SLOVENSKI STANDARD
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Sodobna tehniļ na keramika - Monolitna keramika - Mehanske lastnosti pri sobni temperaturi ï 2. del: Doloļ evanje elastiļ nega modula (Youngov modul), striġnega modula in Poissonovega ġtevila

Advanced technical ceramics - Mechanical properties of monolithic ceramics at room temperature - Part 2: Determination of Young's modulus, shear modulus and Poisson's ratio

Hochleistungskeramik - Mechanische Eigenschaften monolithischer Keramik bei Raumtemperatur - Teil 2: Bestimmung des Elastizitätsmoduls, Schubmoduls und der Poissonzahl

Céramiques techniques avancées - Propriétés mécaniques des céramiques monolithiques a température ambiante - Partie 2: Détermination du module d'Young, du module de cisaillement et du coefficient de Poisson

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ICS:

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Advanced technical ceramics - Mechanical properties of monolithic ceramics at room temperature - Part 2: Determination of Young's modulus, shear modulus and Poisson's ratio

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This European Standard was approved by CEN on 11 November 2006.

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

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Foreword

This document (EN 843-2:2006) 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of an identical text or by endorsement, at the latest by June 2007, and conflicting national standards shall be withdrawn at the latest by June 2007.

This document supersedes ENV 843-2:1995.

EN 843 *Advanced technical ceramics — Mechanical properties of monolithic ceramics at room temperature* comprises six parts:

Part 1: *Determination of flexural strength*

Part 2: *Determination of Young’s modulus, shear modulus and Poisson’s ratio*

Part 3: *Determination of subcritical crack growth parameters from constant stressing rate flexural strength tests*

Part 4: *Vickers, Knoop and Rockwell superficial hardness*

Part 5: *Statistical analysis*

Part 6: *Guidance for fractographic investigation*

At the time of publication of this Revision of Part 2, Part 6 was available as a Technical Specification.

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

1 Scope

This part of EN 843 specifies methods for determining the elastic moduli, specifically Young's modulus, shear modulus and Poisson's ratio, of advanced monolithic technical ceramics at room temperature. This European Standard prescribes four alternative methods for determining some or all of these three parameters:

A The determination of Young's modulus by static flexure of a thin beam in three- or four-point flexure.

B The determination of Young's modulus by forced longitudinal resonance, or Young's modulus, shear modulus and Poisson's ratio by forced flexural and torsional resonance, of a thin beam.

C The determination of Young's modulus, shear modulus and Poisson's ratio from the time-of-flight of an ultrasonic pulse.

D The determination of Young's modulus from the fundamental natural frequency of a struck bar (impulse excitation method).

All the test methods assume the use of homogeneous test pieces of linear elastic materials.

NOTE 1 Not all ceramic materials are equally and linearly elastic in tension and compression, such as some porous materials and some piezoelectric materials.

With the exception of Method C, the test assumes that the test piece has isotropic elastic properties. Method C may be used to determine the degree of anisotropy by testing in different orientations.

NOTE 2 An ultrasonic method for dealing with anisotropic materials (ceramic matrix composites) can be found in ENV 14186 [1]. An alternative to Method D for isotropic materials using disc test pieces is given in Annex A.

NOTE 3 At high porosity levels all of the methods except Method C may become inappropriate. The methods are only suitable for a maximum grain size (see EN 623-3), excluding deliberately added whiskers, of less than 10 % of the minimum dimension of the test piece.

NOTE 4 The different methods given in this European Standard can produce slightly different results on the same material owing to differences between quasi-isothermal quasi-static and quasi-adiabatic dynamic conditions. In addition, the calculation routines for different methods have different origins and different potential uncertainties which have not been rigorously evaluated in producing this European Standard. Some information is given in Annex B (see also reference [2]).

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 623-2, *Advanced technical ceramics — Monolithic ceramics — General and textural properties — Part 2: Determination of density and porosity*

EN 623-3, *Advanced technical ceramics — Monolithic ceramics — General and textural properties — Part 3: Determination of grain size and size distribution (characterized by the Linear Intercept Method)*

EN 623-4, *Advanced technical ceramics — Monolithic ceramics — General and textural properties — Part 4: Determination of surface roughness*

EN 843-1:2006, *Advanced technical ceramics — Mechanical properties of monolithic ceramics at room temperature — Part 1: Determination of flexural strength*

EN ISO 463, *Geometrical Product Specifications (GPS) — Dimensional measuring equipment — Design and metrological characteristics of mechanical dial gauges (ISO 463:2006)*

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 (ISO 7500-1:2004)*

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2005)*

ISO 3611, *Micrometer callipers for external measurement*

ISO 6906, *Vernier callipers reading to 0,02 mm*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 843-1:2006 and the following apply.

