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Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Part 2: Determination of compression properties

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Hochleistungskeramik - Mechanische Eigenschaften von keramischen Verbundwerkstoffen bei Raumtemperatur - Teil 2: Bestimmung der Eigenschaften unter Druck

Céramiques techniques avancées - Propriétés mécaniques des céramiques composites a température ambiante - Partie 2: Détermination des propriétés en compression

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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

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

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Foreword

This document (EN 658-2:2002) has been prepared by Technical Committee CEN /TC 184, "Advanced technical ceramics", the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by June 2003, and conflicting national standards shall be withdrawn at the latest by June 2003.

This document supersedes ENV 658-2 :1993.

EN 658 consists of the following parts, under the general title "*Advanced technical ceramics – Mechanical properties of ceramic composites at room temperature*"

— Part 1 *: Determination of tensile properties*

— Part 2 *: Determination of compressive properties*

— Part 3 *: Determination of flexural strength*

— Part 4 *: Determination of interlaminar shear strength by compression loading of notched test specimens*

— Part 5 *: Determination of interlaminar shear strength by short span bend test (three-points)*

— Part 6 *: Determination of interlaminar shear strength by double-punch shearing*

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, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This part of this European Standard describes a method for determination of compression properties of ceramic matrix composite materials with continuous fibre reinforcement at room temperature. This method applies to all ceramic matrix composites with a continuous fibre reinforcement, unidirectional (1D), bidirectional (2D), and tridirectional (xD, with $2 < x \leq 3$) as defined in ENV 13233, loaded along one principal axis of reinforcement.

Two cases are distinguished:

— compression between platens;

— compression using grips.

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 the publications are 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 (including amendments).

ENV 13233:1998, *Advanced technical ceramics - Ceramic composites - Notations and symbols*.

EN ISO 7500-1:1999, *Metallic materials - Verification of static uniaxial testing machines - Part 1: Tension/compression testing machines (ISO 7500-1:1999)*.

ISO 3611, *Micrometer callipers for external measurements*

3 Principle

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

NOTE 1 Constant loading rate is only allowed in the case of linear stress strain behaviour up to failure.

NOTE 2 When applied, it is recommended to use constant cross head displacement rate when the test is carried out up to failure.

The force and longitudinal deformation are measured and recorded simultaneously.

4 Terms, definitions and symbols

For the purposes of this European Standard, the following terms and definitions and the symbols given in ENV 13233 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_0
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
decrease in the gauge length between reference points under a compression force. Its value corresponding to the maximum force shall be denoted $\Delta L_{c,m}$

4.5
compression 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 $\varepsilon_{c,m}$

4.6
compression stress, σ
the compression force supported by the test specimen at any time in the test divided by the initial cross-section area

4.7
maximum compression force, $F_{c,m}$
highest recorded compression force in a compression test on the test specimen when tested to failure

4.8
compression strength, $\sigma_{c,m}$
ratio of the maximum tensile force to the initial cross-section area

4.9
proportionality ratio or pseudo-elastic modulus Ep**, 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 Ep is defined as:

$$Ep\left(\sigma_1, \sigma_2\right) = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \tag{1}$$

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 Figures 1 and 2).

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 2);

b) material with non-linear section in the stress-strain curve

In this case only stress-strain couples can be fixed.

4.10
axial strain
average of the longitudinal strain measured at the surface of the test specimen at specified locations

4.11
bending strain
the difference between the longitudinal strain at a given location on the test specimen surface and the axial strain

4.12
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 grade 1 or better according to EN ISO 7500-1:1999.

5.2 Load train

The load train is composed of the moveable and fixed crosshead, the loading rods and the grips or platens. Load train couplers may additionally be used to connect the grips or platens 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 maximum percent bending shall not exceed 5 at an average strain of $500 \cdot 10^{-6}$.

There are two alternative means of load application:

a) compression platens are connected to the load cell and on the moving cross head. The parallelism of these platens shall be better than 0,01 mm, in the loading area and they shall be perpendicular to the load direction.

