SLOVENSKI STANDARD
SIST ENV 843-2:2000

01-december-2000

Advanced technical ceramics - Monolithic ceramics - Mechanical properties at room temperature - Part 2: Determination of elastic moduli

Advanced technical ceramics - Monolithic ceramics - Mechanical properties at room temperature - Part 2: Determination of elastic moduli

Hochleistungskeramik - Monolithische Keramik - Mechanische Eigenschaften bei Raumtemperatur - Teil 2: Bestimmung des E-Moduls

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Céramiques techniques avancées - Céramiques monolithiques - Propriétés mécaniques a température ambiante - Partie 2: Détermination des caractéristiques élastiques

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ICS:

81.060.99	Drugi standardi v zvezi s keramiko	Other standards related to ceramics

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2003-01.Slovenski inštitut za standardizacijo. Razmnoževanje celote ali delov tega standarda ni dovoljeno.

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EUROPEAN PRESTANDARD

PRÉNORME EUROPÉENNE

EUROPÄISCHE VORNORM

ENV 843-2

December 1995

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Descriptors: ceramics, technical ceramics, environmental tests, mechanical properties, determination, modulus of elasticity

English version

Advanced technical ceramics - Monolithic ceramics - Mechanical properties at room temperature - Part 2: Determination of elastic moduli

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CEN

European Committee for Standardization
Comité Européen de Normalisation
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Foreword

This European prestandard has been prepared by CEN/TC184 "Advanced technical ceramics", of which the Secretariat is held by BSI.

EN 843 consists of four Parts

Part 1 : Determination of flexural strength

Part 2 : Determination of elastic moduli (ENV)

Part 3 : Determination of subcritical crack growth parameters (ENV)

Part 4 : Determination of hardness (ENV)

CEN/TC184 approved this European prestandard by its resolution 2 during its sixth meeting, held in Alkmaar on 1992-09-30.

In accordance with the CEN/CENELEC Internal regulations, the following countries are bound to announce this European prestandard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK.

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1 Scope

This Part of EN 843 describes methods for determining the elastic moduli, specifically Young's modulus, shear modulus and Poisson's ratio, of advanced monolithic technical ceramics at room temperature. The prestandard 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 bending.

- 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).

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All the test methods assume the use of homogeneous test pieces of linear elastic 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. At high porosity levels all of the methods may become inappropriate. 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.

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2 Normative references

This European prestandard 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 revision 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 the publication referred to applies.

EN 623-2	Advanced technical ceramics - Monolithic ceramics : General and textural properties - Part 2: Determination of density and porosity
ENV 623-3	Advanced technical ceramics - Monolithic ceramics : General and textural properties - Part 3: Determination of grain size
ENV 623-4	Advanced technical ceramics - Monolithic ceramics : General and textural properties - Part 4: Determination of surface roughness

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EN 843-1	Advanced technical ceramics - Monolithic ceramics - Mechanical properties at room temperature - Part 1: Determination of flexural strength
EN 10002-2	Metallic materials -Tensile testing of metallic materials - Part 2 : Verification of the force measuring system of the tensile testing machine
EN 45001	General criteria for the operation of testing laboratories
ISO/R 463	Dial gauges reading in 0,01 mm, 0,001 in, and 0,0001 in.
ISO 3611	Micrometer callipers for external measurement
ISO 6906	Vernier callipers reading to 0,02 mm.

3 Definitions

For the purposes of this prestandard, the following definitions apply:

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

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3.2 Shear modulus : The shear stress required in a material to produce unit angular distortion.

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3.3 Poisson's ratio : The 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 an isothermal condition by stressing statically or quasistatically.

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

4 Method A: Static bending method

4.1 Summary of method

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

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4.2 Apparatus

4.2.1 Test jig, 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 : A span of 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 may be either for three-point or four-point flexure. The latter method is required if displacement is determined by strain gauges or differential transducer.

4.2.2 Mechanical testing 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 10 002-2, Grade 1 (1% of indicated load), and shall be capable of recording to a sensitivity of better than 0,1% of the maximum load employed. The calibration shall have recently been checked.

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4.2.3 The displacement of the loaded test piece shall be measured by one of three methods:

- **Method 1.** Recording the apparent displacements of the test machine with the test piece, 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 (see 4.2.5) contacting the cross-head.

- **Method 2.** Recording the displacement of the test piece directly using a transducer contacting two defined points on the surface of the test piece between the support loading rollers in three-point or four-point bending. 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%.

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- **Method 3.** Recording 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. The strain gauge and its associated bridge circuit shall have an accuracy of better than 0,1%, and 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 : 1978, capable of recording to 0,01 mm.

4.2.5 Dial gauge, in accordance with ISO R/463 : 1965 or other suitable 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 must be taken in selection of the test piece orientation and in the interpretation of the test results.

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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 1, the thickness of the test piece shall be in the range 0,8 to 1,5 mm. For methods 2 and 3, 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 1 they shall not be chamfered. For methods 2 and 3 they may be chamfered as specified in EN 843-1.

At least three test pieces shall be prepared.

4.4 Test method

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 centralise 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 may be estimated by employing the strength calculation in EN 843-1, and inserting a stress level of no more than $0{,}5\sigma_f$, where σ_f is the mean fracture stress.

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Apply a steadily increasing force to the test jig at a constant test machine cross-head displacement rate in the range 0,001 to 0,5 mm/min. Record the load and displacement (either cross-head displacement, transducer displacement or strain gauge output) 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 1) or if the transducer method is employed using a support roller as one of the defined points (Method 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 1, transducer hysteresis in Method 2, and to test strain gauge adhesion in Method 3.

4.5 Calculation of results

4.5.1 From cross-head displacement (Method 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.

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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.

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Calculate Young's modulus according to the following formulae:

For displacement of loading points in three-point bending:

$$E = \frac{(P_2 - P_1)l^3}{4ab^3(d_c - d_s)} \quad (1)$$

For displacement of loading points in four-point bending:

$$E = \frac{2(P_2 - P_1)d_1^2(d_1 + 3d_2)}{ab^3(d_c - d_s)} \quad (2)$$

where:

E = Young's modulus expressed as Newtons per square metre;
P_1 = Lower load level selected from recordings, expressed in Newtons;
P_2 = upper load level selected from recordings, expressed in Newtons;
l = test jig outer span in three-point or four-point bending, expressed in metres;
d_1 = test jig inner roller to outer roller spacing in four-point bending, expressed in metres;
d_2 = one half of the test jig inner span in four-point bending, expressed in metres;
a = test piece width, expressed in metres;
b = test piece thickness, expressed in metres;
d_c = displacement recorded for the test piece in the jig over load interval P_1 to P_2, expressed in metres;
d_s = displacement recorded for the thick bar in the jig over load interval P_1 to P_2, expressed in metres.

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NOTE 3 : For the case of quarter-point bending, $d_1 = d_2$, and Equation 2 reduces to:

$$E = \frac{(P_2 - P_1)l^3}{8ab^3(d_c - d_s)} \quad (2A)$$

Calculate the average Young's modulus figures for the loading and unloading curves. If these values differ by more than 2%, repeat the tests. If they differ by less than 2%, take the overall average as the determined value from the test.

4.5.2 From transducer displacement measurements (method 2)

Use the procedure defined in 4.5.1 to obtain displacements for a defined load range. If one of the defined points for the transducer contact in three-point bending is the support roller, calculate the displacement recorded for the thick bar. Subtract the mean value of the thick bar displacement from the mean specimen displacement over the same load range for both loading and unloading.