SLOVENSKI STANDARD
SIST EN 658-1:2000

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Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Part 1: Determination of tensile properties

Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Part 1: Determination of tensile properties

Hochleistungskeramik - Mechanische Eigenschaften von keramischen Verbundwerkstoffen bei Raumtemperatur - Teil 1: Bestimmung der Eigenschaften unter Zug

Céramiques techniques avançées - Propriétés mécaniques des céramiques composites a température ambiante - Partie 1: Détermination des caractéristiques en traction

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English version

Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Part 1: Determination of tensile properties

Céramiques techniques avancées - Propriétés mécaniques des céramiques composites à température ambiante - Partie 1: Détermination des caractéristiques en traction

This European Standard was approved by CEN on 23 May 1998.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 184 " Advanced technical ceramics", the secretariat of which is held by BSI.

This European Standard supersedes ENV 658-1:1993.

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of an identical text or by endorsement, at the latest by December 1998, and conflicting national standards shall be withdrawn at the latest by December 1998.

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

1 Scope

This standard specifies the conditions for determination of tensile properties of ceramic matrix composite materials with continuous fibre reinforcement at ambient temperature.

This standard applies to all ceramic matrix composites with a continuous fibre reinforcement, unidirectional(1D), bidirectional (2D), and tridirectional(xD, with $2 < x \leq 3$), loaded along one principal axis of reinforcement.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and in the publications listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 10002-2	Metallic materials - Tensile testing - Part 2: Verification of the force measuring system of the tensile testing machines
EN 10002-4	Metallic materials - Tensile test - Part 4: Verification of extensometers used in uniaxial testing
ISO 3611	Micrometer callipers for external measurements
ENV 1892	Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature under inert atmosphere - Determination of tensile properties
ENV 1893	Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature in air at atmospheric pressure - Determination of tensile properties
HTMTC [1)]	Code of practice - Code of practice for the measurement of misalignment induced bending in uniaxially loaded tension compression test pieces.

3 Principle

A test specimen of specified dimensions is loaded in tension. The test is performed at constant crosshead displacement rate, or constant deformation rate.

[1)] Published by JRC Institut for Advanced Materials, ISBN 92-826-9681-2, EUR 16138 EN.

NOTE : The use of constant loading rate only gives a valid tensile curve when the material behaves linearly up to failure.

The force and longitudinal deformation are measured and recorded simultaneously.

4 Definitions and symbols

For the purposes of this European Standard, the following definitions apply:

4.1 calibrated length, *l*

The part of the test specimen which has uniform and minimum cross section area.

4.2 gauge length, L_o

Initial distance between reference points on the test specimen in the calibrated length.

4.3 initial cross section area, A_o

Initial cross section of the test specimen within calibrated length.

4.4 longitudinal deformation, ΔL

Increase in the gauge length between reference points under a tensile force. Its value corresponding to the maximum force shall be denoted $\Delta L_{t,m}$.

4.5 tensile strain, ϵ

Relative change in the gauge length defined as the ratio $\Delta L / L_o$. Its value corresponding to the maximum force shall be denoted $\epsilon_{t,m}$.

4.6 tensile stress, σ

The tensile force supported by the test specimen at any time in the test divided by the initial cross section area.

4.7 maximum tensile force, $F_{t,m}$

Highest recorded tensile force in a tensile test on the test specimen when tested to failure.

4.8 tensile strength, $\sigma_{t,m}$

Ratio of the maximum tensile force to the initial cross-section area.

4.9 proportional limit stress, σ_o

The greatest stress that the test specimen is capable of sustaining without any deviation from proportionality of stress to strain.

4.10 proportionality ratio or pseudo-elastic modulus E_p, elastic modulus, E

The slope of the linear section of the stress-strain curve, if any. Examination of the stress-strain curves for ceramic matrix composites allows definition of the following cases :

a) Material with a linear section in the stress-strain curve
For ceramic matrix composites that have a mechanical behaviour characterised by a linear section, the proportionality ratio E_p is defined as :

$$E_p(\sigma_1, \sigma_2) = \frac{\sigma_2 - \sigma_1}{\epsilon_2 - \epsilon_1} \quad (1)$$

where :

(ϵ_1, σ_1) and (ϵ_2, σ_2) lie near the lower and the upper limits of the linear section of the stress-strain curve (see figure 5).

The proportionality ratio or pseudo-elastic modulus is termed the elastic modulus, ***E***, in the single case where the linearity starts near the origin (see figure 6).

b) Material with nonlinear section in the stress-strain curve (see figure 7). In this case only stress-strain couples can be fixed.

4.11 cumulative damage energy, Φ

The area under the force longitudinal deformation curve up to failure divided by the volume within the gauge length.

NOTE : The cumulative damage energy is to be regarded as an indication for the ability of the material to sustain damage rather than as a material property. For the characterization of the fracture mechanics of ceramic matrix composites suitable methods need to be developed. The determination of the cumulative damage energy as mentioned above will become obsolete as soon as standardized methods for the characterization of the fracture mechanics of these materials are available.

