SLOVENSKI STANDARD
SIST EN 14186:2009

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Nadomeġļ a:
SIST ENV 14186:2007

Sodobna tehniļ na keramika - Mehanske lastnosti keramiļ nih kompozitov pri sobni temperaturi - Doloļ anje upogibnih lastnosti z ultrazvoļ no tehniko

Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Determination of elastic properties by an ultrasonic technique

Hochleistungskeramik - Mechanische Eigenschaften keramischer Verbundwerkstoffe bei Raumtemperatur - Bestimmung von elastischen Eigenschaften mittels Ultraschallwellen

Céramiques techniques avancées - Propriétés mécaniques des céramiques composites à température ambiante - Détermination des propriétés élastiques par une méthode ultrasonore

Ta slovenski standard je istoveten z: **EN 14186:2007**

ICS:

81.060.30	Sodobna keramika	Advanced ceramics

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English Version

Advanced technical ceramics - Mechanical properties of ceramic composites at room temperature - Determination of elastic properties by an ultrasonic technique

Céramiques techniques avancées - Propriétés mécaniques des céramiques composites à température ambiante - Détermination des propriétés élastiques par une méthode ultrasonore

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

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Contents

Foreword

This document (EN 14186:2007) 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of an identical text or by endorsement, at the latest by May 2008, and conflicting national standards shall be withdrawn at the latest by May 2008.

This document supersedes ENV 14186:2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, 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 European Standard specifies an ultrasonic method to determine the components of the elasticity tensor of ceramic matrix composite materials at room temperature. Young's moduli, shear moduli and Poisson coefficients, can be determined from the components of the elasticity tensor.

This European Standard applies to ceramic matrix composites with a continuous fibre reinforcement: unidirectional (1D), bidirectional (2D), and tridirectional (×D, with 2 < × ≤ 3) which have at least orthotropic symmetry, and whose material symmetry axes are known.

This method is applicable only when the ultrasonic wave length used is larger than the thickness of the representative elementary volume, thus imposing an upper limit to the frequency range of the transducers used.

NOTE Properties obtained by this method might not be comparable with moduli obtained by EN 658-1, EN 658-2 and EN 12289.

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 1389, *Advanced technical ceramics — Ceramic composites — Physical properties — Determination of density and apparent porosity*

CEN/TR 13233:2007, *Advanced technical ceramics — Notations and symbols*

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

ISO 3611, *Micrometer callipers for external measurements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CEN/TR 13233:2007 and the following apply.

3.1
stress-strain relations for orthotropic material

elastic anisotropic behaviour of a solid homogeneous body described by the elasticity tensor of fourth order C_{ijkl}, represented in the contracted notation by a symmetrical square matrix (6 × 6)

NOTE 1 If the material has at least orthotropic symmetry, its elastic behaviour is fully characterised by nine independent stiffness components C_{ij}, of the stiffness matrix (C_{ij}), which relates stresses to strains, or equivalently by nine independent compliance components S_{ij} of the compliance matrix (S_{ij}), which relates strains to stresses. The stiffness and compliance matrices are the inverse of each other.

If the reference coordinate system is chosen along the axes of symmetry, the stiffness matrix C_{ij} and the compliance matrix S_{ij} can be written as follows:

$$\begin{bmatrix}\sigma_1\\\sigma_2\\\sigma_3\\\sigma_4\\\sigma_5\\\sigma_6\end{bmatrix}=\begin{bmatrix}C_{11} & C_{12} & C_{13} & 0 & 0 & 0\\C_{12} & C_{22} & C_{23} & 0 & 0 & 0\\C_{13} & C_{23} & C_{33} & 0 & 0 & 0\\0 & 0 & 0 & C_{44} & 0 & 0\\0 & 0 & 0 & 0 & C_{55} & 0\\0 & 0 & 0 & 0 & 0 & C_{66}\end{bmatrix}\begin{bmatrix}\varepsilon_1\\\varepsilon_2\\\varepsilon_3\\\varepsilon_4\\\varepsilon_5\\\varepsilon_6\end{bmatrix}$$

