INTERNATIONAL STANDARD

ISO 17561

First edition
2002-03-01

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance

Céramiques techniques — Méthode d'essai des modules d'élasticité des céramiques monolithiques, à température ambiante, par résonance acoustique

Reference number
ISO 17561:2002(E)

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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
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Printed in Switzerland

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17561 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance

1 Scope

This International Standard describes the method of test for determining the dynamic elastic moduli of fine ceramics at room temperature by sonic resonance. This International Standard is for fine ceramics that are elastic, homogeneous and isotropic.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 International Standard, the following terms and definitions apply.

3.1
dynamic elastic moduli
adiabatic elastic moduli, which are dynamic Young's modulus, shear modulus and Poisson's ratio

NOTE Adiabatic elastic moduli are obtained by the sonic resonance method.

3.1.1
Young's modulus (E)
elastic modulus in tension or compression

$$E = \sigma / \varepsilon$$

where

E is Young's modulus in pascals;

σ is the tension or compression stress in pascals;

ε is the tension or compression strain.

3.1.2
shear modulus (G)
elastic modulus in shear or torsion

$$G = \tau / \gamma$$

where

G is the shear modulus in pascals;

τ is the shear or torsional stress in pascals;

γ is the shear or torsional strain.

3.1.3
Poisson's ratio (ν)
ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material

NOTE In isotropic materials, Young's modulus (E), shear modulus (G) and Poisson's ratio (ν) are related by the following equation:

$$\nu = E/(2G) - 1$$

3.2
Vibrations

3.2.1
flexural vibrations
those vibrations apparent when the oscillation in a slender bar is in plane normal to the length dimension

NOTE Also defined as vibrations in a flexural mode.

3.2.2
torsional vibrations
those vibrations apparent when the oscillation in each cross-section plane of a slender bar is such that the plane twists around the length dimension axis

NOTE Also defined as vibrations in a torsional mode.

3.3
resonance
the state if, when a slender bar driven into one of the above modes of vibration, the imposed frequency is such that the resultant displacements for a given amount of driving force are at a maximum

NOTE The resonant frequencies are natural vibration frequencies which are determined by the elastic modulus, mass and dimensions of the test piece.

4 Summary of test method

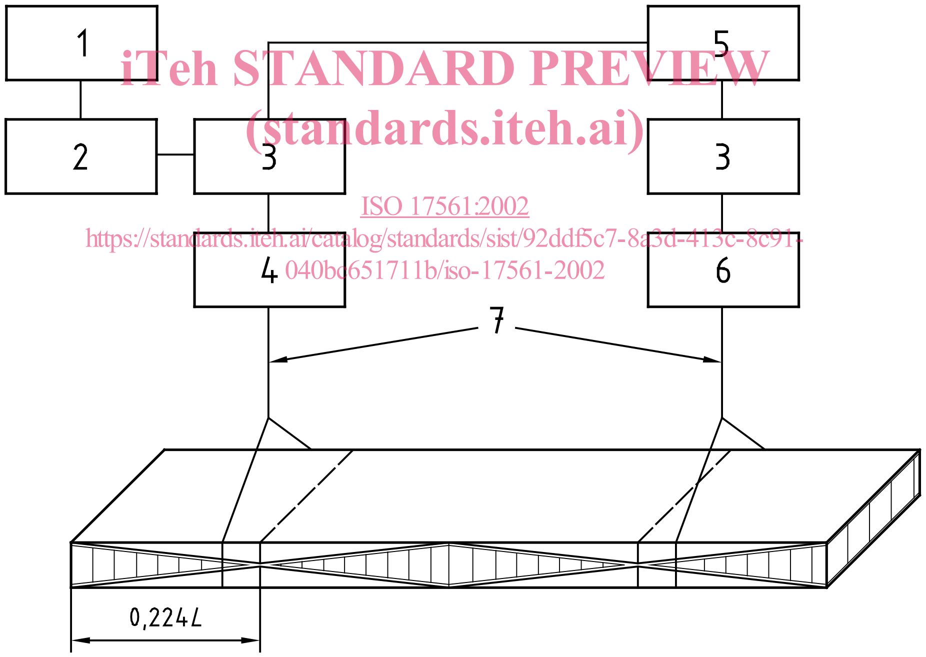
This test method measures the flexural or torsional frequencies of test specimens of rectangular prism or cylindrical geometry by exciting them at continuously variable frequencies. Mechanical excitation of the specimens is provided through the use of a transducer that transforms a cyclic electrical signal into a cyclic mechanical force on the test piece. A second transducer senses the resulting mechanical vibrations of the test piece and transforms them into an electrical signal. The amplitude and the frequency of the signal are measured by an oscilloscope or other means to detect resonance. The peak response is obtained at the resonant frequency. The fundamental resonant frequencies, dimensions and mass of the specimen are used to calculate the dynamic elastic moduli. The Young's modulus is determined from the flexural resonance frequency, and the shear modulus is determined from the torsional resonance frequency, together with the test piece dimensions and mass. Poisson's ratio is determined from the Young's modulus and the shear modulus.

