Metallic materials — Test methods —

Part 1: Tensile testing at ambient temperature

The European Standard EN 2002-1:2005 has the status of a British Standard

ICS 49.025.05; 49.025.15

British Standards

National foreword

This British Standard is the official English language version of EN 2002-1:2005.

The UK participation in its preparation was entrusted by Technical Committee ACE/61, Metallic materials for aerospace purposes, to Subcommittee ACE/61/-/1, Mechanical testing of metallic materials, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This European Standard (EN 2002-001:2005) has been prepared by the European Association of Aerospace Manufacturers - Standardization (AECMA-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of AECMA, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2006, and conflicting national standards shall be withdrawn at the latest by May 2006.

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Introduction

This standard is part of the series of EN metallic material standards for aerospace applications. The general organization of this series is described in EN 4258.

1 Scope

This standard specifies the requirements for the tensile testing of metallic materials at ambient temperature for aerospace applications.

It shall be applied when referred to in the EN technical specification or material standard unless otherwise specified on the drawing, order or inspection schedule.

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.

EN 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.*

EN ISO 9513, *Metallic materials – Calibration of extensometers used in uniaxial testing.*

EN 4258, *Aerospace series – Metallic materials – General organization of standardization – Links between types of EN standards and their use.*

EN 4259, *Aerospace series – Metallic materials – Definition of general terms.* [1]

ASTM E-1012, *Standard practice for verification of specimen alignment under tensile loading.* [2]

3 Terms, definitions and symbols

For the purposes of this standard, the terms, definitions and symbols given in EN 4259 and the following given in Table 1 apply.

1) Published as AECMA Prestandard at the date of publication of this standard.

2) This standard is published by: American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

Table 1 — Terms, definitions and symbols

Symbol	Unit	Term	Definition
–	–	Test piece	The portion of the test sample on which the tensile test is carried out
–	–	Proportional test pieces	A test piece with an original gauge length (L_0) having a specified relationship to the square root of the cross-sectional area (S_0). The proportionality coefficient, K, has the internationally recognized value of 5,65 for test pieces of circular cross-section. The gauge length of a proportional test piece is therefore equal to 5,65 $\sqrt{S_0}$. Certain material standards use proportional test pieces with other than the 5,65 proportionality coefficient. In this case, see A_x for the percentage elongation symbol used.
–	–	Non-proportional test piece	A test piece where the original gauge length is independent of the cross-sectional area
–	mm	Extension	The increase of the extensometer gauge length (L_e) at any moment during the test
–	MPa	Limit of proportionality	The stress at which the stress-strain (or force-extension) relationship deviates from a straight line
A	%	Percentage elongation (proportional test piece) NOTE For non-standard proportional test piece, see A_x.	Elongation after fracture expressed as a percentage of the original gauge length (L_0) for a proportional test piece with an original gauge length of L_0 = 5,65 $\sqrt{S_0}$. $A = \frac{L_u - L_0}{L_0} \times 100$
A_{L0}	%	Percentage elongation (non-proportional test piece)	Elongation after fracture expressed as a percentage of the original gauge length (L_0) for a non-proportional test piece with an original gauge length of L_0. For a non-proportional test piece, the original gauge length is given in millimetres, e.g. A_{50mm}. $A_{L0} = \frac{L_u - L_0}{L_0} \times 100$
A_x	%	Percentage elongation (non standard proportional test piece)	Elongation after fracture expressed as a percentage of original gauge length (L_0) for a non-standard proportional test piece with an original gauge length of L_0 = x (e.g.: A_{4D}) A non-standard proportional test piece is one in which the proportionality coefficient has a value other than 5,65. In the example above the gauge length is four times the diameter, equivalent to a proportionality coefficient of 4,51.
a	mm	Test piece thickness	Thickness of a test piece of rectangular cross-section or wall thickness of a tube
b	mm	Test piece width	Width of test pieces of rectangular cross-section, average width of the longitudinal strip taken from a tube or width of a flat wire
D	mm	Tube external diameter	External diameter of a tube
d	mm	Test piece diameter	Diameter of the parallel length of a circular test piece or diameter of round wire or internal diameter of a tube