3.1
Young's modulus
stress required in a material to produce unit strain in uniaxial extension or compression

3.2
shear modulus
shear stress required in a material to produce unit angular distortion

3.3
Poisson's ratio
negative value of the ratio of lateral strain to longitudinal strain in an elastic body stressed longitudinally

3.4
static elastic moduli
elastic moduli determined in a quasi-isothermal condition by stressing statically or quasistatically

3.5
dynamic elastic moduli
elastic moduli determined non-quasistatically, i.e. under quasi-adiabatic conditions, such as in the resonant, ultrasonic pulse or impulse excitation methods

4 Method A: Static flexure method

4.1 Principle

Using three- or four-point flexure of a thin beam test piece, the elastic distortion is measured, from which Young's modulus may be calculated according to thin-beam equations.

4.2 Apparatus

4.2.1 Test jig

capable of three-point or four-point flexure.

The test jig shall be in accordance with that described in EN 843-1 in terms of its function, i.e. the support and loading rollers shall be free to roll, and to articulate to ensure axial and even loading.

NOTE 1 Articulation is not essential for carefully machined flat and parallel-faced test pieces.

The outer span of the test jig shall be 40 mm or greater.

NOTE 2 If the availability of test material allows, a span of at least 100 mm is recommended to obtain large displacements and to ensure that the compliance of the machine is a small correction if displacement is recorded as a machine cross-head movement.

The test jig shall be for four-point flexure, if displacement is determined by strain gauges or differential transducer.

4.2.2 Test machine

capable of applying a force to the test jig at a constant displacement rate. The test machine shall be equipped for recording the load applied to the test jig at any point in time. The accuracy of the test machine shall be in accordance with EN ISO 7500-1, Grade 1 (1 % of indicated load), and shall be capable of recording to a sensitivity of ≤ 0,1 % of the maximum load employed. The calibration shall have been checked within the previous year.

4.2.3 Displacement or strain measuring device

4.2.3.1 General

Equipment shall be installed to measure the displacement or strain of the loaded test piece by one of three methods, in accordance with 4.2.3.2, 4.2.3.3 or 4.2.3.4.

4.2.3.2 Method A.1

A facility is designed to measure the apparent displacements of the test machine with the test piece (Figure 1 a)), and with the test piece replaced by a steel or ceramic bar at least 15 mm thick. The difference between these displacements is equivalent to the displacement of the test piece in the test jig. The displacement recording device shall be calibrated by comparing machine cross-head displacement with the movement indicated on a dial gauge or other displacement measuring device (see 4.2.5) contacting the cross-head.

4.2.3.3 Method A.2

A facility is designed to measure the displacement of the test piece directly using transducers contacting two defined points on the surface of the test piece between the support loading rollers in three-point or four-point bending (Figure 1 b)). The defined points shall be the centre of the span and one or both loading rollers in four-point bending, or the centre of the span and one or both support rollers in three-point bending. The transducer shall be capable of detecting movements with an accuracy of 0,001 mm, shall have output linear to 0,01 % and shall be calibrated to an accuracy of 0,1 %.

4.2.3.4 Method A.3

A facility is designed to record the strain on the surface of the test piece by using a strain gauge placed on the surface of the test piece between the central loading rollers in four-point bending (Figure 1 c)). The strain gauge and its associated bridge circuit shall have an accuracy of better than 0,1 % and shall be capable of resolving a strain of less than 10^{-5}.

NOTE It is recommended that the strain gauge should only be applied by experienced personnel in order to ensure it performs accurately. It is also recommended that two or more gauges are fitted and their outputs recorded simultaneously in order to provide a check on reproducibility.

4.2.4 Micrometer

in accordance with ISO 3611, but capable of recording to 0,002 mm, or other device of equivalent accuracy, for measuring the dimensions of the test piece.

4.2.5 Dial gauge

in accordance with EN ISO 463 or other calibrated displacement measuring device, capable of recording to 0,01 mm.

4.3 Test pieces

Test pieces shall be rectangular section bars selected and prepared by agreement between parties. They may be directly prepared close to final dimensions or machined from larger blocks. This test measures Young's modulus parallel to the length of the test piece. If the test material is likely to be elastically anisotropic, care shall be taken in selection of the test piece orientation and in the interpretation of the test results. The maximum grain size (see EN 623-3), excluding deliberately added whiskers, shall be less than 10 % of the minimum dimension of the test piece.

