SLOVENSKI STANDARD
SIST ENV 12788:2000

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Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature under inert atmosphere - Determination of flexural strength

Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature under inert atmosphere - Determination of flexural strength

Hochleistungskeramik - Mechanische Eigenschaften von keramischen Verbundwerkstoffen bei hoher Temperatur an inerter Atmosphäre - Bestimmung der Biegesfestigkeit

Céramiques techniques avancées - Propriétés mécaniques composites a haute température sous atmosphere inerte - Détermination de la résistance en flexion

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English version

Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature under inert atmosphere - Determination of flexural strength

Céramiques techniques avancées - Propriétés mécaniques composites à haute température sous atmosphère inerte - Détermination de la résistance en flexion

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

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Contents

Foreword

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

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this European Prestandard: 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 European prestandard ENV 12788 specifies the conditions for determination of the flexural strength of ceramic matrix composite materials with continuous fibre reinforcement under three-point or four-point bending for temperatures up to 2 000 °C under vacuum or a gas atmosphere which is inert to the material under test.

This Prestandard 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 : The use of these environments is aimed at avoiding changes of the material affecting its flexural strength caused by chemical reaction with its environment during the test.
NOTE 2 : The method should not be used to obtain values of flexural strength for design purposes.

2 Normative references

This European prestandard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at 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 Prestandard only when incorporated in it by amendment or revision. For undated references the latest edition of publication referred to applies.

ENV 843-5	Advanced technical ceramics - Monolithic ceramics - Mechanical tests at room temperature - Part 5 : Statistical analysis
ENV 12789	Advanced technical ceramics - Mechanical properties of ceramic composites at high temperature under air at atmospheric pressure - Determination of flexural strength
EN 10002-2	Metallic materials - Tensile testing - Part 2 : Verification of the force measuring system of the tensile testing machines
EN 60584-1	Thermocouples - Part 1 : Reference tables
EN 60584-2	Thermocouples - Part 2 : Tolerances
ISO 3611	Micrometer callipers for external measurement

3 Principle

A test specimen of specified dimensions is heated to the testing temperature. It is subsequently flexion loaded to fracture in such a way that failure occurs in tension or in compression along one principal axis of reinforcement.

The test is performed at constant crosshead displacement rate.

The test duration is limited to reduce any time dependent effects (creep, etc.).

4 Definitions and symbols

For the purpose of this prestandard, the following definitions and symbols apply :

4.1 test temperature, *T*

Temperature at the centre of the test piece.

4.2 maximum flexural force, *Fm*

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

4.3 flexural stress, σ

The nominal stress on the outer surface of the test specimen, calculated at mid span.

NOTE : This stress is conventionally calculated according to the simple beam theory, whose basic assumptions may not be met by ceramic matrix composite materials.

4.4 flexural strength, $\sigma_{f,m}$

Maximum flexural stress applied to a test specimen that fractures during a flexural test

5 Apparatus

5.1 Test machine

The machine shall be equipped with a system for measuring the force applied to the test specimen. The system shall conform to grade 1 according to EN 10002-2.

5.2 Test jig

The test jig is composed of two parts, linked to the fixed and mobile parts of the machine. It has two outer support rollers and one (three-point bending) or two (four-point bending) inner support rollers.

The material of the jig and that of the rollers shall not react with that of the specimen, nor with the environment.

The cylindrical rollers shall have a diameter of 4 mm to 10 mm. Their length shall be at least equal to the width of the specimen. They shall be made of a material with a hardness at least equal to that of the specimen. The axes of the rollers shall be parallel to within 0,01 mm/mm.

The outer rollers (three and four-point bending) and inner rollers (four-point bending) shall be free to rotate (see figure 1).

Either two or three rollers, for three-point or four-point bending respectively, shall be free to pivot around an axis parallel to the longitudinal direction of the test specimen, in order to adapt to the non-parallelism of the upper and lower faces of unmachined test specimens(see figure 1).

The rolling and pivoting ability of the rollers shall not be affected by heating. The distance between rollers shall be in accordance to clause 6.

The inner roller(s) shall be centred with respect to the outer rollers to within 0,2 mm. In the case of four-point bending a levelling system shall be used to ensure symmetrical loading of the test specimen.

The performance shall not change because of heating.

5.3 Test chamber

Gastight chamber which allows proper control of the test specimen environment in the vicinity of the test specimen during the test. The installation shall be such, that the variation of the load during the time of loading, which may occur due to parasitic effects(variation of pressure, seals, etc.) is less than 1 % of the range of the load cell being used.

5.3.1 Gas atmosphere

The gas atmosphere shall be inert to the specimen material and test jig under test conditions.

5.3.2 Vacuum chamber

The level of vacuum shall not induce chemical and/or physical instabilities of the test specimen material and test jig.

5.4 Set-up for heating

The set-up for heating shall be constructed in such a way that the variation of temperature of the test specimen which is between the outer support rollers is less than 50 °C at test temperature.