continued

Table 1 — Terms, definitions and symbols *(concluded)*

Symbol	Unit	Term	Definition
E	GPa	Young's modulus of elasticity	The value of the increment in stress divided by the corresponding increment in strain for the straight portion of the stress-strain (or force-extension) diagram
F_m	N	Maximum force	The greatest force which the test piece withstands during the test
L	mm	Gauge length	The length of the cylindrical or prismatic portion of the test piece on which elongation is measured
L_c	mm	Parallel length	The length of the reduced section of the parallel portion of the test piece. The concept of parallel length is replaced by the concept of distance between grips for non-machined test pieces.
L_e	mm	Extensometer gauge length	The length of the parallel portion of the test piece used for the measurement of extension by means of an extensometer at any moment during the test. This length may differ from L_0 but can be of any value greater than b, d or D (see above) but shall be less than the parallel length (L_c). It is recommended that the extensometer gauge length is as large as possible.
L_0	mm	Original gauge length	The gauge length before the application of force
L_t	mm	Test piece length	Total length of test piece
L_u	mm	Final gauge length	The gauge length after fracture of the test piece
L_u-L_0	mm	Elongation	Elongation after fracture. The permanent increase in the original gauge length (L_0) after fracture.
R_m	MPa	Tensile strength	The maximum force (F_m) divided by the original cross-sectional area (S_0) of the test piece
R_p	MPa	Proof stress	The stress at which a non-proportional extension is equal to a specified percentage of the extensometer gauge length (L_e) (see Figure 1). The symbol used is followed by a suffix giving the prescribed percentage of the original gauge length for example: $R_{p0,2}$
r	mm	Test piece transition radius	Radius at ends of parallel length
S_0	mm^2	Original cross-sectional area	Original cross-sectional area of the parallel length
S_u	mm^2	Minimum cross-sectional area	Minimum cross-sectional area of test piece after fracture
Z	%	Percentage reduction of area after fracture	The maximum decrease of the cross-sectional area ($S_0 - S_u$) expressed as a percentage of the original cross-sectional area (S_0) i.e $Z = \frac{S_0 - S_u}{S_0} \times 100$
ε	–	Strain	The extension of any moment during the test divided by the original gauge length (L_0) of the test piece
σ	MPa	Stress	The force at any moment during the test divided by the original cross-section area (S_0) of the test piece
θ	°C	Specified temperature	The temperature at which the test is to be carried out

4 Health and safety

Resources, test pieces, test samples, test materials, test equipment and test procedures shall comply with the current health and safety regulations/laws of the countries where the test is to be carried out.

Where materials and/or reagents that may be hazardous to health are specified, appropriate precautions in conformity with local regulations and/or laws shall be taken.

5 Principle

The test involves straining a test piece by a tensile force at ambient temperature to fracture for the purpose of determining one or more of, Young's modulus of elasticity, proof stress, tensile strength, elongation, reduction of area.

6 Testing requirements

6.1 Resources

6.1.1 Equipment/plant

6.1.1.1 Testing machine

Testing machine accuracy shall be verified at intervals not exceeding 12 months in accordance with EN ISO 7500-1 and shall be certified to class 1 or better.

Its design shall permit automatic loading alignment. The loading system alignment shall be checked at least annually with a strain-gauged test piece. The difference between the recorded maximum and minimum strains shall not exceed 10 % of the mean strain at an appropriate verification force relative to the forces expected during a subsequent series of tests. Reference may be made to ASTM E1012 for a verification method.

It may be computer controlled and capable of automatic calculation and recording of Young's modulus of elasticity, proof stress, tensile strength and elongation.

6.1.1.2 Extensometer

The extensometer accuracy shall be verified at intervals not exceeding 12 months in accordance with EN ISO 9513 and shall be certified for determination of:

— Young's modulus of elasticity to class 0,5 or better and a type that is capable of measuring extension on both sides of a test piece and allows readings to be averaged is preferred.

— Proof stress to class 1 or better.

6.1.1.3 Grips

Grips shall consist of screwed holders, shouldered holders, wedge pieces, pin grips or other means such that the tensile test force is applied axially.

The use of screwed holders is recommended and shall be mandatory in case of dispute.

Grips for tubes may, in addition, use plugs that shall be of:

— an appropriate diameter in order to be gripped at both ends;

— a length at least equal to that of the grips and may project beyond the grips for a maximum length equal to the external diameter of the tube;

— a shape that shall have no effect on the deformation of the gauge length.

6.1.2 Materials/reagents

Materials/reagents may include suitable:

— degreasing fluids;

— recording paper;

— means of electronic recording, if appropriate;

— marking inks.

6.1.3 Qualification of personnel

Testing to the requirements of this test method shall only be undertaken and/or supervised by personnel who have demonstrated their competence by a suitable education or appropriate training and experience. Such competence shall be documented in an appropriate form.

6.2 Test samples/test pieces

6.2.1 Shape and dimensions

The shape and dimensions of the test piece depend on the shape and dimensions of the metallic product and the mechanical properties which are to be determined.

Where sufficient material is available the test piece shall be obtained by machining a sample from the product in accordance with Annex A, C or D. However, product of constant cross-section (section, bar and wire in accordance with Annex B) may be subjected to test without being machined.

A machined test piece shall incorporate a transition radius between the gripped ends and the parallel length if these have different dimensions. The dimensions and tolerances and the transition radius of a test piece shall be in accordance with the appropriate annex (see 6.2.2).

