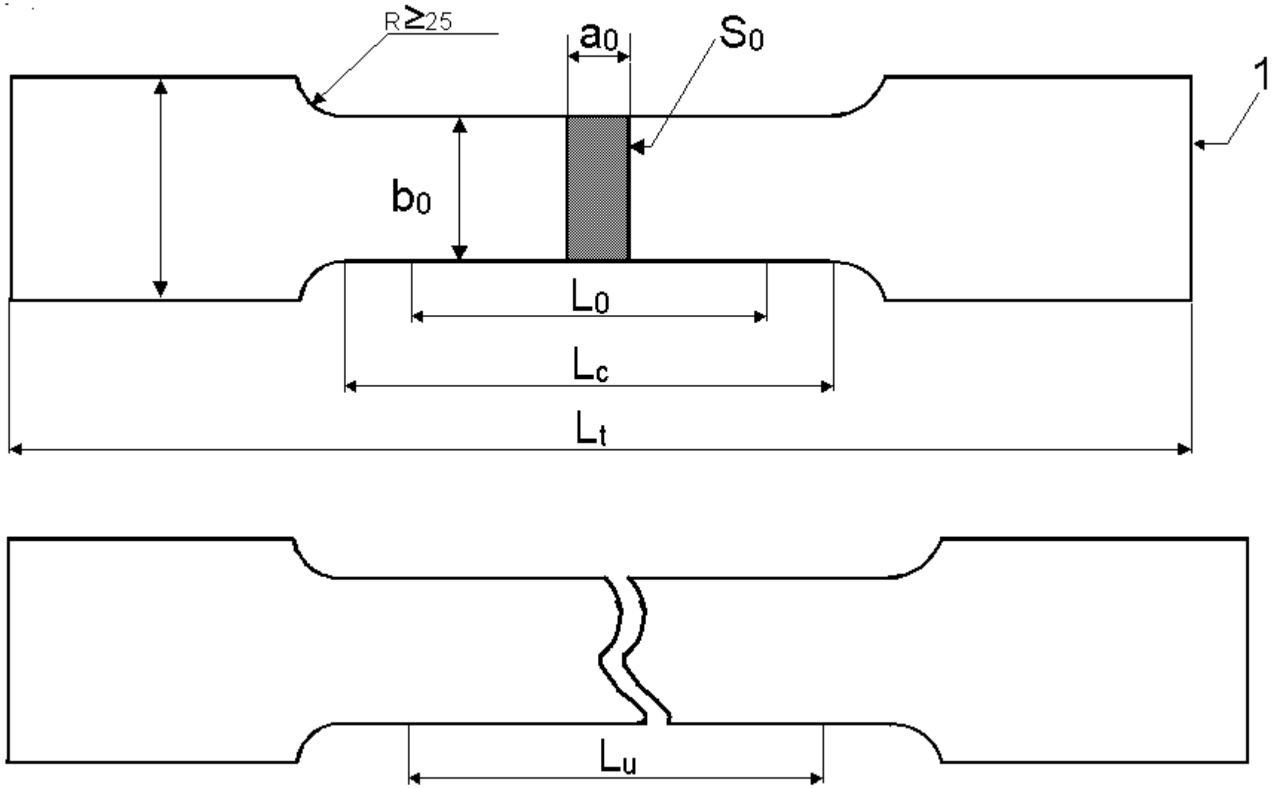
Principle of the method – Test Samples



a_0 – original thickness of a flat test piece or wall thickness of a tube

b_0 – original width of the parallel length of a flat test piece

L_c – parallel length

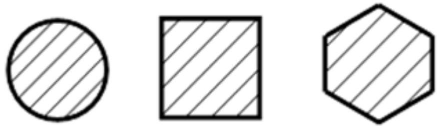
L_0 – original gauge length

L_t – total length of test piece

L_u – final gauge length after fracture

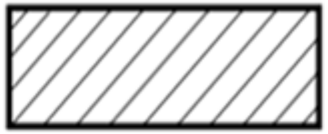
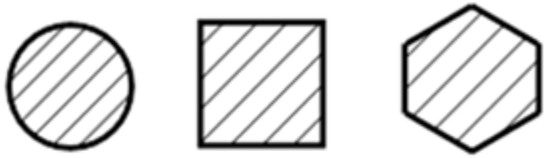
S_0 – original cross-section area of parallel length

1 – gripped ends



Principle of the method – Test Samples

ISO 6892-1 also provides sample dimensions that can be used for various components. The following table summarises main types of test pieces according to product type.