The length of the test pieces shall be at least 10 mm longer than the test-jig span. The width of the test piece shall be in the range 4 mm to 10 mm. For Method A.1 (4.2.3.2), the thickness of the test piece shall be in the range 0,8 mm to 1,5 mm. For methods A.2 (4.2.3.3) and A.3 (4.2.3.4), the test piece may be up to 3 mm thick. The test pieces shall be machined to final dimensions. They shall be flat and parallel-faced to better than ± 0,5 % of thickness on the faces to be placed on the loading rollers of the test-jig. They shall similarly be machined flat and parallel-faced to better than ± 0,5 % of width on the side faces. For Method A.1 they shall not be chamfered.

NOTE For methods 2 and 3 they can be chamfered as specified in EN 843-1.

At least three test pieces shall be prepared.

4.4 Procedure

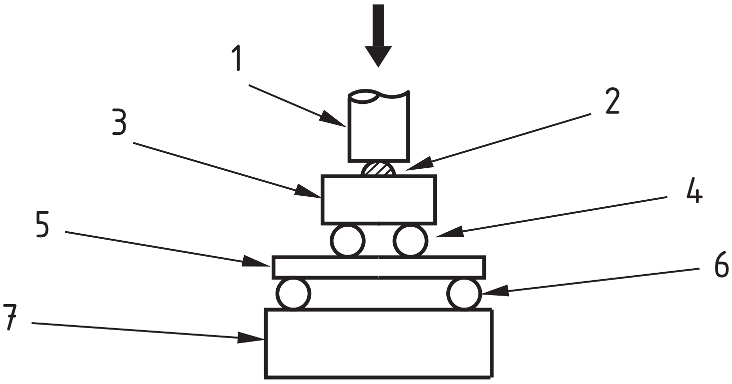
Measure the width and thickness of the test pieces at several places and record the average values.

Insert a test piece in the test-jig and centralize it in accordance with the requirements of EN 843-1. Select a maximum force to be applied to the test piece which will avoid fracture.

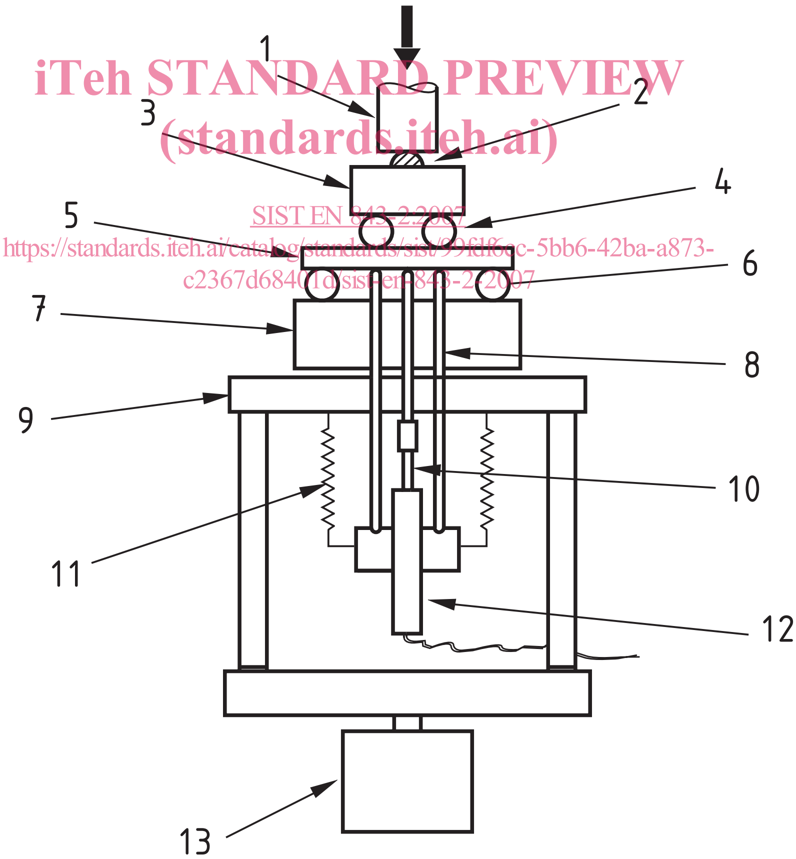
NOTE 1 The upper level of force can be estimated by employing the strength calculation in EN 843-1:2006, Clause 8 and inserting a stress level of no more than $0,5\sigma_f$, where σ_f is the mean fracture stress.

Apply a steadily increasing force to the test jig at a constant test machine cross-head displacement rate in the range 0,001 mm/min to 0,5 mm/min. Record the load and displacement (either cross-head displacement (Method A.1, 4.2.3.2), transducer displacement (Method A.2, 4.2.3.3), or strain gauge output (Method A.3, 4.2.3.4)) continuously. When the maximum selected force is achieved, reverse the direction of the machine and reduce the load to zero. Repeat the cycle at least twice more to the same peak load, or until repeatable results are obtained. Repeat the test on each test piece. If the machine displacement is to be employed (Method A.1) or if the transducer method is employed using a support roller as one of the defined points (Method A.2), replace the test piece with the thick parallel-sided steel or ceramic bar and repeat the loading cycles to the same peak load, recording load and displacement.

