SLOVENSKI STANDARD
SIST EN 2002-002:2006

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Aeronavtika – Kovinski materiali – Preskusne metode – 2. del: Natezni preskus pri povišani temperaturi

Aerospace series - Metallic materials - Test methods - Part 2: Tensile testing at elevated temperature

Luft- und Raumfahrt - Metallische Werkstoffe - Prüfverfahren - Teil 2: Zugversuch bei Hochtemperatur

Série aérospatiale - Matériaux métalliques - Méthodes d'essais applicables - Partie 2 : Essais de traction a temperature élevée

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Aerospace series - Metallic materials - Test methods - Part 2: Tensile testing at elevated temperature

Série aérospatiale - Matériaux métalliques - Méthodes d'essais applicables - Partie 2 : Essais de traction à temperature élevée

Luft- und Raumfahrt - Metallische Werkstoffe - Prüfverfahren - Teil 2: Zugversuch bei Hochtemperatur

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Foreword

This European Standard (EN 2002-002:2005) 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of an identical text or by endorsement, at the latest by May 2006, and conflicting national standards shall be withdrawn at the latest by May 2006.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 elevated 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)

EN 60584-2, *Thermocouples – Part 2: Tolerances.*

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.

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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	Extension	Extension 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
R_1	mm	Ridge transition radius	Radius at ridge
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
θ_i	°C	Indicated temperature	The temperature which is measured at the surface of the parallel length of the test piece

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 elevated temperature to fracture for the purpose of determining one or more of the following properties: Young's modulus of elasticity, proof stress, tensile strength, elongation and 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. Otherwise 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 E-1012 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 shall be of a type suitable for use at elevated temperatures.

Its 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;

— Lengths 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.

6.1.1.4 Heating device

The heating device for the test piece:

— shall be such that the test piece can be heated to the specified temperature (θ);

— shall be able to maintain an indicated test temperature (θ_i), which at any time throughout the duration of the test and at any point within the gauge length, shall not deviate from the specified temperature (θ) by more than the values shown in Table 2;

Table 2 — Tolerances on test temperature

Test temperature	Tolerance
θ ≤ 600 °C	± 3 °C
600 °C < θ ≤ 800 °C	± 4 °C
800 °C < θ ≤ 1 000 °C	± 5 °C
θ > 1 000 °C	± 1 %

The permitted deviation in temperature along the original gauge length (L_0) shall comply with the above at least until the point corresponding to the proof stress of non-proportional elongation is reached.

The heating characteristics of the furnace and temperature control system shall prevent the limits specified above being exceeded during the heating of the test piece.

6.1.1.5 Temperature measurements

Platinum/platinum-rhodium thermocouples of type R or type S to Class 1 according to EN 60584-2 shall be used. They shall be verified over the working temperature range by a method traceable to the international unit (SI) of temperature, at intervals not exceeding one year.

6.1.1.6 Recording

A recorder/data logger, accurate to ± 1,0 °C and with a resolution of 0,5 °C, shall be verified at intervals not exceeding 12 months.

Verification shall be performed using a thermocouple measuring/simulating instrument, accurate to ± 0,5 °C and with a resolution of 0,2 °C, it self verified at intervals not exceeding 12 months.

Verification errors shall be recorded in a report.

6.1.2 Materials/reagents

Materials/reagents may include suitable:

- degreasing fluids;
- recording paper;
- means of electronic recording, if appropriate;
- marking inks.
- refractory materials

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.

The 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 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 3.

Table 3 — Product types

Type of product	Corresponding annex
Sheet and strip ≤ 8 mm	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