The gripped ends may be of any shape to suit the grips of the testing machine (see 6.3.3). The parallel length (L_c) or, in the case where the test piece has no transition radius, the free length between the grips, shall always be greater than the original gauge length (L_0).

6.2.2 Types

The main types of test piece are given in Annexes A to D according to the shape and type of product as shown in Table 2.

Table 2 — Product types

Type of product	Corresponding annex
Sheet and strip	A
Bar, section and wire of diameter or thickness ≤ 8 mm	B
Bar, section, plate and wire of diameter or thickness > 8 mm and for forgings and castings	C
Tubes	D

6.2.3 Preparation of test pieces

Machining, if required, shall be carried out at ambient temperature in accordance with a machining procedure. Precautions shall be taken to minimize superficial cold working, appreciable heating of the part or surface irregularities that could affect the results of the test.

The surface finish of the parallel length shall have a R_a value not exceeding 0,8 µm.

In the case of material with an elongation specified in the material standard to be less than 10 %, tensile test pieces of other than circular cross-section shall have the edges along the parallel length and the transition radii slightly rounded and lengthwise polished. The reduction of the cross-sectional area by this treatment shall be negligible.

The test piece shall be protected from damage or contamination until the start of the test.

6.3 Testing procedure

6.3.1 Determination of the cross-sectional area (S_0)

6.3.1.1 Determination of the original cross-sectional area (S_0)

The original cross-sectional area shall be calculated from measurement of the appropriate dimensions, with an accuracy of 0,2 % or 0,005 mm, whichever the greater value, for each dimension.

In the case of a length of tube, the original cross-sectional area (S_0) shall be calculated as follows:

$$S_0 = \pi a\,(D - a)$$

When using test piece consisting of a longitudinal strip cut from a tube, the original cross-sectional area shall be calculated according to one of the following equations:

When $0{,}17 \leq \frac{b}{D} < 0{,}25$ $\qquad S_0 = ab\left(1 + \frac{b^2}{6D(D-2a)}\right)$

When $\frac{b}{D} < 0{,}17$ $\qquad S_0 = ab$

6.3.1.2 Determination of final cross-sectional area (S_u)

The dimensions of the test piece shall be measured at the location of the fracture to an accuracy of 0,01 mm, and be used to calculate the final cross-sectional area.

In the case of a length of tube or longitudinal test piece cut from a tube, the final cross-sectional area shall be calculated according to the equations in 6.3.1.1.

6.3.2 Marking the original gauge length (L_0)

For proportional test pieces, the calculated value of the original gauge length shall be rounded to the nearest 1 mm. The original gauge length shall be marked or measured to an accuracy of ± 1 %.

A fine scribed line or a small punched dot shall mark each end of the original gauge length.

Incised scribed lines or punched dots shall not be used on low ductility materials, on which such markings may cause premature failure. The recommended method of marking gauge lengths is using standard engineering marking out practice, by painting the parallel length of the test piece with a suitable marking media, such as quick-drying ink and then lightly scribing through this coating.

If the parallel length (L_c) is much in excess of the original gauge length, for instance, with non-machined test pieces, a series of overlapping original gauge lengths shall be marked; some of these lengths may extend up to the grips.

6.3.3 Method of gripping

The grips shall be of an appropriate type specified in 6.1.1.3.

For proof stress determination, it is recommended that pin grips should be used for all flat test pieces unless the test piece is too narrow.

The ends of a longitudinal test piece cut from the wall of a tube may be flattened to aid gripping, provided that the parallel length is not affected by the flattening.

6.3.4 Extensometer

The extensometer shall be attached to the parallel length in such a manner that it accurately measures the extension without damage to the gauge length.

6.3.5 Temperature of test

The test shall be carried out at $(10 \leq \theta \leq 35)$ °C unless otherwise specified. In cases of dispute the test shall be performed at $\theta = (23 \pm 5)$ °C.

6.3.6 Speed of testing

6.3.6.1 Young's modulus of elasticity (E)

The test shall be performed at the speed given in 6.3.6.2.

6.3.6.2 Proof stress (R_p)

The test shall be performed at a controlled strain rate of:

0,003 to 0,007 (0,3 % to 0,7 %) per min., a strain rate of 0,005 (0,5 %) per min is preferred.

For special applications or materials, other testing rates may apply and shall be specified in the material or technical standard or on the drawing, order or inspection schedule.

6.3.6.3 Tensile strength (R_m)

If the test is to be continued to fracture, the strain rate of the parallel length may be increased beyond the proof stress but shall not exceed a value of 0,1 (10 %) per min.

6.3.7 Young's modulus of elasticity (E), selection of test method

Young's modulus of elasticity shall be determined by one of three methods of which Method 1 is the most accurate and Method 3 the least accurate. Method 3 shall only be used when neither Method 1 nor Method 2 can be applied. In case of dispute Method 1 shall be used.