Type of product		Table
Sheets – Plates - Flats	Wire – Bars – Sections	
		
Thickness a, mm	Diameter or side Mm	
0,1≤ a < 3	-	Table 2
-	< 4	Table 3
A ≥ 3	≥ 4	Table 4
Tubes		Table 5

Principle of the method – Test Samples

Table 2. Dimensions and tolerances of test pieces for thin products: sheets, stripes and flats between 0.1 mm and 3 mm thick

Test piece type	Width b_0	Original gauge length L_0	Parallel length L_c		Free length between the grips for parallel sided test piece
			Minimum	Recommended	
1	12.5 ± 1	50	57	75	87.5
2	20 ± 1	80	90	120	140
3	25 ± 1	50[1]	60[1]	-	Not defined
Tolerances on the width of the test piece					
Nominal width of the test piece		Machining tolerance[2]		Tolerance on shape[3]	
12.5		±0.05		0.06	
20		±0.10		0.12	
25		±0.10		0.12	

[1]The ratio L_0/b_0 of a type 3 test piece in comparison to one of types 1 and 2 is very low. As a result, the properties, especially the elongation after fracture, measured with this test piece, will be different from other test piece types.
[2] These tolerances are applicable in nominal width of the test piece is to be used in the calculation of the original cross-sectional area S_0, without having to measure the width of each test piece.
[3] Maximum deviation between the measurements of the width along the entire parallel length L_c, of the test piece

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Principle of the method – Test Samples

Table 3. Dimensions and tolerances of test pieces for wire, bars and sections with diameter or thickness of less than 4 mm

1. The original gauge length, L_0, shall be taken as: - 200 mm ± 2 mm - 100 mm ± 1 mm
2. The distance between the grips of the machine shall be equal to at least $L_0 + 3b_0$, but minimum of $L_0 + 20$ mm.
3. If the percentage elongation after fracture is not to be determined, a distance between the grips of at least 50 mm may be used.
4. Determine S_0 to an accuracy of ± 1 % or better For products of circular cross-section, the original cross-secional area may be calculated from the arithmetic mean of two measurements carried out in two perpendicular directions.
5. The original cross-sectional area, S_0, in square millimetres, may be determined from the mass of a known length and its density: $S_0 = \frac{1000 \cdot m}{\rho \cdot L_t}$ m, mass, in grams, of the test piece, ρ, is the density, in grams per cubic centimetre, of test piece material, L_t is the total length, in millimetres, of the test pieces.

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Principle of the method – Test Samples

Table 4. Dimensions and tolerances of test pieces for sheets and flats thickness equal to or greater than3 mm and wires, bars and sections of diameter or thickness equal to or greater than 4 mm.

1.	The minimum transition radius between the gripped ends and the parallel length shall be: - 0.75d_0 where d_0 is the diameter of the parallel length, for the cylindrical test piece, - 0,12 mm for other test pieces.
2.	The cross-section of the test piece may be: circular, square, rectangular or another shape,
3.	For test pieces with rectangular cross-section, the width to thickness ratio should not exceed 8:1
4.	The diameter of the parallel length of machined cylindrical test piece shall be not less than 3 mm.
5.	The parallel length, L_c, shall be at least equal to: $L_0 + \left(\frac{d_0}{2}\right)$ *for cylindrical tes piece* $L_0 + 1.5\sqrt{S_0}$ *for proportional test pieces other than cylindrical tes pieces* $L_0 + \left(\frac{b_0}{2}\right)$ *for non – proportional tes pieces* In case of dispute, the length L_0+2d_0 or $L_0+2\sqrt{S_o}$ shall be used depending on the type of test piece, unless there is insufficient material
6.	The free length between grips of the machine shall be adequate for marks to be at least a distance of $\sqrt{S_o}$from the grips.
7.	As a general rule, proportional test pieces are used where L_0 is related to the original cross-sectional area S_0, $L_0 = k\sqrt{S_0}$, where k is equal to 5,65. Alternatively, 11.3 may be used as the k value.