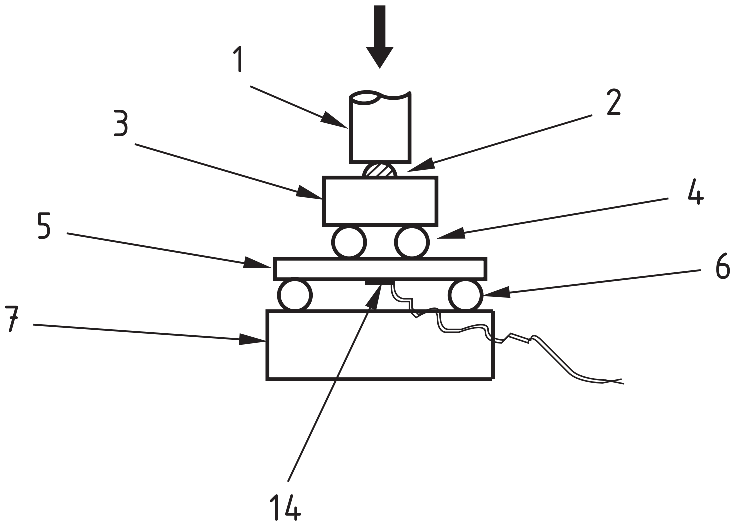
NOTE 2 The use of both loading and unloading cycles is required in order to take into account machine hysteresis in Method A.1, transducer hysteresis in Method A.2 and to test strain gauge adhesion in Method A.3.



a) Method A.1, using machine displacement



b) Method A.2, using a displacement transducer



c) Method A.3, using a strain gauge

Key

1	push-rod or top platen	8	rods detecting deflection
2	metallic half-sphere	9	support frame
3	metallic loading block	10	adjusting screw
4	loading rollers (freely rolling)	11	suspension springs
5	test piece	12	displacement transducer
6	support rollers (freely rolling)	13	load cell
7	support block	14	strain gauge

Figure 1 — Methods of measuring displacement or strain in quasi-statically loaded flexural test pieces, a) Method A.1 using machine displacement, b) Method A.2 using a displacement transducer and c) Method A.3 using a strain gauge

4.5 Calculations

4.5.1 From cross-head displacement (Method A.1)

Inspect the recordings of load and displacement for the test piece and the thick steel or ceramic bar for uniformity and linearity. Select a region of the recordings from a minimum load of not less than 10 % of peak load or 0,2 N, whichever is the greater, to a maximum load of not more than 90 % of the peak load applied. The same load range shall be selected for each loading cycle on the test piece and the thick bar.

NOTE 1 The region of the recordings selected should avoid strong non-linearities at low load which may include irreproducible effects of machine movement and test piece alignment and also the effects of cross-head reversal near peak load.

Calculate or measure the displacement recorded over the selected load range for each loading and unloading cycle for the test piece and for the thick bar. Calculate the average displacement in each direction. If the displacement of the first cycle is more than 2 % different from that of the second or subsequent cycle, ignore the first cycle when computing the average.

NOTE 2 The first cycle may show a different response to subsequent cycles as the test piece beds down into the test jig and the machine movement stabilises.

Calculate Young's modulus according to the following equations:

For displacement of loading points in three-point bending:

$$E = \frac{(F_2 - F_1)l^3}{4bh^3(d_c - d_s)} \tag{1}$$

For displacement of loading points in four-point bending:

$$E = \frac{2(F_2 - F_1)d_1^2(d_1 + 3d_2)}{bh^3(d_c - d_s)} \tag{2}$$

where

E is the Young's modulus expressed in newtons per square metre (N m^{-2}) or pascals (Pa);

F_1 is the lower load level selected from recordings, expressed in newtons (N);

F_2 is the upper load level selected from recordings, expressed in newtons (N);

l is the test jig outer span in three-point or four-point bending, expressed in metres (m);

d_1 is the test jig inner roller to outer roller spacing in four-point bending, expressed in metres (m);

d_2 is the one half of the test jig inner span in four-point bending, expressed in metres (m);

b is the test piece width, expressed in metres (m);

h is the test piece thickness, expressed in metres (m);

d_c is the displacement recorded for the test piece in the jig over load interval F_1 to F_2, expressed in metres (m);

d_s is the displacement recorded for the thick bar in the jig over load interval F_1 to F_2, expressed in metres.