4.12 axial strain

Average of the longitudinal strain measured at the surface of the test specimen at specified locations (see the HTMTC code of practice).

4.13 bending strain

The difference between the longitudinal strain at a given location on the test specimen surface and the axial strain (see the HTMTC code of practice).

4.14 percent bending

The bending strain times 100 divided by the axial strain.

5 Apparatus

5.1 Test machine

The machine shall be equiped with a system for measuring the force applied to the test specimen which shall conform to class of machine 1 or better in accordance with EN 10002-2.

5.2 Load train

5.2.1 General

The load train is composed of the moveable and fixed crosshead, the loading rods, and the grips. Load train couplers may additionally be used to connect the grips to the loading rods.

The load train shall align the specimen axis with the direction of load application without introducing bending or torsion in the specimen. The misalignment of the specimen shall be verified and documented according to the procedure described in the HTMTC Code of Practice. The maximum percent bending shall not exceed 5 at an axial strain of 500×10^{-6}.

5.2.2 Grips

The grips transmit the axial load applied by the testing machine to the specimen. They shall prevent slipping of the specimen in the gripping section. The selection of a particular type of grips depends on specimen design and critically influences the alignment.

NOTE 1 : When the grip design relies on friction to transmit the axial load to the specimen, the use of an adjustable clamping pressure is recommended.

NOTE 2 : Care should be taken to avoid the introduction of torsion loading on the specimen when tightening the grips.

5.2.3 Load train couplers

Load train couplers may be used to connect the grips to the loading rods. Their primary function is to assure axial alignment of the grips in the loading train.

NOTE 3 : Load train couplers are of two types: fixed or non-fixed. Fixed couplers usually consist of angularity and/or concentricity adjusters. Non fixed couplers promote self-alignement of the load train upon movement of the cross-head. This self-aligning action is limited by the inherent friction between moving parts in the coupler.

NOTE 4 : The self-aligning action of non-fixed load train couplers may result in non-uniform loading of the unbroken ligament of the specimen after appearance of damage in the specimen, which can modify the shape of the tensile curve.

NOTE 5 : The use of well-aligned couplers and grips does not guarantee low bending in the specimen. The latter additionally depends on the type and operation of the grips, and on the type of the specimen.

5.3 Strain measurement

For continuous measurement of the longitudinal deformation as a function of the applied force either strain gauges or a suitable extensometer complying with EN 10002-4 may be used. Measurement of longitudinal deformation over a length as large as possible compatible with the calibrated length of the specimen is recommended.

5.3.1 Strain gauges

Strain gauges are used for the verification of the alignment on the specimen. They may also be used for measuring longitudinal deformation during testing. In both cases, the length of the strain gauges shall be such that the readings are not affected by local features on the surface of the specimen such as fibre crossovers. Care shall be taken to insure that the strain gauge readings are not influenced by the surface preparation and the adhesive used.

5.3.2 Extensometry

The linearity tolerance of the extensometer shall be lower than 0,15% of the extensometer range used.

The commonly used type of extensometer is :

5.3.2.1 Mechanical extensometer

For a mechanical extensometer the gauge length corresponds to the initial longitudinal distance between the two locations where the extensometer rods contact the specimen. The mounting of the rods on the specimen shall prevent slippage of the extensometer as well as failure initiation under the contact points. The contact forces shall not introduce bending greater than that allowed in 5.2.1. Contact points shall be placed along the longitudinal axis of symmetry of the specimen.

Another type of extensometer which is sometimes used is :

5.3.2.2 Electro-optical extensometer

Electro-optical measurements in transmission require reference marks on the specimen. For this purpose rods or flags are attached to the specimen surface along the axis of the specimen. The gauge length corresponds to the initial longitudinal distance between the two reference marks.

NOTE : The use of integral flags as part of the specimen geometry is not recommended because of stress concentration induced by such features.

5.4 Data recording system

A calibrated recorder may be used to record force-longitudinal deformation. The use of a digital data recording system combined with an analogue recorder is recommended.

5.5 Micrometers

Micrometers used for the measurement of the dimensions of the test specimen shall be in accordance with ISO 3611.

6 Test specimens

The choice of test specimen geometry depends on several parameters :

- the nature of the material and of the reinforcement structure ;

- the type of gripping system.

Total length l_t, depends on the type of machine, on the type of grips and on the type of extensometer. It is recommended to use a total length of at least 100 mm.
The volume in the gauge length shall be representative for the material.

Two types of test specimens can be distinguished :

- as fabricated test specimens, where only the length and the width are machined to give to the specimens the proper size. In this case the two faces of the specimen may present an irregular surface.,

- machined test specimens, where the length and the width and also the two sides of the specimen have been machined.

Tolerance on thickness is only for machined specimens. For as-fabricated specimens the difference in thickness taken out of three measurements (at the center and at each end of the calibrated length) shall not exceed 5 % of the average of the three measurements.

Type 1 test specimen is represented in figure 1 below and dimensions are given in table 1.