Method 1

The test piece shall be loaded to a stress below the limit of proportionality and unloaded. This shall be repeated twice more. Young's modulus of elasticity shall be taken as the average of the three values. It is recommended that the location of the extensometer be changed for each successive determination.

The initial part of the stress-strain (or force-extension) line may be omitted to compensate for any non-linearity at the start of the test.

Method 2

The test piece shall be loaded to a stress below the limit of proportionality and loading shall continue without interruption to determine the 0,2 % proof stress ($R_{p0,2}$).

The initial part of the stress-strain (or force-extension) line may be omitted to compensate for any non-linearity at the start of the test.

Method 3

The test piece shall be loaded without interruption to determine the 0,2 % proof stress ($R_{p0,2}$). It shall then be unloaded to 10 % of the 0,2 % proof stress ($R_{p0,2}$) and re-loaded to just above the proof stress to produce a hysteresis loop. Young's modulus of elasticity shall be determined from the line passing through the hysteresis intercepts.

6.4 Determination and expression of results

6.4.1 Determination of Young's modulus of elasticity (E)

Computer controlled machines are capable of calculating Young's modulus of elasticity automatically. In which case drawing of a stress-strain (or force-extension) diagram, although recommended, is not necessary. Otherwise the modulus shall be calculated by determining the slope of the straight portion of the curve on the diagram. When stress-strain (or force-extension) data is obtained in numerical form, the best fit to the slope of the straight-line portion of the curve may be determined by statistical methods.

The value for Young's modulus of elasticity shall be given in GPa unless specified otherwise and the method of its determination shall be stated.

6.4.2 Determination of proof stress (R_p)

Computer controlled machines are capable of calculating proof stress automatically, in which case drawing a stress-strain (or force-extension) diagram, although recommended, is not essential. Otherwise the proof stress (or stresses) shall be determined from an accurately drawn curve on the diagram.

A line is drawn parallel to the straight portion of the curve and distant from it by an amount representing the increase of strain equal to the required non-proportional amount, e.g. 0,2 %. The point at which the line cuts the curve represents the required proof stress (see Figure 1) or shall be determined by dividing the force at the specified extension by the original cross-sectional area (S_0). It shall be given in MPa unless specified otherwise.

In specifying or quoting a proof stress value, the required percentage strain shall be stated, e.g. 0,2 % proof stress ($R_{p0,2}$).

If the material does not give a stress-strain (or force-extension) curve containing a straight line portion sufficiently defined to permit the drawing of an accurate parallel line, the line shall be drawn parallel to the mean line of the hysteresis loop produced by applying a force exceeding the proof stress value, reducing the force to a maximum of 10 % of this value and then reapplying It (see Figure 2 as an example). The test report shall state when this method has been employed.

6.4.3 Determination of tensile strength (R_m)

The tensile strength shall be determined by dividing the maximum force (F_m) reached during the test by the original cross-sectional area (S_0). It shall be given in MPa unless specified otherwise.

6.4.4 Determination of percentage elongation after fracture (A or A_{L0})

6.4.4.1 The percentage elongation after fracture shall be determined by the permanent increase in gauge length after fracture expressed as a percentage of the original gauge length. For this purpose, the two broken parts of the test piece are carefully fitted back together so that their axes lie in a straight line. Special precautions shall be taken to ensure proper contact between the broken parts of the piece when measuring the final gauge length. This is particularly important in the case of test pieces of small cross-section and test pieces having low elongation values.

NOTE For ease of measurement a simple jig can be used which will enable the broken pieces to be mated axially.

6.4.4.2 The percentage elongation after fracture, $\frac{L_u - L_0}{L_0} \times 100$, where specified in the material standard to be:

a) equal to or greater than 5 %: shall be determined with sufficient resolution to give the percentage elongation to the nearest 0,5 %.

b) less than 5 %: shall be determined by means of an optical microscope, or an equivalent method, having sufficient accuracy and resolution to give the percentage elongation to the nearest 0,1 %.

The measurement is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one-third of the original gauge (L_0). However, the measurement is valid, irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value and this shall be stated in the test report.

6.4.4.3 For machines capable of measuring extension at fracture using an extensometer, it is not necessary to mark gauge lengths. The elongation is measured as the total extension at fracture. It is therefore necessary to deduct the elastic extension in order to determine the percentage elongation after fracture unless the machine does it automatically.

In principle, this measurement is only valid if fracture occurs within the extensometer gauge length (L_e). The measurement is valid regardless of the position of the fracture if the percentage elongation after fracture reaches at least the specified value and this shall be stated in the test report.

NOTE Marking of the gauge is not necessary but is advisable in cases of dispute.

6.4.5 Determination of percentage reduction of area after fracture (Z)

The percentage reduction of area after fracture shall be determined as the maximum change in cross-sectional area that has occurred during the test ($S_0 - S_u$) expressed as a percentage of the original cross-sectional area (S_0).

