Aerospace series – Metallic materials –
Test methods –
Part 1: Tensile testing at ambient temperature

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Tensile testing at ambient temperature

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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of an identical text or by endorsement, at the latest by May 2006, and conflicting national standards shall be withdrawn at the latest by May 2006.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.
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 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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>–</td>
<td>–</td>
<td>Test piece</td>
<td>The portion of the test sample on which the tensile test is carried out</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>Proportional test pieces</td>
<td>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.</td>
</tr>
<tr>
<td>–</td>
<td>mm</td>
<td>Extension</td>
<td>The increase of the extensometer gauge length (L_e) at any moment during the test</td>
</tr>
<tr>
<td>–</td>
<td>MPa</td>
<td>Limit of proportionality</td>
<td>The stress at which the stress-strain (or force-extension) relationship deviates from a straight line</td>
</tr>
<tr>
<td>(A)</td>
<td>%</td>
<td>Percentage elongation (proportional test piece)</td>
<td>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}).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOTE For non-standard proportional test piece, see (A_x).</td>
<td></td>
</tr>
<tr>
<td>(A_{L0})</td>
<td>%</td>
<td>Percentage elongation (non-proportional test piece)</td>
<td>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_{50\text{mm}}).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A_{L0} = \frac{L_u - L_0}{L_0} \times 100)</td>
<td></td>
</tr>
<tr>
<td>(A_x)</td>
<td>%</td>
<td>Percentage elongation (non-standard proportional test piece)</td>
<td>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.</td>
</tr>
<tr>
<td>(a)</td>
<td>mm</td>
<td>Test piece thickness</td>
<td>Thickness of a test piece of rectangular cross-section or wall thickness of a tube</td>
</tr>
<tr>
<td>(b)</td>
<td>mm</td>
<td>Test piece width</td>
<td>Width of test pieces of rectangular cross-section, average width of the longitudinal strip taken from a tube or width of a flat wire</td>
</tr>
<tr>
<td>(D)</td>
<td>mm</td>
<td>Tube external diameter</td>
<td>External diameter of a tube</td>
</tr>
<tr>
<td>(d)</td>
<td>mm</td>
<td>Test piece diameter</td>
<td>Diameter of the parallel length of a circular test piece or diameter of round wire or internal diameter of a tube</td>
</tr>
</tbody>
</table>

\(L_u\) is the ultimate extensometer gauge length.
Table 1 — Terms, definitions and symbols (concluded)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$</td>
<td>GPa</td>
<td>Young's modulus of elasticity</td>
<td>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</td>
</tr>
<tr>
<td>$F_m$</td>
<td>N</td>
<td>Maximum force</td>
<td>The greatest force which the test piece withstands during the test</td>
</tr>
<tr>
<td>$L$</td>
<td>mm</td>
<td>Gauge length</td>
<td>The length of the cylindrical or prismatic portion of the test piece on which elongation is measured</td>
</tr>
<tr>
<td>$L_c$</td>
<td>mm</td>
<td>Parallel length</td>
<td>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.</td>
</tr>
<tr>
<td>$L_e$</td>
<td>mm</td>
<td>Extensometer gauge length</td>
<td>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.</td>
</tr>
<tr>
<td>$L_0$</td>
<td>mm</td>
<td>Original gauge length</td>
<td>The gauge length before the application of force</td>
</tr>
<tr>
<td>$L_t$</td>
<td>mm</td>
<td>Test piece length</td>
<td>Total length of test piece</td>
</tr>
<tr>
<td>$L_u$</td>
<td>mm</td>
<td>Final gauge length</td>
<td>The gauge length after fracture of the test piece</td>
</tr>
<tr>
<td>$L_{u0}$</td>
<td>mm</td>
<td>Elongation</td>
<td>Elongation after fracture. The permanent increase in the original gauge length ($L_0$) after fracture.</td>
</tr>
<tr>
<td>$R_m$</td>
<td>MPa</td>
<td>Tensile strength</td>
<td>The maximum force ($F_m$) divided by the original cross-sectional area ($S_0$) of the test piece</td>
</tr>
<tr>
<td>$R_p$</td>
<td>MPa</td>
<td>Proof stress</td>
<td>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: $R_{p0.2}$</td>
</tr>
<tr>
<td>$r$</td>
<td>mm</td>
<td>Test piece transition radius</td>
<td>Radius at ends of parallel length</td>
</tr>
<tr>
<td>$S_0$</td>
<td>mm²</td>
<td>Original cross-sectional area</td>
<td>Original cross-sectional area of the parallel length</td>
</tr>
<tr>
<td>$S_u$</td>
<td>mm²</td>
<td>Minimum cross-sectional area</td>
<td>Minimum cross-sectional area of test piece after fracture</td>
</tr>
<tr>
<td>$Z$</td>
<td>%</td>
<td>Percentage reduction of area</td>
<td>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 $Z = \frac{S_0 - S_u}{S_0} \times 100$</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>–</td>
<td>Strain</td>
<td>The extension of any moment during the test divided by the original gauge length ($L_0$) of the test piece</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>MPa</td>
<td>Stress</td>
<td>The force at any moment during the test divided by the original cross-section area ($S_0$) of the test piece</td>
</tr>
<tr>
<td>$\theta$</td>
<td>°C</td>
<td>Specified temperature</td>
<td>The temperature at which the test is to be carried out</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Type of product</th>
<th>Corresponding annex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet and strip</td>
<td>A</td>
</tr>
<tr>
<td>Bar, section and wire of diameter or thickness ≤ 8 mm</td>
<td>B</td>
</tr>
<tr>
<td>Bar, section, plate and wire of diameter or thickness &gt; 8 mm and for forgings and castings</td>
<td>C</td>
</tr>
<tr>
<td>Tubes</td>
<td>D</td>
</tr>
</tbody>
</table>

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 $0.17 \leq \frac{b}{D} < 0.25$

$$S_0 = ab \left(1 + \frac{b^2}{6D(D-2a)}\right)$$

When $\frac{b}{D} < 0.17$

$$S_0 = ab$$