SLOVENSKI STANDARD
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Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature in air at atmospheric pressure - Determination of compression properties

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Hochleistungskeramik - Mechanische Eigenschaften von Keramischen Verbundwerkstoffen bei hoher Temperatur an Luft bei Atmosphärendruck - Bestimmung der Eigenschaften unter Druck

Céramiques techniques avancées - Propriétés mécaniques des céramiques composites a haute température sous air a la pression atmosphérique - Détermination des caractéristiques en compression

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This European Standard was approved by CEN on 23 May 2003.

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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.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

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 12291:2003) 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of an identical text or by endorsement, at the latest by January 2004, and conflicting national standards shall be withdrawn at the latest by January 2004.

This document supersedes ENV 12291:1996.

Annex A is normative.

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, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard EN 12291 specifies the conditions for determination of compression properties of ceramic matrix composite materials with continuous fibre reinforcement for temperatures up to 1 700 °C in air at atmospheric pressure.

This European 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.

NOTE 1 In most cases, ceramic matrix composites to be used at high temperature in air are coated with an anti oxidation coating.

NOTE 2 The purpose of this European standard is to determine the compression properties of a material when it is placed under an oxidizing environment but not to measure material oxidation.

Two cases are distinguished:

a) compression between platens;

b) 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).

EN 10002-4, *Metallic materials - Tensile testing - Part 4 : Verification of extensometers used in uniaxial testing*.

EN 60584-1, *Thermocouples - Part 1 : Reference tables (IEC 60584-1:1995)*.

EN 60584-2, *Thermocouples - Part 2 : Tolerances (IEC 60584-2:1982 + A1:1989)*.

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

ISO 3611, *Micrometer callipers for external measurement*.

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

3.1

test temperature, *T*
temperature of the test piece at the centre of the gauge length

3.2

calibrated length, *l*
part of the test specimen which has uniform and minimum cross section area

3.3

gauge length, L_o
initial distance between reference points on the test specimen in the calibrated length. The temperature variation in the gauge length shall be within 20 °C at test temperature

3.4

controlled temperature zone
part of the calibrated length including the gauge length where the temperature is in a range of ± 50 °C of the test temperature

3.5

initial cross section area, A_o
initial cross section area of the test specimen within the calibrated length, at test temperature

two initial cross section areas of the test specimen can be defined:

— apparent cross section area: This is the total area of the cross section, $A_{o,a}$;

— effective cross section area: This is the total area corrected by a factor, to account for the presence of an antioxidant protection, $A_{o,e}$

3.6

longitudinal deformation, ΔL
decrease in the gauge length between reference points under a compression force. It's value corresponding to the maximum force shall be denoted as $\Delta L_{c,m}$

3.7

compression strain, $\in$
relative change in the gauge length defined as the ratio $\Delta L/L_o$.Its value corresponding to the maximum force shall be denoted as $\in_{c,m}$

3.8

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

two compression stresses can be distinguished:

— apparent compression stress, σ_a, when the apparent cross section area (or total cross section area) is used

— effective compression stress, σ_e, when the effective cross section area is used

3.9

maximum compression force, F_m
highest recorded compression force in a compression test on the test specimen when tested to failure

3.10

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

two compression strengths can be distinguished:

— apparent compression strength, $\sigma_{c,m,a}$, when the apparent cross section area (or total cross section area) is used.

— effective compression strength, $\sigma_{c,m,e}$, when the effective cross section area is used.

3.11

proportionality ratio or pseudo-elastic modulus, *E*p
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 is defined as:

$$E\mathrm{p}\left(\sigma_1 - \sigma_2\right) = \frac{\sigma_2 - \sigma_1}{\epsilon_2 - \epsilon_1} \tag{1}$$

where

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

the proportionality ratio or pseudo-elastic modulus is termed the elastic modulus, *E*, in the single case where the material has a linear behaviour from the origin

two proportionality ratio or pseudo-elastic moduli can be distinguished:

— apparent proportionality ratio, $E\mathrm{p}_a$, when the apparent compression stress is used

— effective proportionality ratio, $E\mathrm{p}_e$, when the effective compression stress is used

b) material with no-linear section in the stress-strain curve

in this case only stress-strain couples can be fixed

4 Principle

A test specimen of specified dimensions is heated to the testing temperature, and loaded in compression. The test is performed at constant crosshead displacement rate, or constant deformation rate.

Force and longitudinal deformation are measured and recorded simultaneously.

The test duration is limited to reduce creep effects.

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

NOTE 2 In order to protect fixture, it is recommended to use constant crosshead displacement rate when the test is carried out until rupture.