$$\begin{bmatrix}\varepsilon_1\\\varepsilon_2\\\varepsilon_3\\\varepsilon_4\\\varepsilon_5\\\varepsilon_6\end{bmatrix}=\begin{bmatrix}S_{11} & S_{12} & S_{13} & 0 & 0 & 0\\S_{12} & S_{22} & S_{23} & 0 & 0 & 0\\S_{13} & S_{23} & S_{33} & 0 & 0 & 0\\0 & 0 & 0 & S_{44} & 0 & 0\\0 & 0 & 0 & 0 & S_{55} & 0\\0 & 0 & 0 & 0 & 0 & S_{66}\end{bmatrix}\begin{bmatrix}\sigma_1\\\sigma_2\\\sigma_3\\\sigma_4\\\sigma_5\\\sigma_6\end{bmatrix}$$

NOTE 2 For symmetries of higher level than the orthotropic symmetry, the C_{ij} and S_{ij} matrices have the same form as here above. Only the number of independent components reduces.

3.2
engineering constants

compliance matrix components of an orthotropic material which are in terms of engineering constants:

$$\left[S_{\mathrm{ij}}\right]=\begin{bmatrix}\frac{1}{E_{11}} & -\frac{\nu_{21}}{E_{22}} & -\frac{\nu_{31}}{E_{33}} & 0 & 0 & 0\\-\frac{\nu_{12}}{E_{11}} & \frac{1}{E_{22}} & -\frac{\nu_{32}}{E_{33}} & 0 & 0 & 0\\-\frac{\nu_{13}}{E_{11}} & -\frac{\nu_{23}}{E_{22}} & \frac{1}{E_{33}} & 0 & 0 & 0\\0 & 0 & 0 & \frac{1}{G_{13}} & 0 & 0\\0 & 0 & 0 & 0 & 0 & \frac{1}{G_{12}}\end{bmatrix}$$

where

E_{11}, E_{22} and E_{33}	are the elastic moduli in directions 1, 2 and 3 respectively;
G_{12}, G_{13} and G_{23}	are the shear moduli in the corresponding planes;
ν_{12}, ν_{13}, ν_{23}	are the respective Poisson coefficients

3.3
angle of incidence

θ_{i}

angle between the direction 3 normal to the test specimen front face and the direction n_i of the incident wave (see Figure 1 and Figure 2)

3.4
refracted angle
θ_i
angle between the direction 3 normal to the test specimen front face and the direction n of propagation of the wave inside the test specimen (see Figure 1 and Figure 2)

3.5
azimuthal angle
ψ
angle between the plane of incidence (3, n_i) and plane (2, 3) where n_i corresponds to the vector oriented along the incident plane wave and direction 2 corresponds to one of the axes of symmetry of the material (see Figure 1)

