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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at ambient temperature in air atmospheric pressure — Determination of elastic properties by ultrasonic technique

Céramiques techniques (céramiques avancées, céramiques techniques avancées) — Propriétés mécaniques des céramiques composites à température ambiante sous air à pression atmosphérique — Détermination des propriétés élastiques par méthode ultrasonore

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The committee responsible for this document is ISO/TC 206, *Fine ceramics*.

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Mechanical properties of ceramic composites at ambient temperature in air atmospheric pressure — Determination of elastic properties by ultrasonic technique

1 Scope

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

This method is applicable only when the ultrasonic wavelength 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 ISO 15733, ISO 20504 and EN 12289.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 3611, *Geometrical product specifications (GPS) — Dimensional measuring equipment: Micrometers for external measurements — Design and metrological characteristics*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

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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 to entry: If the material has at least orthotropic symmetry, its elastic behaviour is fully characterized 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 to entry: 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:

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

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.

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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

Note 1 to entry: See Figures 1 and 2.

3.4
refracted angle
θ_r
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

Note 1 to entry: See Figures 1 and 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

Note 1 to entry: See Figure 1.

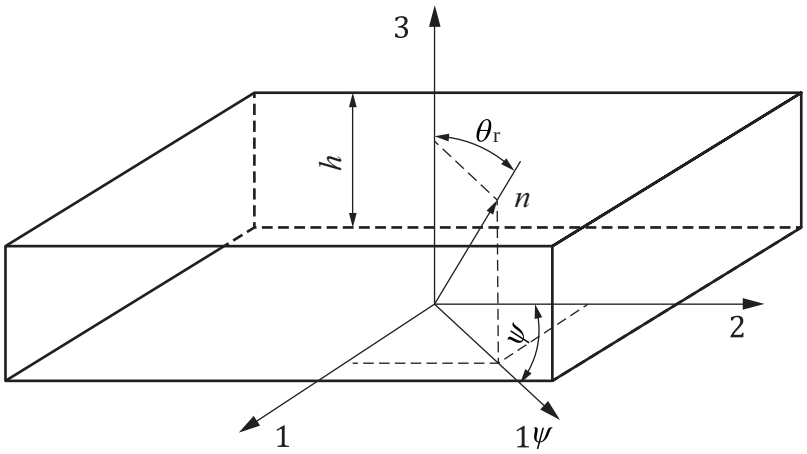


Figure 1 — Definition of angles

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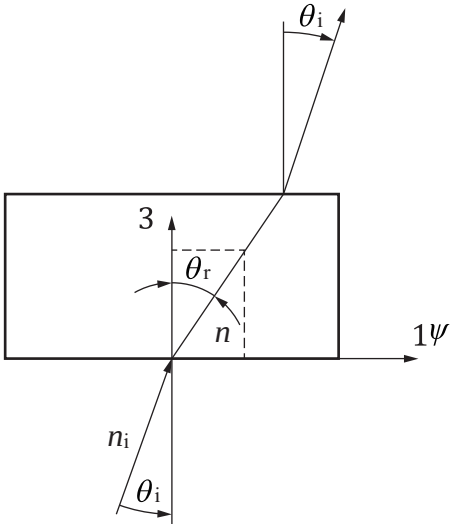


Figure 2 — Propagation in the plane of incidence

3.6
first critical angle
θ_c
angle of incidence θ_i that provides an angle of refraction of 90 degrees of the quasi longitudinal wave angle

3.7
unit vector
n
vector of length 1 oriented along the propagation direction of the incident plane wave inside the specimen, with its components n_k (k = 1, 2, 3):

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

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

$$n_3 = \cos\theta_r$$

Note 1 to entry: See Figures 1 and 2.

3.8
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_r)

Note 1 to entry: V_o is the propagation velocity in the coupling fluid.

3.9
delay
$\delta t(n)$
difference between the time-of-flight of the wave when the test specimen is in place and the time-of-flight of the wave in the coupling fluid with the test specimen removed under the same configuration of the probes in dependence on unit vector n

3.10
bulk density
ρ
ratio of the mass of the material without porosity to its total volume including porosity

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