Circular cross-section test pieces			
Coefficient of proportionality, k	Diameter, d, mm	Original gauge length, $L_0 = k\sqrt{S_0}$, mm	Minimum parallel length, L_c, mm
5.65	20	100	110
	14	70	77
	10	50	55
	5	25	28
Non-proportional test pieces			
Non proportional test pieces may be used if specified by the product standard. The parallel length, L_c, should not be less than L_0 + b_0/2. In case of dispute, the parallel length L_c=L_0 + 2b_0 shall be used unless there is insufficient material			
Typical flat test piece dimensions			
Width, b_0, mm	Original gauge length, L_0, mm	Minimum parallel length L_c, mm	Approximately total length L_t, mm
40 ± 0.7	200	220	450
25 ± 0.7	200	212,5	450
20 ± 0.5	80	90	300

Principle of the method – Test Samples

Table 5. Dimensions and tolerances of test pieces for tubes

1.	The tube length may be plugged at both ends. The free length between each plug and the nearest gauge marks shall be greater than $D_0/4$. In case of dispute the value D_0 shall be used, if there is sufficient material.
2.	The length of the plug projecting beyond the grips of the machine in the direction of the gauge marks shall not exceed D_0, and its shape shall be such that it does not interfere with deformation of the gauge length.
3.	The parallel length L_c, of the longitudinal strips shall not be flattened byt the heads may be flattened for gripping in the testing machine
4.	S_0 for the test piece shall be determined to the nearest ±1 % or better.
5.	The original cross-sectional area, S_0, in square millimetres, of the length of tube or longitudinal or transverse strip may be determined from the mass of the test piece, the length of which has been measures and from its density: $S_0 = \frac{1000 \cdot m}{\rho \cdot L_t}$ m, mass, in grams, of the test piece, ρ, is the density, in grams per cubic centimetre, of test piece material, L_t is the total length, in millimetres, of the test pieces.
6.	The original cross-sectional area S_0, of a test piece consisting of a longitudinal sample shall be calculated according to: $S_0 = \frac{b_0}{4}(D_0^2 - b_0^2)^{\frac{1}{2}} + \frac{D_0^2}{4} \arcsin\left(\frac{b_0}{D_0}\right) - \frac{b_0}{4}[(D_0 - 2a_0)^2 - b_0^2]^2 - \left(\frac{D_0 - 2a_0}{2}\right)^2 arcsin\left(\frac{b_0}{D_0 - 2a_0}\right)$
7.	The simplified formula can be used for longitudinal test pieces where the ratio between width and external tube diameter falls below set limits: $S_0 = a_0 b_0 \left[1 + \frac{b_0^2}{6D_0(D_0 - 2a_0)}\right] \quad if\ \frac{b_0}{D_0} < 0.25$ $S_0 = a_0 b_0 \quad if\ \frac{b_0}{D_0} < 0.10$
8.	For length of tube, the original cross-section area S_0 shall be calculated from $S_0 = \pi a_0 (D_0 - a_0)$

Principle of the method – Marking the original gauge length

For the manual determination of the elongation after fracture A, each end of the original gauge length, L_0 shall be marked by means of fine marks, scribed lines or punch marks, but not by marks which could result in permature fracture.

For proportional test pieces, the calculated value of the original gauge length may be rounded to the nearest multiple of 5 mm, provided that the difference between the calculated and marked gauge length is less than 10 % of L_0.

If the paralel length, L_c is much greater than the original gauge length as for instance with unmachined test pieces, a series of overlapping gauge lengths may be marked.

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Conditions of testing – Setting the zero point

The force-measuring system shall be set to zero after testing loading train has been assembled, but before the test piece is actually gripped at both ends. Once the force zero point has been set, the force-measuring system shall not be changed in any way during the test.

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Conditions of testing – Method of gripping

The test pieces shall be gripped by suitable means, such as wedges, screwed grips, parallel jaw faces or shouldered holder.

Every endeavour should be made to ensure that test pieces are held in such a way that the force is applied as axially as possible in order to minimize bending. This is of particular importance when testing brittle materials or when determining proof strength (plastic extension), proof strength (total extension) or yield strength.

Conditions of testing – Method of gripping

In order to ensure the alignment to the test piece and grip arrangement, a preliminary force may be applied provided it does not exceed a value corresponding to 5 % of the specified or expected yield strength. A correction of the extension should be carried out to take into account the effect of the preliminary force.

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Conditions of testing – Testing rates

Unless otherwise agreed the choice of the method (A1, A2 or B) and test rates are at the direction of the procedure or the test laboratory assigned by the producer.

Method A – Testing rate based on strain rate

This method is intended to minimize the variation of the test rates during the moment when strain rate sensitive parameters are determined and to minimize and minimize the measurement uncertainty of the test results.

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Conditions of testing – Testing rates

There are two different types of strain rate control:

A1 – closed loop involves the control of the strain rate itself, $\dot{e}_{L_e}$, that is based on the feedback obtained from an extensometer.