5 Apparatus

5.1 General

There are various techniques that may be used to determine the resonant frequency of the test piece. The test piece may be excited by direct mechanical contact of a vibrator, or it may be suspended by a wire from a vibrator. It may be driven electromagnetically by attaching thin foils of magnetic material to one surface, or electrostatically by attaching an electrode to one surface.

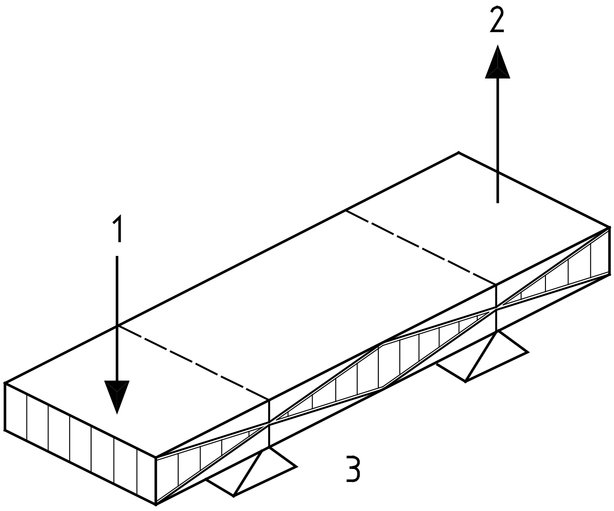
One example of the test apparatus is shown in Figure 1. The driving circuit consists of an oscillator, an amplifier, a driver and a frequency counter. The detecting circuit consists of a detector, an amplifier and an oscilloscope. Figure 1 shows the suspension style of the apparatus. The direct contact support style of the test apparatus, shown in Figure 2, is also possible. It consists of a variable-frequency audio oscillator, used to generate a sinusoidal voltage, and a power amplifier and suitable transducer to convert the electrical signal to a mechanical driving vibration. A frequency meter (preferably digital) monitors the audio oscillator output to provide accurate frequency determination. A suitable suspension coupling system supports the test piece. A transducer detector acts to detect mechanical vibration in the specimen and to convert it into an electrical signal which is passed through an amplifier and displayed on an indicating meter. The meter may be a voltmeter, a microammeter or an oscilloscope. An oscilloscope is recommended because it enables the operator to positively identify resonances, including higher order harmonics, by Lissajous figure analysis. If a Lissajous figure is desired, the output of the oscillator is also coupled to the horizontal plates of the oscilloscope.



Key

1 Frequency counter
2 Oscillator
3 Amplifier
4 Driver
5 Oscilloscope
6 Detector
7 Suspending string

Figure 1 — Example of the test apparatus and the suspension for fundamental flexural resonance



Key

1 Driving
2 Detecting
3 Flexural

Figure 2 — Example of the direct contact support of the test piece for fundamental flexural resonance

5.2 Oscillator

The oscillator shall be able to vary the frequency from 100 Hz to 20 kHz, with a frequency resolution of 1 Hz and a maximum frequency drift of 1 Hz/min.

