SLOVENSKI STANDARD

SIST ENV 14186:2007

01-januar-2007

Sodobna tehniļ na keramika - Keramiļ ni kompoziti - Mehanske lastnosti pri sobni temperaturi, doloļ anje upogibnih lastnosti z ultrazvoļ no tehniko

Advanced technical ceramics - Ceramic composites - Mechanical properties at room temperature, determination of elastic properties by an ultrasonic technique

Céramiques techniques avancées - Céramiques composites - Propriétés mécaniques a température ambiante, détermination des propriétés élastiques par une méthode ultrasonore

Ta slovenski standard je istoveten z: ENV 14186:2002

ICS:

81.060.30	Sodobna keramika	Advanced ceramics

SIST ENV 14186:2007 **en**

EUROPEAN PRESTANDARD

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EUROPÄISCHE VORNORM

ENV 14186

August 2002

ICS 81.060.30

English version

Advanced technical ceramics - Ceramic composites - Mechanical properties at room temperature, determination of elastic properties by an ultrasonic technique

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

This European Prestandard (ENV) was approved by CEN on 13 July 2001 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

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

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Contents

Foreword

This document (ENV 14186:2002) 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, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This ENV specifies an ultrasonic method to determine the components of the elasticity tensor of ceramic matrix composite materials at room temperature. Young moduli, shear moduli and Poisson coefficients, can be determined from the components of the elasticity tensor.

This standard applies to ceramic matrix composites with a continuous fibre reinforcement: unidirectional (1D), bidirectional (2D), and tridirectional (xD, with $2< x \leq 3$) 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 may not be comparable with moduli obtained by EN 658-1, ENV 658-2 and ENV 12289.

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 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 the publication referred to applies.

ENV 1389, *Advanced technical ceramics – Composite ceramics – Physical properties – Determination of density and of apparent porosity.*

ENV 13233:1998, *Advanced technical ceramics – Composite ceramics – Notations and symbols.*

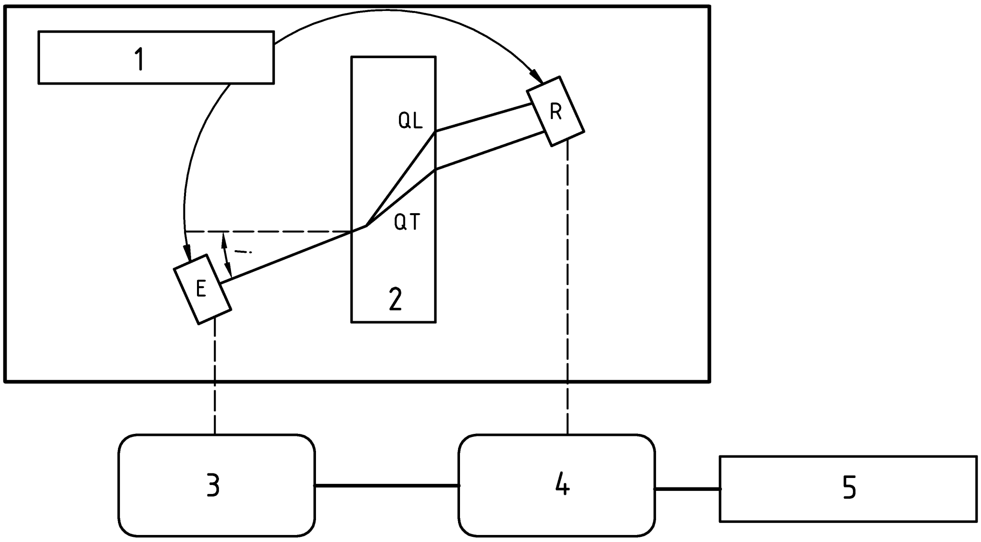
ISO 3611, *Micrometer callipers for external measurements.*

ISO 653, *Long-solid-stem thermometers for precision use.*

3 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 planparallel faces is immersed in an acoustically coupling fluid (e.g. water) – see Figure 1. 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.

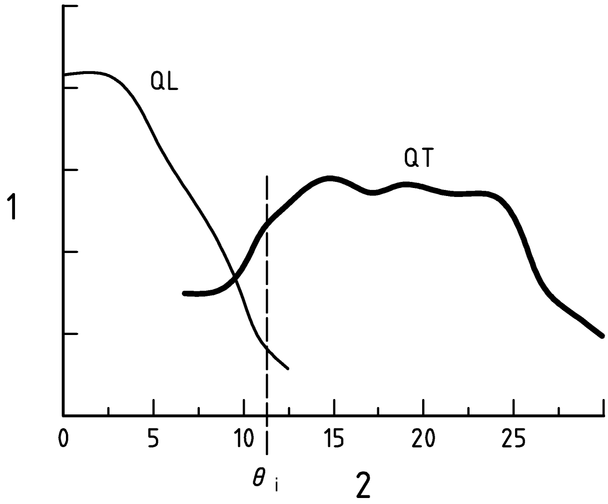


Key

1	Rotation drive
2	Test specimen
3	Pulse generator
4	Digital Oscilloscope
5	Micro-computer

Figure 1 — 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 quasilongitudinal and one or both quasitransverse waves, and is only valid when the QL and the QT waves are appropriately separated (see Figure 2).