A2 – open loop involves the control of the estimated strain rate over parallel length $\dot{e}_c$, which is achieved by using the crosshead separation rate calculate by multiplying the required strain rate by the parallel length.

The strain rate shall be maintained during the determination of the relevant material property.

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Conditions of testing – Testing rates

Method B – Testing rate based on stress rate

The testing rates shall conform to the following requirements depending on the nature of the material. Unless otherwise specified, any convenient speed of testing may be used up to a stress equivalent to half of the specified yield strength.

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Conditions of testing – Testing rates

Upper yield strength, R_{eH}

The rate of separation of the crossheads of the machine shall be kept as constant as possible and within the limits corresponding to the stress rates:

Modulus of elasticity of the material E MPa	Stress rate $\dot{R}$ $MPa\ s^{-1}$	
	min.	max.
<150 000	2	20
≥150 000	6	60

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Conditions of testing – Testing rates

Lower yield strength, R_{eL}

If only the lower yield strength is being determined, the strain rate during yield of the parallel length of the test piece shall be between:

0.0 25 s-1 and 0.002 5 s-1

The strain rate within the parallel length shall be kept as constant as possible. If this rate cannot be regulated directly, it shall be fixed by regulating the stress rate just before yield begins, the control of the machine not being further adjusted until completion of yield.

In case shall the strass rate in the elastic range exceed the maximum rates in table 6.

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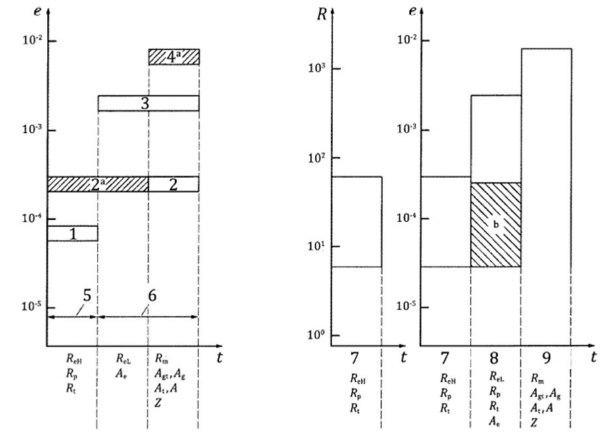
Conditions of testing – Testing rates



a) Method A

b) Method B

Key

$\dot{e}$ strain rate, in s^{-1}

$\dot{R}$ stress rate, in MPa s^{-1}

t time

1 range 1: $\dot{e}$ = 0,000 07 s^{-1}, with a relative tolerance of ±20 %

2 range 2: $\dot{e}$ = 0,000 25 s^{-1}, with a relative tolerance of ±20 %

3 range 3: $\dot{e}$ = 0,002 s^{-1}, with a relative tolerance of ±20 %

4 range 4: $\dot{e}$ = 0,006 7 s^{-1}, with a relative tolerance of ±20 % (0,4 min^{-1}, with a relative tolerance of ±20 %)

5 control mode: extensometer control (Method A1 closed loop) or crosshead control (Method A2 open loop)

6 control mode: crosshead control (Method A2 open loop)

7 elastic range of the test

8 plastic range for the determination of R_{eL}, R_p, R_t, A_e

9 maximum strain rate for the determination of R_m, A_{gt}, A_g, A_t, A, Z

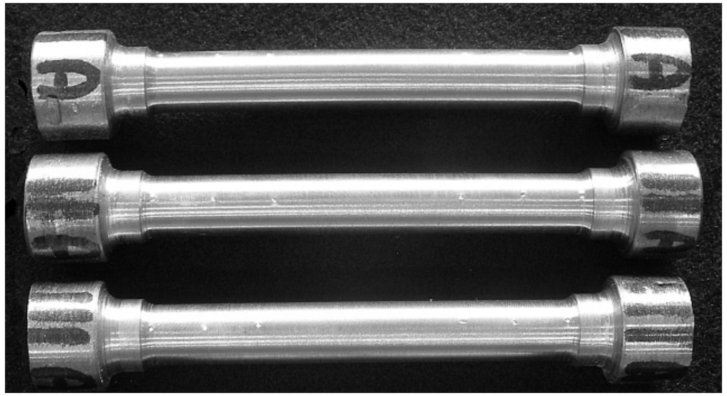
ᵃ Recommended.