NOTE 1 The use of platens is not recommended for compression testing of 1D and 2D materials with low thicknesses because of buckling.

NOTE 2 A compliant interlayer material between the test specimen and platens can be used for testing macroscopically inhomogeneous materials to ensure uniform contact pressure.

When the dimensions of specimen are such that buckling may occur, it is recommended to use an antibuckling tool such as one of those which are described in EN ISO 14126. This tool should not induce parasitic stresses during loading of the specimen;

b) grips are used to clamp and load the test specimen.

The grip design shall prevent the test specimen from slipping.

The grips must align the test specimen axis with that of the applied force.

NOTE This point should be verified and documented, according to, for example the procedure described in WI 00184136.

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 ensure 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.

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 perpendicular to the longitudinal specimen axis. 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 concentrations induced by such features.

5.4 Data recording system

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

5.5 Dimension measuring devices

Devices used for measuring linear dimensions of the test specimen shall be accurate to ± 0,1 mm. Micrometres shall be in accordance with ISO 3611.

6 Test specimens

The choice of specimen geometry depends on several parameters:

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

— the type of loading system.

The ratio between the length of the specimen submitted to buckling and the thickness of the test specimen and also the stiffness of the material will influence the resistance of the test specimen towards buckling.

If buckling occurs, it will be necessary to modify the dimensions of the test specimen or alternatively to use an antibuckling tool.

The volume in the gauge length shall be representative of the material.

Two types of test specimens can be distinguished:

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

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

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

6.1 Compression between platens

The test specimen geometry and/or compliant interlayers may be adapted in order to avoid buckling and damage at the edges due to contact forces.

Type 1 is commonly used and is represented in Figure 1 below.

Recommended dimensions are given in Table 1.

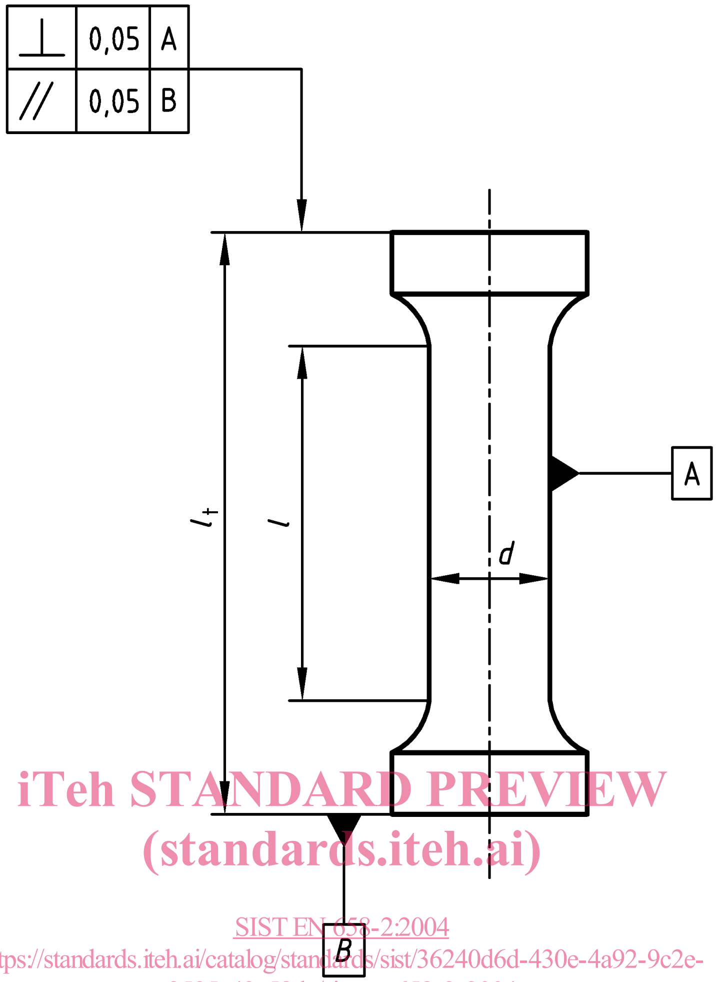

Figure 1