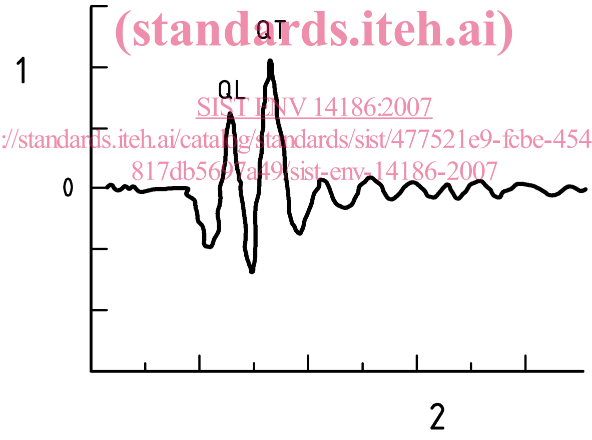


Key

1 Amplitude

2 Incidence angle

Figure 2a) — Amplitude of the QL and QT waves as a function of the incidence angle



Key

1 Amplitude

2 Time

Figure 2b) — Temporal waveform of the overlapping QL and QT waves at an incidence angle θ_i

Figure 2 — 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 moduli, shear moduli and Poisson coefficients are determined from these components.

4 Significance and use

Only two constants (Lamé's coefficients or Young modulus and Poisson coefficient) are sufficient in order to fully describe the elastic behaviour of an isotropic body. When anisotropy, which is a specific feature of composite materials, has to be taken into account, the use of an elasticity tensor with a larger number of independent coefficients is needed. While conventional mechanical methods allow only a partial identification of the elasticity of anisotropic bodies, ultrasonic techniques allow a more exhaustive evaluation of the elastic properties of these materials particularly transverse elastic moduli and shear moduli for thin specimens.

Successful application of the method critically depends on an appropriate selection of the central frequency of the transducers. Frequency has to be sufficiently low for the measurement to be representative of the elementary volume response but at the same time high enough to achieve a separation between the QL and the QT waves.

Contrary to mechanical test methods, the determination of elastic properties by the ultrasonic method described here is not based on the evaluation of the stress-strain response over a given deformation range obtained under quasi static loading conditions, but is based on a non-destructive dynamic measurement of wave propagation velocities. Therefore the values of Young moduli, shear moduli and Poisson ratios determined by the two methods may not be comparable, particularly for ceramic matrix composites which exhibit non linear stress-strain behaviour.

NOTE Mechanical test methods are based on a measurement performed under isothermal conditions, whereas the ultrasonic method assumes adiabatic conditions.

In addition to the ultrasonic method described here, there also exist other non destructive methods to determine the elastic properties, for instance the resonant beam technique and the impulse excitation method. Each of these has its relative merits and disadvantages; the selection of a particular non destructive method has to be considered on a case by case basis.

5 Terms and definitions and symbol

For the purposes of this European Prestandard, the terms and definitions and symbols given in EN 13233 and the following apply.

5.1
stress-strain relations for orthotropic material

the elastic anisotropic behaviour of a solid homogeneous body can be described by the elasticity tensor of fourth order C_{ijkl}, represented in the contracted notation by a symmetrical square matrix (6 × 6). If the material has at least orthotropic symmetry, its elastic behaviour is fully characterised by 9 independent stiffness components C_{ij}, of the stiffness matrix (C_{ij}), which relates stresses to strains, or equivalently by 9 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 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.

5.2
engineering constants

the compliance matrix components of an orthotropic material are in terms of the 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.

5.3
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 Figures 3 and 4)

5.4

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 Figures 3 and 4)

5.5

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 3)

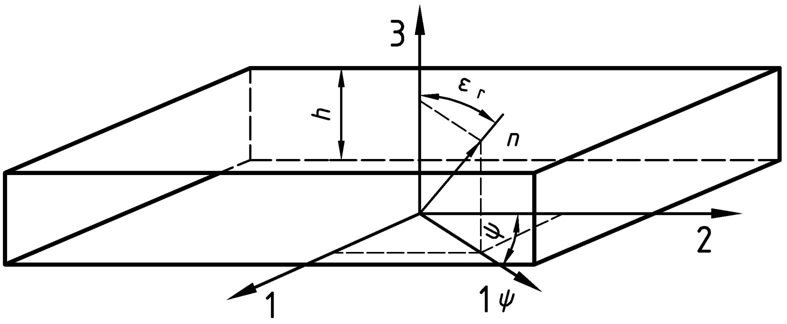


Figure 3 — Definition of the angles

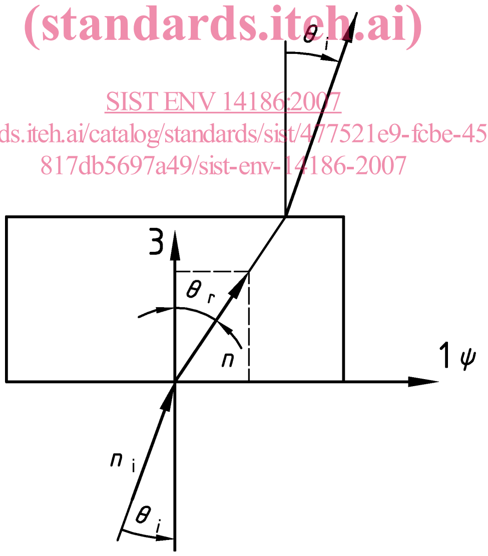


Figure 4 — Propagation in the plane of incidence

5.6

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); $n_1 = \sin\theta_r \sin\psi$, $n_2 = \sin\theta_r \cos\psi$, $n_3 = \cos\theta_r$, (see Figures 3 and 4)

5.7

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)

V_o is the propagation velocity in the coupling fluid.