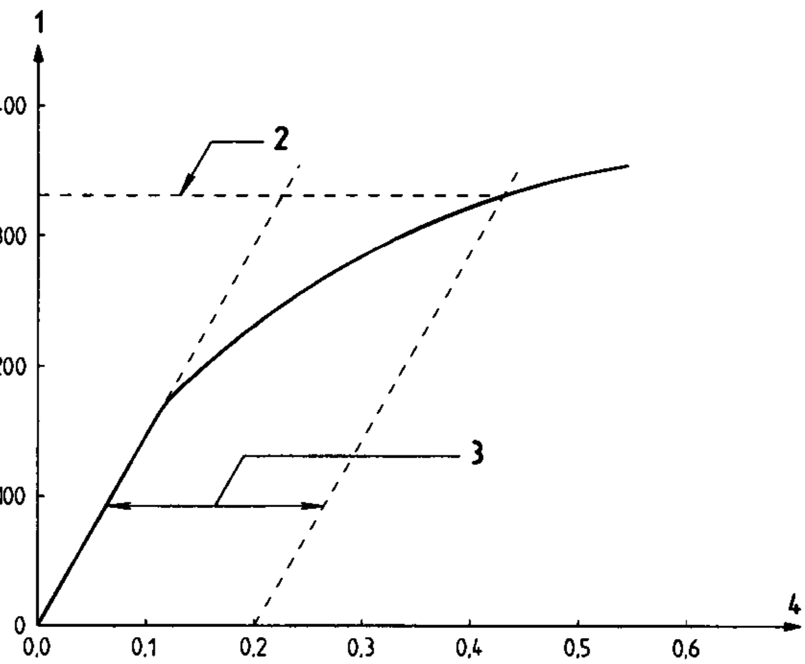
7 Test report

All results shall be in written form and the test report shall include when relevant at least the following information:

- reference to this standard;
- any other information relevant to the test method (e.g. test conditions, test equipment, test procedure, verification...);
- identification and traceability to the semi-finished product to be tested in accordance with the technical specifications;
- identification and traceability of test samples taken from the semi-finished product (e.g. location, orientation, size);
- identification and traceability of test pieces taken from the test samples (e.g. number, preparation, method, conditioning, use/method of mechanical straightening of coiled wire);

In certain cases the test piece may be the test sample;

- expression of results (e.g. individual values or mean values, units, if fracture outside middle third of gauge length, use of an extensometer to measure elongation after fracture, unusual features in the fracture surface...);
- the method and type of extensometer used to determine Young's modulus of elasticity;
- recorded plots/graphs, when necessary;
- date of test;
- traceability of individual performing the test;
- any incident which may have affected the results;
- any deviation from the test method standard.



Key

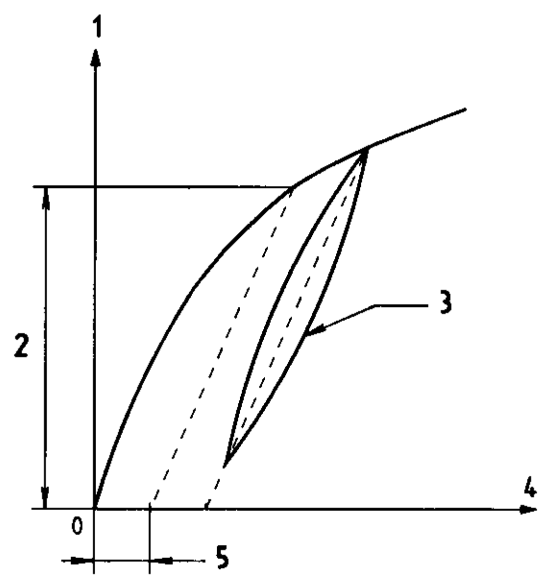
1 Stress σ (MPa)

2 Proof stress

3 Specified non-proportional strain, i.e. 0,2 %

4 Strain ε (%)

Figure 1 — Characteristic stress-strain diagram



Key

1 Stress σ (MPa)

2 Stress corresponding to R_p

3 Hysteresis loop

4 Strain ε (%)

5 Specific non-proportional strain, e.g. $R_{p0,2}$

Figure 2 — Proof stress determination using hysteresis loop

Annex A
(normative)

Types of test piece to be used for sheet and strip with thickness less than or equal to 8 mm

A.1 Shape of the test piece

Generally, the test piece has gripped ends, which are wider than the width (b) of the parallel length. The width of these ends shall be at least 20 mm and not more than 40 mm. The parallel length (L_c) shall be connected to the ends by means of transition curves with a radius (r) of at least 12 mm (see Figure A.1).

The test piece may also consist of a strip with parallel sides. For products of width equal to or less than 20 mm, the width of the test piece may be the same as that of the product.

A.2 Dimensions of the test piece

A.2.1 Non-proportional test piece

The parallel length shall be not less than $L_0 + \frac{b}{2}$.