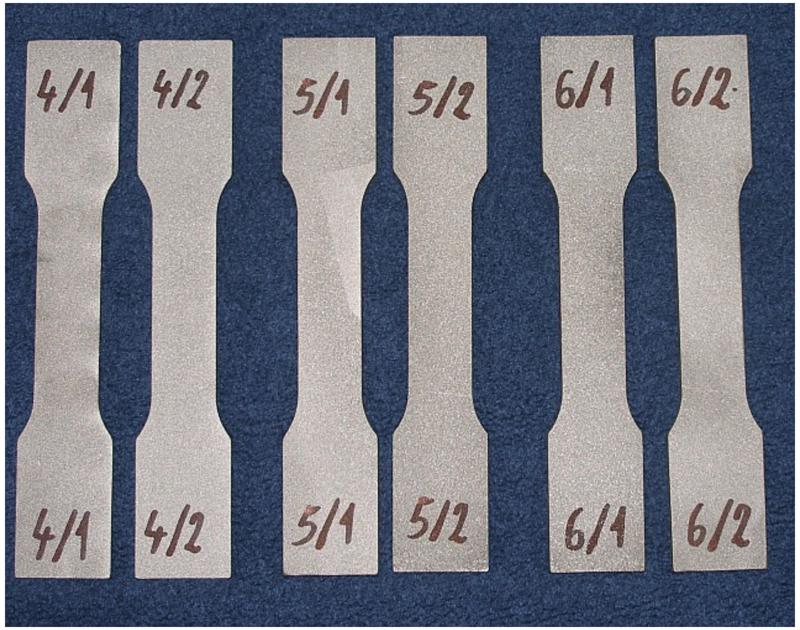
ᵇ Expanded range to lower rates, if testing machine is not capable of measuring or controlling the strain rate (see 10.3.3.2.5).

NOTE 1 Symbols refer to Table 1.

NOTE 2 Strain rate in the elastic range for method B is calculated from stress rate using a Young's modulus of 210 000 MPa (steel).

Samples





Description of the test (step by step)

Preparing samples in accordance with the procedure

- The samples shall be visually inspected and the presence of any imperfections on the measuring surface should be noted in the test report.
- Measure the specimen dimensions in accordance with the procedure
- Determine the measurement bases on the specimen in accordance with the guidelines Principle - Percentage elongation after fracture – A of the procedure

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Description of the test (step by step)

Preparing the testing machine

- check zero position of force gauges
- select the tensile strength
- place the specimen in the machine.

Description of the test (step by step)

Perform the tensile test

- The test shall be carried out in accordance with the provisions of Standard ISO 6892-1 and the guidelines given in this procedure.
- The method of testing on individual machines depends on the equipment available. Operating instructions must be provided for the machine available.

Description of the test (step by step)

Test report

The test report shall contain at least the following information, unless otherwise agreed by the parties concerned:

- Reference to standard or this document, extended with the test condition information,
- Identification of the test piece
- Specified material if known
- Type of test piece

Description of the test (step by step)

Test report

- Location and direction of sampling of the test piece, if known
- Testing control mode and testing rate or testing rate range if different from the recommended methods (A or B)
- Test results (results should be rounded to the following precisions or better, if not otherwise specified in product standards: strength values in MPa to the nearest whole number, percentage yield point values Ae, to the nearest 0,1 %., all other percentage extension and elongation values to the nearest 0,5%, percentage reduction of area Z, to the nearest 1 %.

Description of the test (step by step)

Test report - Sample

SIEĆ BADAWCZA ŁUKASIEWICZ
INSTYTUT SPAWALNICTWA

Name of the Company

TEST REPORT No.

City:

Customer
Order No.: Standard No.
Object of research Type of test: Test Temperature: °C
Identification number: Humidity: %
Test device no:

Parent Material: **Thickness:** Welding consumable: Type of welded joint Welding Method

No.	Specimen				Mechanical properties										Bend Test		Charpy impact test in temperature [°C]:				Remarks
	Specimen No.	Specimen dimensions			F_e	$F_{0,2}$	F_m	R_e	$R_{0,2}$	R_m	L_u	A_5	d_u	Z	d_f	Results*					
		a_0xb_0, d_0 [mm]	L_o [mm]	S_o [mm²]	[kN]	[kN]	[kN]	[MPa]	[MPa]	[MPa]	[mm]	[%]	[mm]	[%]	[mm]		[J]	[J/cm²]	[J]	[J/cm²]	
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Form: /* WCS - Without cracks and scratches; CS- crack or scratch

The research was performed by: Head of research:

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TRUST
DESTRUCTIVE TESTING TECHNICIAN

Any Questions?

Thank You!

[Name & contact email]

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