5.5 Temperature measurement

Thermocouples shall comply to EN 60584-1 and EN 60584-2. Alternatively, pyrometers or thermocouples which are not covered by EN 60584-1 and EN 60584-2 but which are appropriately calibrated can be used.

5.6 Data recording system

A calibrated recorder shall be used to record force-time curve. 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

Recommended specimen dimensions are given in table 1. These dimensions have been successfully used and take due account of the following factors:

The amount of material under load shall be representative of the nature of the material and of the reinforcement structure. This sets minimum limits to the span and to the width and thickness of the specimen. In the case of flexural, as opposed to tensile testing, also the distribution of the longitudinal reinforcement through the thickness has to be considered. When this distribution is not symmetrical with respect to the neutral plane, care shall be taken to insure that it is similar between specimens.

The thickness and the distance between the inner and outer roller(s) shall be chosen so as to avoid shear failure. This is achieved by setting a minimum limit to the ratio between the moment arm and the specimen thickness. A value of 10 is commonly used and translates into a minimum L/h ratio of 20 in three-point bending, and a minimum (L-Li)/h ratio of 20 in four-point bending with Li=L/3.

Other factors affecting the size and dimensions of the specimens are the type of the heating and of the loading system, as well as the size of the test chamber.

Table 1: Recommended test specimen and span dimensions

Dimensions in millimeters

	1D, 2D & xD	Tolerance
L_t, total length	L + 10	± 1
b, width	10	± 0,2
h, thickness	2,5	± 0,2
Inner span four-point bending, L_i	25	± 0,1
Outer span four-point bending, L three-point bending, L	 75 50	 ± 0,1 ± 0,1

NOTE : If it is necessary to define test specimens of different dimensions, the conditions of clause 6 should be taken into account.

7 Test specimen preparation

7.1 Machining and preparation

During cutting out, care shall be taken to align the longitudinal test specimen axis with one of the principal axes of reinforcement.

Specimens may be tested with either machined or non-machined top and bottom surfaces. In some cases machining is not recommended because it may cause breakage of the fibers near the top and bottom surfaces. When machining these surfaces, care shall be taken to maintain a reinforcement geometry across the thickness of the specimen, which is representative of the material in the as-processed condition. In particular, it shall be assured that the symmetry of an originally symmetric reinforcement geometry is preserved in the specimen cross section after machining.

Machining parameters which avoid damage to the material shall be established and documented. These parameters shall be adhered to during test specimen preparation.

7.2 Number of test specimens

At least five valid test results, as specified in paragraph 8.4 are required per loading condition. For specimens with a non-symmetric reinforcement geometry with respect to the neutral plane, tests in two orientations for which the tensile and compressive face are interchanged may be necessary.

If a statistical evaluation of the flexural strength is required, the number of test specimens shall be in accordance with ENV 843-5.

8 Test procedures

8.1 Test set-up : Temperature considerations

The following determination shall be carried out under conditions representative of the tests, and shall be repeated every time there is a change in material, in specimen geometry, in loading attachments, etc . In establishing them, time shall be allowed for temperature stabilisation.

Prior to testing, the temperature gradient within the outer span shall be established over the temperature range of interest. This shall be done by measuring the specimen temperature at a minimum of three locations, which shall be the points over the supports and at the centre. The temperature variation within the outer span shall meet the requirements of paragraph 5.4.

During a series of tests, the test temperature can be determined either directly by measurement on the specimen itself, or indirectly from the temperature indicated by the temperature control device. In the latter case, the relationship between the control temperature and test specimen temperature at the centre of the length shall be established beforehand on a dummy test specimen over the range of temperature of interest. The dummy specimen shall be made of the same material as the specimen to be tested.

NOTE: The relationship between the temperature indicated by the temperature control system and the test temperature is usually established simultaneously with the temperature gradient.

Temperature may be measured by any means complying with paragraph 5.5. If thermocouples are used to measure the temperature at different locations of the specimen, they shall be embedded (and sealed if necessary) into a dummy specimen to a depth approximately equal to half the specimen dimension in the direction of insertion.

8.2 Test set-up : Other considerations

8.2.1 Displacement rate

Use a crosshead displacement rate which allows specimen rupture within 1 min. The displacement rate shall be reported.

If the material to be tested is sensitive to creep at the temperature of test, the speed shall be significantly increased, but impact loading shall be avoided.

8.2.2 Measurement of dimensions

Dimensions vary with temperature and variations are difficult to measure, for this reason dimensions are measured at room temperature.

8.2.2.1 Specimen dimensions

The width and thickness shall be measured to the nearest 0,01 mm in three points near the centre for three-point bending and between the inner rollers for four-point bending, and at each end of the specimen.

The arithmetic means of the measurements shall be used for calculations.

8.2.2.2 Distances between supporting rollers