In case of dispute, the length $L_o + 2b$ shall always be used unless there is insufficient material. In the case of parallel-sided test pieces less than 20 mm wide, and unless otherwise specified in the product standard, the original gauge length (L_0) shall be equal to $4b$. For this type of test piece, the free length between the grips shall be equal to $L_0 + 3b$.

There are four types of non-proportional test pieces, with dimensions as given in Table A.1.

In the case of test pieces where the width is the same as that of the product, the original cross-sectional area (S_0) shall be calculated on the basis of the measured dimensions of the test piece.

Table A.1 — Dimensions of non-proportional test pieces

Dimensions in millimetres

Width b	Original gauge length L_0	Minimum parallel length L_c	Minimum free length between the grips for parallel side test piece
20	80	90	140,5
12,5	50	57	87,5
6,0	24	27	42
3,0	12	13,5	18

A.2.2 Proportional test piece

For test pieces of shape as defined in A.2.1, it is possible to take the original gauge length (L_0) as proportional to the original cross-sectional area (S_0) using the relation:

$$L_0 = 5{,}65\sqrt{S_0}$$

A.2.3 Tolerances

The tolerance on the width of the parallel length shall be ± 1 % of the width (b) of the test piece. Furthermore the width of the parallel length shall not vary by more than 0,03 mm.

A.3 Preparation of test pieces

The test pieces shall be prepared so as not to affect the properties of the metal. Any areas that have been hardened by shearing or pressing shall be removed by machining.

NOTE See Table 1 for explanation of symbols.

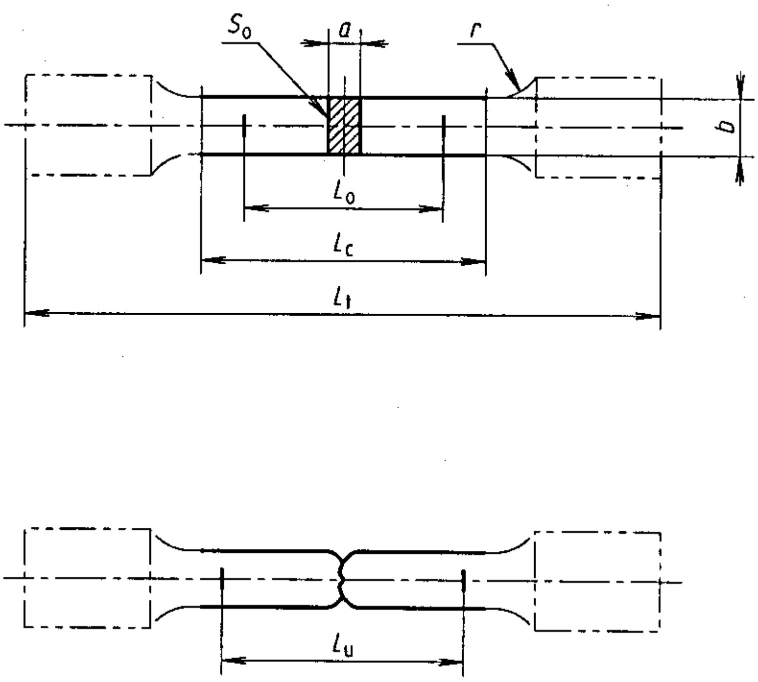


Figure A.1 — Machined test piece of rectangular cross-section before and after fracture

Annex B
(normative)

Types of non-machined test piece to be used in the case of bar, section and wire with a diameter or thickness less than or equal to 8 mm

B.1 Shape of the test piece

The test piece generally consists of a non-machined portion of the product (see Figure B.1).

B.2 Dimensions of the test piece

The original gauge length (L_0) shall be 50 mm unless otherwise specified in the product standard.

The distance between the grips of the machine shall be equal to at least $L_0 + 50$ mm, except in the case of small diameter wires where this distance can be taken as equal to L_0.

NOTE In cases where the percentage elongation after fracture is not to be determined, a distance between the grips of at least 50 mm may be used.

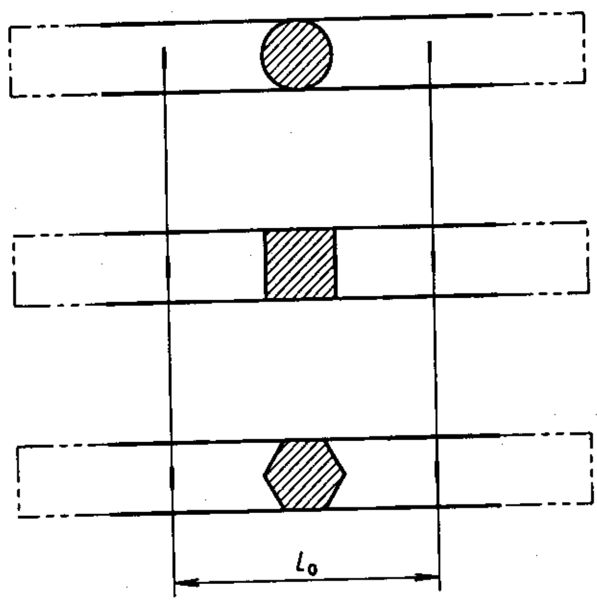


Figure B.1 — Example of test pieces comprising a non-machined portion of the product

B.3 Preparation of test pieces

If the product is delivered coiled, care shall be taken in straightening it.