5.3 Amplifier

The audio amplifier shall have a power output sufficient to ensure that the type of transducer used can excite any specimen the mass of which falls within a specified range. A power amplifier in the detector circuit shall be impedance-matched with the type of detector transducer selected and shall serve as a prescope amplifier.

5.4 Driver

The driver shall be able to convert electrical vibration to mechanical vibration. The frequency response of the driver transducer across the frequency range of interest shall have at least a 6,5 kHz bandwidth before – 3 dB power loss occurs.

NOTE For flexibility in testing, the bandwidth can, with advantage, be at least as large as the frequency range given in Table 1.

5.5 Detector

The detector shall generate a voltage proportional to the amplitude, velocity or acceleration of the mechanical vibration of the specimen. The frequency response of the detector across the frequency range of interest shall have at least a 6.5 kHz bandwidth before a – 3 dB power loss occurs.

NOTE For flexibility in testing, the bandwidth can, with advantage, be at least as large as the frequency range given in Table 1.

Table 1 — Examples of the test piece size and the calculated resonant frequencies

Where the density = 3 g/cm^3			
$L \times b\ (d) \times t$	E = 200 GPa ν = 0,25	E = 300 GPa ν = 0,25	E = 400 GPa ν = 0,25
75 × 15 × 3	f_f = 4 453 Hz f_t = 12 706 Hz	5 453 Hz 15 561 Hz	6 297 Hz 17 969 Hz
100 × 20 × 2	f_f = 1 676 Hz f_t = 5 016 Hz	2 053 Hz 6 143 Hz	2 371 Hz 7 094 Hz
75 × 20 × 2	f_f = 2 977 Hz f_t = 6 688 Hz	3 646 Hz 8 191 Hz	4 210 Hz 9 458 Hz
Where the density = 6 g/cm^3			
$L \times b\ (d) \times t$	E = 200 GPa ν = 0,25	E = 300 GPa ν = 0,25	E = 400 GPa ν = 0,25
75 × 15 × 3	f_f = 3 148 Hz f_t = 8 984 Hz	3 856 Hz 11 004 Hz	4 453 Hz 12 706 Hz
100 × 20 × 2	f_f = 1 185 Hz f_t = 3 547 Hz	1 452 Hz 4 344 Hz	1 676 Hz 5 016 Hz
75 × 20 × 2	f_f = 2 105 Hz f_t = 4 729 Hz	2 578 Hz 5 792 Hz	2 977 Hz 6 688 Hz

where

L is the length in millimetres;

b is the width in millimetres;

d is the diameter in millimetres;

t is the thickness in millimetres.

5.6 Frequency counter

The frequency counter, preferably digital, shall be able to measure frequencies to within ± 1 Hz.

5.7 Specimen suspension means

Any method of specimen support shall be used that permits the free vibration of the test piece with no significant effect on the vibration frequencies. Test pieces are commonly supported either by suspension from threads or wires, or on direct contact supports. If the test piece is to be supported from beneath, the support shall be made of rubber, cork or similar material, and shall have a minimum contact area with the test piece. If the test piece is suspended from the driving and detecting transducers, fine thread or metal wires shall be used. The vibrating mass of the suspension system shall have negligible mass compared with the mass of the test piece. For the electromagnetic or electrostatic method, the mass of any magnetic foil or electrode attached to the test piece shall be negligible compared with the mass of the test piece.

5.8 Micrometer

A micrometer with a resolution of 0,002 mm or 0,1 % of the specimen, in accordance with ISO 3611, shall be used to measure the thickness, width and diameter of the test piece. Alternative dimension measuring instruments may be used that have a resolution of 0,002 mm or finer.