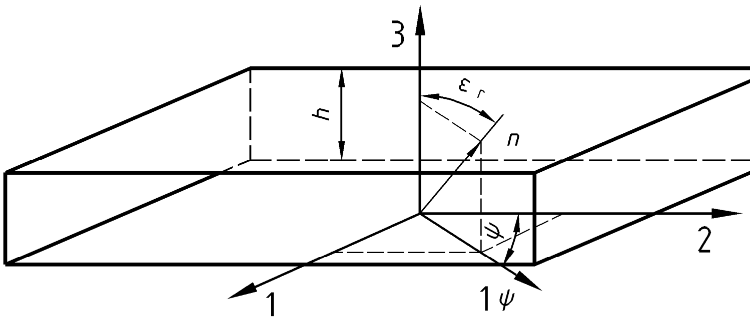


Figure 1 — Definition of the angles

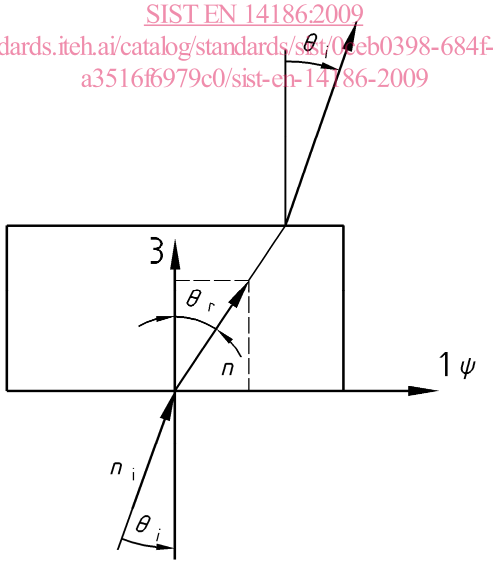


Figure 2 — Propagation in the plane of incidence

3.6
unit vector

n

unit vector oriented along the propagation direction of the incident plane wave inside the specimen, with its components n_k (k = 1, 2, 3) (see Figure 1 and Figure 2):

$n_1 = \sin\theta_r \sin\psi$

$n_2 = \sin\theta_r \cos\psi$

$n_3 = \cos\theta_r$

3.7
propagation velocity

V(n)

phase velocity of a plane wave inside the specimen in dependence on unit vector n (i.e. in dependence on ψ and θ_i)

NOTE V_o is the propagation velocity in the coupling fluid.

3.8
delay

δt(n)

difference between the flight time of the wave when the test specimen is in place and the flight time of the wave in the coupling fluid with the test specimen removed under the same configuration of the transducers in dependence on unit vector n

3.9
thickness of the test specimen

h

thickness of the test specimen

3.10
bulk density

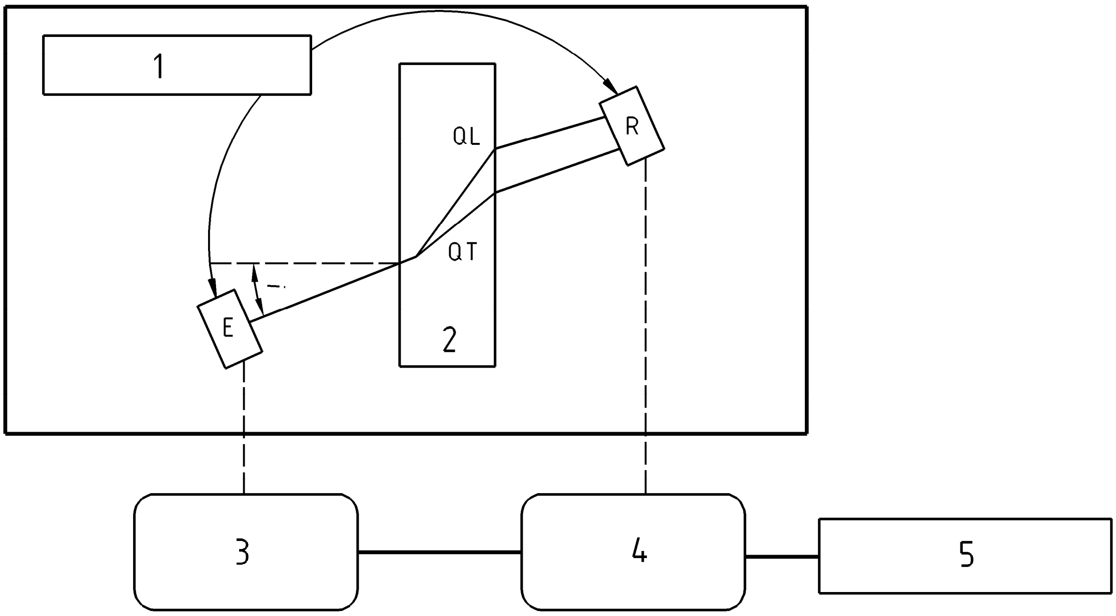
ρ_b

bulk density of the specimen

4 Principle

The determination of the elastic properties consists of calculating the coefficients of the propagation equation of an elastic plane wave, from a set of properly chosen velocity measurements along known directions.