NOTE If the test pieces are mechanically straightened, their subsequent properties may be affected.

Annex C
(normative)

Types of machined test piece to be used in the case of bar, section, plate and wire with diameter or thickness greater than 8 mm and for forgings and castings

C.1 Shape of the test piece

In general, the test piece is machined and the parallel length shall be connected by means of transition radii to the gripped ends that may be of any suitable shape for the grips of the test machine (see Figure C.1).

The transition radius (r) shall be at least:

— 0,8d for round test pieces;

— 2,0b for test pieces of rectangular cross-section.

NOTE For certain materials, these values may be too low and are likely to result in fracture of the test piece in the area of the transition.

C.2 Dimensions of the test piece

C.2.1 Parallel length of machined test piece

For test pieces of circular cross section, the parallel length (L_c) shall be $L_0 + 2d$ (preferred) or at least $L_0 + \frac{d}{2}$.

For test pieces of prismatic cross-section, the parallel length shall be $L + 2\sqrt{S_0}$ (preferred) or at least $L_0 + 1{,}5\sqrt{S_0}$.

C.2.2 Original gauge length (L_0)

Test pieces of circular cross-section shall preferably have the dimensions given in Table C.1.

C.3 Tolerances

C.3.1 The gripped ends shall be coaxial with the parallel length to within 0,03 mm.

C.3.2 The tolerance on the diameter or width and thickness of the parallel length shall be ± 0,5 %. Furthermore the diameter or width and thickness of the parallel length shall not vary by more than 0,03 mm.

C.4 Determination of the original cross-sectional area (S_0)

The diameter or width and thickness of the test piece shall be measured at three positions along the parallel length to an accuracy of 0,2 % or 0,005 mm, whichever is the greater value. The average dimensions shall be used to calculate the original cross-sectional area.

C.5 Determination of final cross-sectional area (S_u)

The diameter or width and thickness of the test piece shall be measured at the location of the fracture to an accuracy of 0,2 % or 0,005 mm, whichever is the greater value, and be used to calculate the final cross-sectional area.