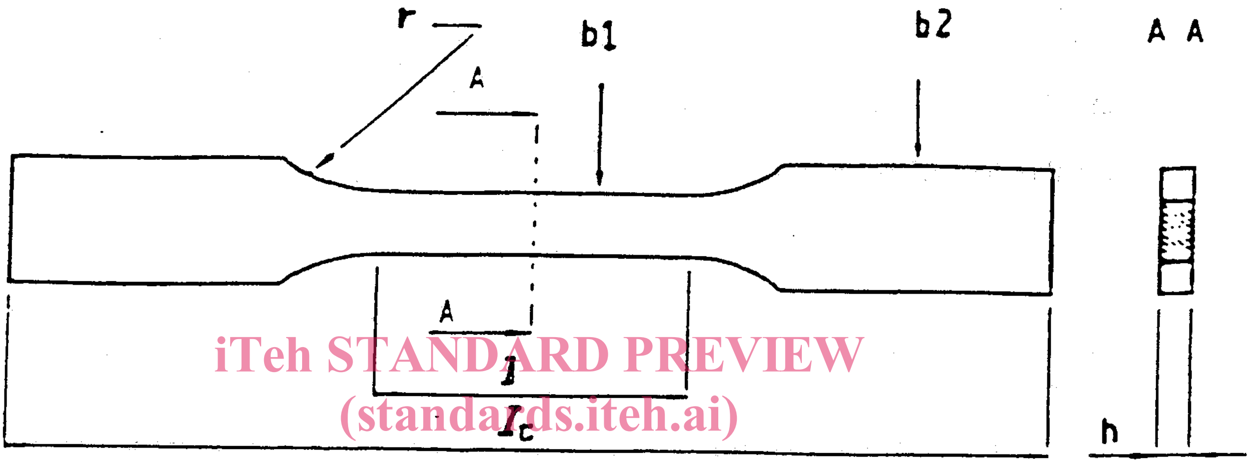

Figure 1

Table 1

Dimensions in millimetres

l_t, total length	≥ 100	± 0,5
l, calibrated length	≥ 40	± 0,2
h, thickness	≥ 3	± 0,2
b_2, width	≥ 10	± 0,2
b_1, width in the calibrated length	≥ 8	± 0,2
r, Blend radius	≥ 30	± 2
Plan parallelism of machined parts	0,05	-

Type 2, is a straight-sided test specimen. It is represented in figure 2 below and dimensions are given in table 2.

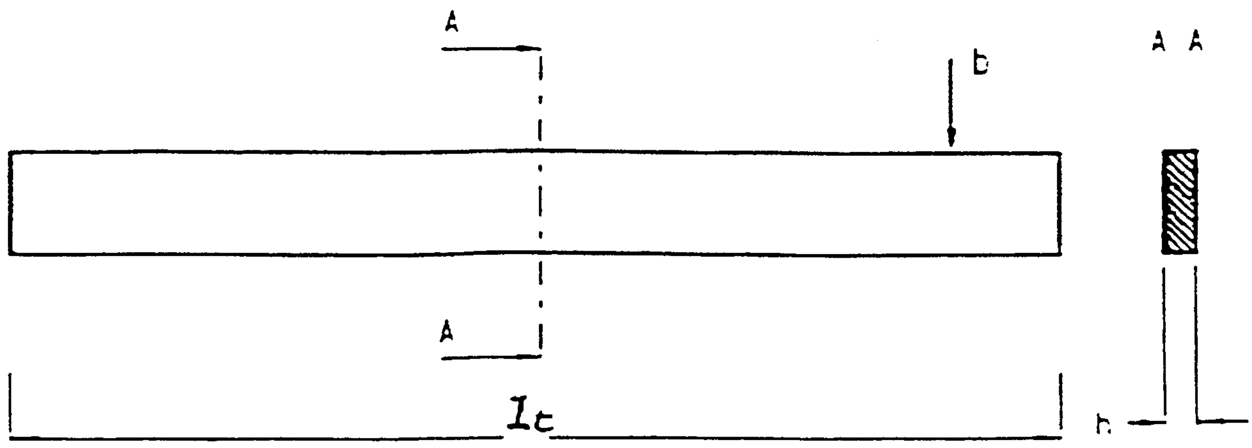

Figure 2

Table 2

Dimensions in millimetres

h, thickness	≥ 3	± 0,2
b, width	≥ 10	± 0,2
Plan parallelism of machined parts	0,05	-

NOTE : This test specimen is easy to machine and its use allows mainly the determination of modulus; it should not be used for strength measurement.

Type 3 is a straight sided test specimen equipped with tabs.

Two types of tabs which cover the total gripped length can be used :

- metallic or composite tabs bonded or cured on the test specimen. The dimensions are given in table 3 and the test specimen is represented in figure 3. This type of test specimen is mainly used for 1D, 2D and xD (with 2< x ≤ 3) materials ;

- polymeric tabs moulded on the test specimen. The dimensions are given in table 4 and the test specimen is represented in figure 4. This type of test specimen is mainly used for 3D materials.