A thin specimen with plane parallel faces is immersed in an acoustically coupling fluid (e.g. water): see Figure 3. The specimen is placed between an emitter (E) and a receiver (R), which are rigidly connected to each other and have two rotational degrees of freedom. Using appropriate signal processing, the propagation velocities of each wave in the specimen are calculated.



Key

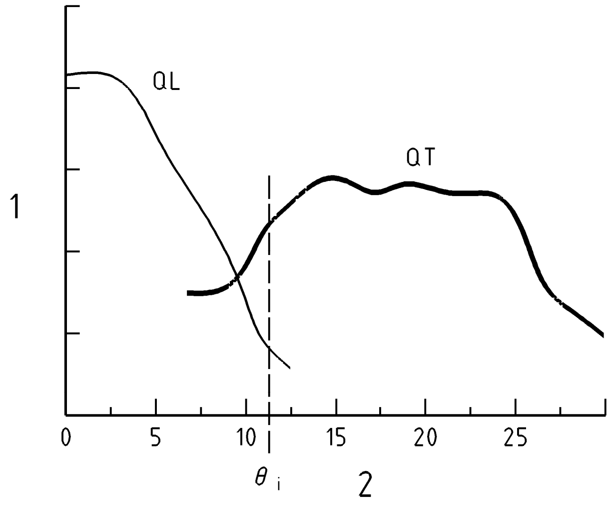
1	rotation drive
2	test specimen
3	pulse generator
4	digital oscilloscope
5	micro-computer

Figure 3 — Ultrasonic test assembly

Depending on the angle of incidence, the pulse sent by the emitter E is refracted within the material in one, two or three bulk waves (one quasi longitudinal wave QL, one quasi transverse wave QT, or two quasi transverse waves QT_1, QT_2) that propagate in the solid at different velocities and in different directions.

The receiver R collects one, two or three pulses, corresponding to each of these waves.

The difference in propagation time of each of the waves and the propagation time of the emitted pulse in the coupling fluid without the specimen is measured. The evaluation procedure is based on the measurement of the time difference of the quasi-longitudinal and one or both quasi-transverse waves, and is only valid when the QL and the QT waves are appropriately separated (see Figure 4).

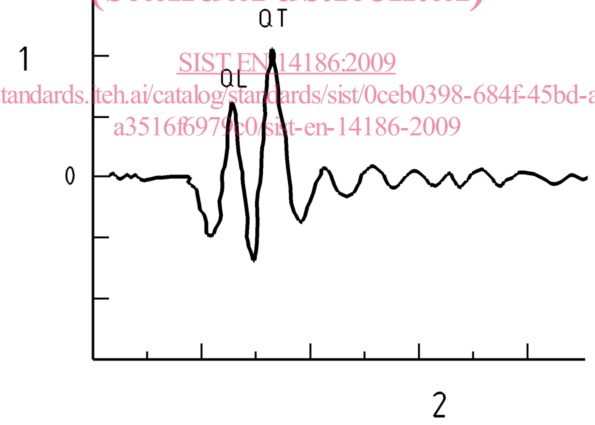


Key

1 amplitude

2 incidence angle

Figure 4a) — Amplitude of the QL and QT waves as a function of the incidence angle



Key

1 amplitude

2 time

Figure 4b) — Temporal waveform of the overlapping QL and QT waves at an incidence angle θ_i

Figure 4 — Overlapping of QL and QT waves at an incidence angle θ_i

From the propagation velocities the components of the elasticity tensor are obtained through a least square regression analysis which minimises the residuals of the wave propagation equations.

Young's moduli, shear moduli and Poisson coefficients are determined from these components.