5 Apparatus

5.1 Test machine

The machine shall be equipped 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. This shall prevail during actual test conditions (gas pressure, temperature).

5.2 Load train

The load train configuration shall ensure that the load indicated by the load cell and the load experienced by the test specimen are the same.

The load train performance including the alignment system and the force transmitting system shall not change because of heating.

There are two alternative means of load application:

a) compression platens are connected to the load cell and on the moving crosshead. The parallelism of these platens shall be better than 0,01 mm, in the loading area, at room temperature 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 even contact pressure. This material should be chemically compatible with both test specimen and platen materials.

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 1 This point should be verified and documented, according to, for example, the procedure described in the HTMTC code of practice.

The grips or the platens can be either in the hot zone of the furnace or outside.

NOTE 2 When grips or platens are outside the furnace, a temperature gradient exists between the centre of the specimen, which is at the prescribed temperature, and the ends, which are at the same temperature as the grips or platens.

5.3 Set-up for heating

The set-up for heating shall be constructed in such a way that the temperature gradient within the gauge length is less than 20 °C at test temperature.

5.4 Extensometer

5.4.1 General

Extensometry shall be capable of continuously recording the longitudinal deformation at test temperature.

The use of an extensometer with the greatest possible gauge length is recommended. The linearity tolerance shall be lower than or equal to 0,15 % of the extensometer range used.

The extensometer shall comply with class 1 or better, according to EN 10002-4.

Besides other types, two commonly used types of extensometer are:

5.4.2 Mechanical extensometer

In this case, the gauge length is the initial longitudinal distance between the two locations where the extensometer rods contact the test specimen.

The rods may be exposed to temperatures higher than the test specimen temperature. Temperature and/or environment induced structural changes in the rod material shall not affect the accuracy of deformation measurement. The material used for the rods shall be compatible with the test specimen material.

Care should be taken to correct for changes in calibration of the extensometer which may occur as a result of operating under conditions different from calibration.

NOTE Rod pressure onto the test specimen should be the minimum necessary to prevent slipping of the extensometer rods.

5.4.3 Electro-optical extensometer

Electro-optical measurements in transmission require reference marks on the test specimen. For this purpose rods or flags are attached to the surface perpendicularly to its axis. The gauge length is the distance between the two reference marks. The material used for marks (and adhesive if used) shall be compatible with the test specimen material and the test temperature and shall not modify the stress field in the specimen.

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

5.5 Temperature measurement

Thermocouples shall comply to EN 60584-1 and EN 60584-2.

Alternatively, when thermocouples which are not covered by EN 60584-1 and EN 60584-2 or pyrometers are used, the calibration data shall be added to the test report.

5.6 Data recording system

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

5.7 Micrometers

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

6 Test specimens

6.1 General

The choice of specimen geometry depends on several factors, such as:

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

— the type of heating system;

— the type of loading system.

The volume in the gauge length shall be representative of the material and calibrated length shall be chosen such as to avoid buckling failure.

6.2 Compression between platens

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

Recommended dimensions are given in Table 1.

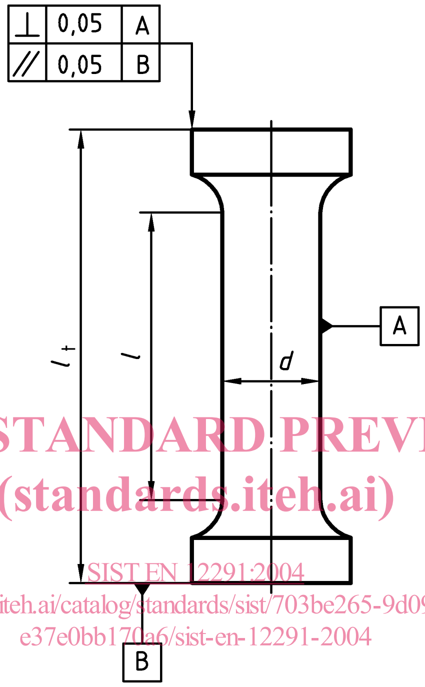

Figure 1 - Type 1 compression

Table 1 - Recommended dimensions for Type 1 compression

Dimensions in millimetres

	1D, 2D and xD	Tolerance
l Calibrated length	≥ 15	± 0,5
l_t Total length	≥ 1,5 x l	± 0,5
d Circular or square section diameter or side length	≥ 8	± 0,2
Parallelism of machined parts	0,05	
Perpendicularity of machined parts	0,05	
Concentricity of machined parts	0,05	

Type 2 which is sometime used, is represented in Figure 2 below.

Recommended dimensions are given in Table 2.