SLOVENSKI STANDARD
kSIST prEN 820-5:2009

01-marec-2009

Sodobna tehniļ na keramika - Termomehanske lastnosti monolitske keramike - 5. del: Ugotavljanje elastiļ nih modulov pri poviģanih temperaturah

Advanced technical ceramics - Thermomechanical properties of monolithic ceramics - Part 5: Determination of elastic moduli at elevated temperatures

Hochleistungskeramik - Thermomechanische Eigenschaften monolithischer Keramik - Teil 5: Bestimmung der elastischen Moduln bei erhöhten Temperaturen

Céramiques techniques avancées - Propriétés thermomécaniques des céramiques monolithiques - Partie 5 : Détermination des modules élastiques à température élevées

Ta slovenski standard je istoveten z: **prEN 820-5**

ICS:

81.060.30	Sodobna keramika	Advanced ceramics

kSIST prEN 820-5:2009 **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

FINAL DRAFT
prEN 820-5

December 2008

ICS 81.060.30

Will supersede CEN/TS 820-5:2004

English Version

Advanced technical ceramics - Thermomechanical properties of monolithic ceramics - Part 5: Determination of elastic moduli at elevated temperatures

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Ref. No. prEN 820-5:2008: E

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Foreword

This document (prEN 820-5:2008) has been prepared by Technical Committee CEN/TC 184 “Advanced technical ceramics”, the secretariat of which is held by BSI.

This document is currently submitted to the Unique Acceptance Procedure.

This document will supersede CEN/TS 820-5:2004.

EN 820 consists of five parts, under the general title "Advanced technical ceramics - Methods of testing monolithic ceramics - Thermomechanical properties":

Part 1: Determination of flexural strength at elevated temperatures;

Part 2: Determination of self-loaded deformation;

Part 3: Determination of resistance to thermal shock by water quenching;

Part 4: Determination of flexural creep deformation at elevated temperatures;

Part 5: Determination of elastic moduli at elevated temperatures.

1 Scope

This part of EN 820 describes methods for determining the elastic moduli, specifically Young's modulus, shear modulus and Poisson's ratio, of advanced monolithic technical ceramics at temperatures above room temperature. The standard prescribes three 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 from the fundamental natural frequency of a struck bar (impulse excitation method).

This part of EN 820 extends the above-defined room-temperature methods described in EN 843-2 to elevated temperatures. All the test methods assume the use of homogeneous test pieces of linear elastic materials. The test assumes that the test piece has isotropic elastic properties. At high porosity levels all of the methods can become inappropriate. The maximum grain size (see EN 623-3), excluding deliberately added whiskers, should be less than 10 % of the minimum dimension of the test piece.

NOTE 1 Method C in EN 843-2 based on ultrasonic time of flight measurement has not been incorporated into this part of EN 820. Although the method is feasible to apply, it is specialised, and outside the capabilities of most laboratories. There are also severe restrictions on test piece geometries and methods of achieving pulse transmission. For these reasons this method has not been included in EN 820-5.

NOTE 2 The upper temperature limit for this test depends on the properties of the test pieces, and can be limited by softening within the timescale of the test. In addition, for method A there can be limits defined by the choice of test jig construction materials.

NOTE 3 Methods B and C may not be appropriate for materials with significant levels of porosity (i.e. > 15 %) which cause damping and an inability to detect resonances or natural frequencies, respectively.

NOTE 4 This method does not provide for the effects of thermal expansion, i.e. the measurements are based on room temperature dimensions. Depending upon the use to which the data are put, it can be necessary to make a further correction by multiplying each dimensional factor in the relevant equations by a factor $(1 + \overline{\alpha}\,\Delta T)$ where $\overline{\alpha}$ is the mean linear expansion coefficient over the temperature interval ΔT from room temperature.

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 820-1, *Advanced technical ceramics — Method of testing monolithic ceramics — Thermo-mechanical properties — Part 1: Determination of flexural strength at elevated temperatures*

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

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

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 part of EN 820, the following terms and definitions 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 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 Principle

Using three- 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.

4.2 Apparatus

4.2.1 *Test jig*, in accordance with that described in EN 820-1 for flexural strength testing at elevated temperatures 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 as described in EN 843-1. The test jig shall be made of materials which do not interact with the test piece and which remain essentially elastic at the maximum test temperature. A typical arrangement is shown in Figure 1.

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 displacement is to be measured by method 1 (see 4.2.5), a span of up to 100 mm, or a span to thickness ratio in excess of 20, 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 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 ISO 7500-1, 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.

4.2.3 *Thermal enclosure and control system*, surrounding the test piece, capable of achieving the maximum desired temperature and maintaining it to ± 2 °C for test temperatures up to 1 000 °C, and ± 4 °C at higher temperatures.

NOTE The system can operate with an air or inert atmosphere, or with a vacuum inside the thermal enclosure. Especially with regard to use in vacuum, efforts should be made to ensure that the force applied at the test piece is correctly recorded by the load cell outside the enclosure, taking account of friction or elastic resistances in seals or bellows systems.

4.2.4 *Thermocouple*, conforming to EN 60584-2 for measuring the test piece temperature. The thermocouple shall be in close proximity to but shall not touch the test piece.

4.2.5 *Displacement measuring device*, for recording the displacement of the loaded test piece by one of two methods:

Method 1 Recording the apparent displacements of the test machine as the test piece is loaded in the test jig, and again with the test piece replaced by a ceramic bar at least 15 mm thick with flat and parallel faces to within 0,05 mm. The difference between these displacements is equivalent to the displacement of the test piece in the test jig. The displacement recording device (chart recorder, digital indicator, etc.) shall be calibrated by comparing machine cross-head displacement with the movement indicated on a dial gauge contacting the cross-head, or other suitable calibrated displacement measuring device. The dial gauge shall be in accordance with ISO 463, or the alternative device otherwise certified as accurate to 0,01 mm.

The parts of the load train subjected to elevated temperatures shall be made of materials which remain elastic at the maximum test temperature.

Method 2 Recording the displacement of the test piece directly using a transducer extensometer contacting at least 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 preferably be:

- for four-point bending: the centre of the span and one or both loading rollers (see for example Figure 1, right);
- for three-point bending: the centre of the span and one or both support rollers (see for example Figure 1, left).

NOTE The equations given in 4.5 assume these preferred positions. Other displacement detection positions require alternative formulations.

The transducer shall be capable of detecting movements with an accuracy of 0,001 mm, shall have output linear to 1 % over the expected displacement range in making this test and its sensitivity shall be calibrated to an accuracy of 0,1 %.