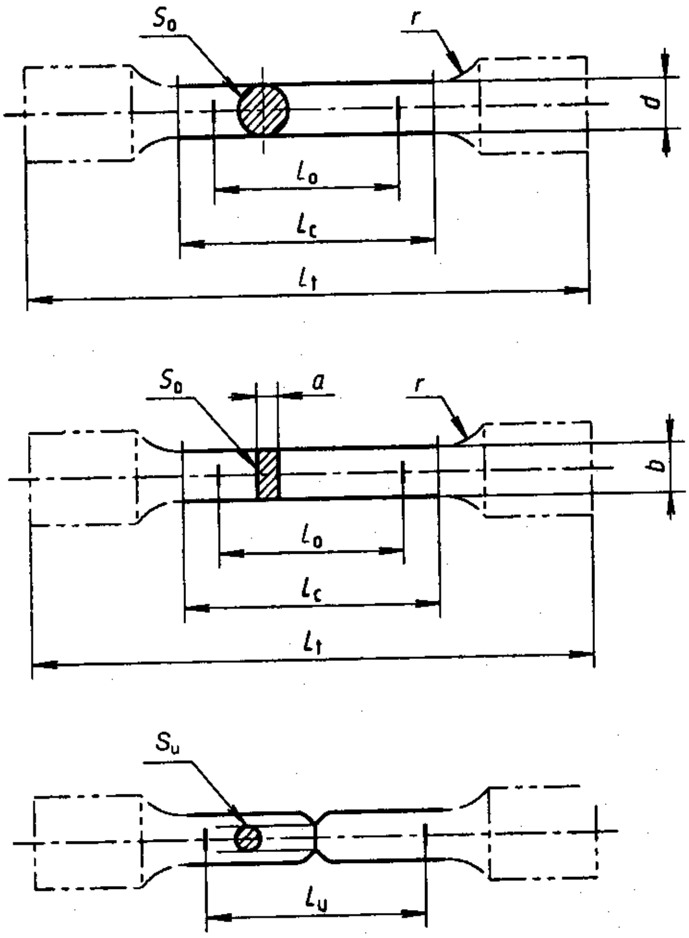


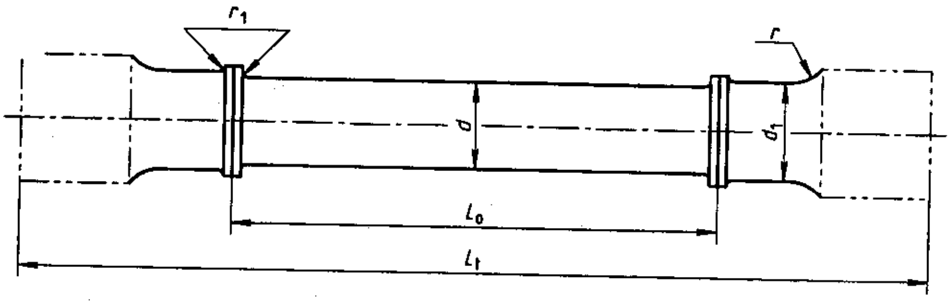
Figure C.1 — Examples of proportional test pieces before and after fracture

Table C.1 — Dimensions of preferred proportional round test pieces

Diameter d mm	Original cross-sectional area S_0 mm²	Original gauge length $L_o = 5{,}65\sqrt{S_0}$ mm	Preferred parallel length L_c mm	Minimum transition radius r mm
20	314,2	100	140	16
10	78,5	50	70	8
5	19,6	25	35	4

C.6 Ridged test piece

The extensometer shall be attached to the annular ridges on round test pieces (see Figure C.2), or, on rectangular cross-section test pieces, to small projections or on the shoulders.



NOTE $d_1 > d$

$r > r_1$

Figure C.2 — Test piece with annular ridges

Annex D
(normative)

Types of test piece to be used in the case of tubes

D.1 Shape of the test piece

The test piece consists either of a length of tube or a longitudinal strip cut from the tube and having the full thickness of the wall of the tube, or of a test piece of circular-cross-section machined from the wall of the tube (see Figures D.1 and D.2).

D.2 Dimensions and tolerances of the test piece

Machined longitudinal test pieces are described in:

a) Annex A for tube of wall thickness less than or equal to 8 mm;

b) Annex C for tube of wall thickness greater than 8 mm.

A test piece consisting of a length of tube shall conform to Annex B. Where a tube is fitted with plugs to assist gripping, the free length between a plug and the closest gauge mark shall be greater than *D*/4.

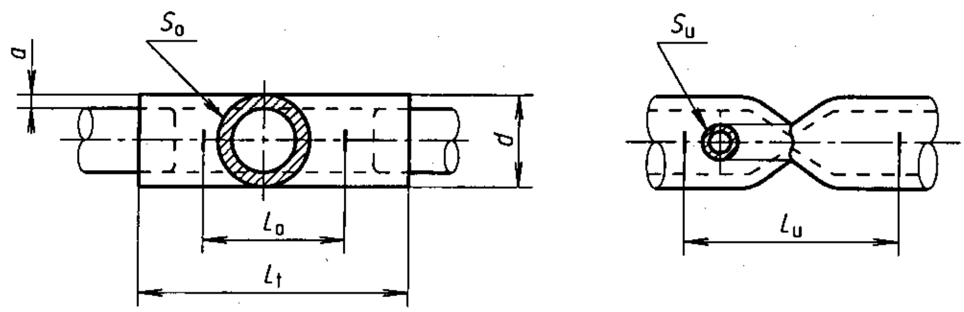


Figure D.1 — Test pieces comprising a length of tube before and after fracture

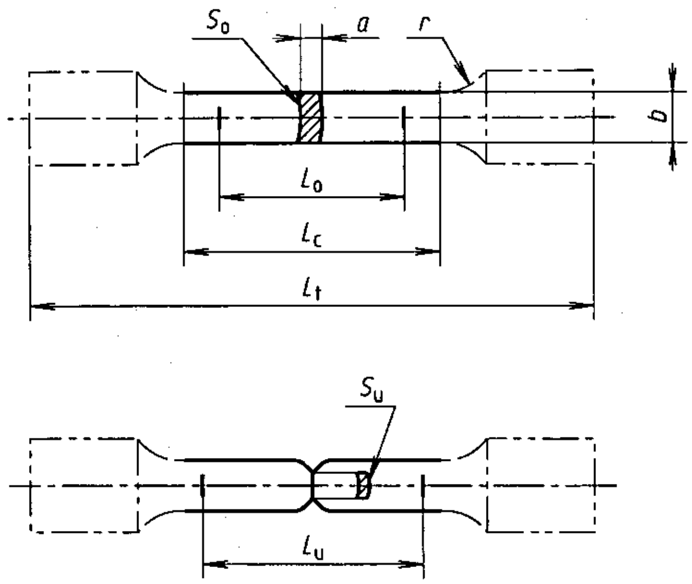


Figure D.2 — Example for test piece cut from a tube before and after fracture

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