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INTERNATIONAL

Designation: ~~C1259 – 15~~ C1259 – 21

Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Impulse Excitation of Vibration[1]

This standard is issued under the fixed designation C1259; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. ~~Scope~~ Scope*

1.1 This test method covers determination of the dynamic elastic properties of advanced ceramics at ambient temperatures. Specimens of these materials possess specific mechanical resonant frequencies that are determined by the elastic modulus, mass, and geometry of the test specimen. The dynamic elastic properties of a material can therefore be computed if the geometry, mass, and mechanical resonant frequencies of a suitable (rectangular, cylindrical, or disc geometry) test specimen of that material can be measured. The resonant frequencies in flexure and torsion are measured by excitation of vibrations of the test specimen in a supported mode by a singular elastic strike with an impulse tool (Section 4 and Fig. 1, Fig. 3, and Fig. 4). Dynamic Young's modulus is determined using the resonant frequency in the flexural mode of vibration. The dynamic shear modulus, or modulus of rigidity, is found using torsional resonant vibrations. Dynamic Young's modulus and dynamic shear modulus are used to compute Poisson's ratio.

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~~1.2 This test method measures the fundamental resonant frequency of test specimens of suitable geometry by exciting them mechanically by a singular elastic strike with an impulse tool. Specimen supports, impulse locations, and signal pick-up points are selected to induce and measure specific modes of the transient vibrations. A transducer (for example, contact accelerometer or non-contacting microphone) senses the resulting mechanical vibrations of the specimen and transforms them into electric signals. (See Fig. 1.) The transient signals are analyzed, and the fundamental resonant frequency is isolated and measured by the signal analyzer, which provides a numerical reading that is (or is proportional to) either the frequency or the period of the specimen vibration. The appropriate fundamental resonant frequencies, dimensions, and mass of the specimen are used to calculate dynamic Young's modulus, dynamic shear modulus, and Poisson's ratio.~~

[1] This test method is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.01 on Mechanical Properties and Performance.

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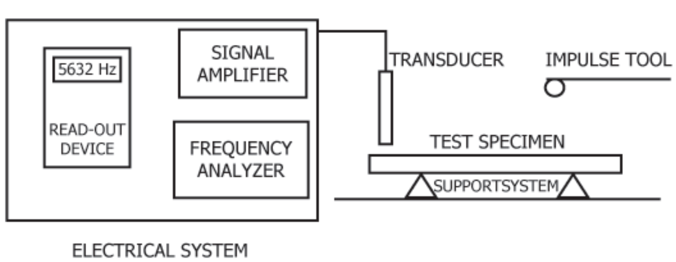

FIG. 1 Block Diagram of Typical Test Apparatus

***A Summary of Changes section appears at the end of this standard**

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1.2 Although not specifically described herein, this test method can also be performed at cryogenic and high temperatures with suitable equipment modifications and appropriate modifications to the calculations to compensate for thermal expansion, in accordance with ~~sections~~Subsections 9.2, 9.3, and 10.4 of Test Method C1198.

1.3 ~~Where possible, the procedures, sample specifications, and calculations in this test method are consistent with~~ There are material-specific ASTM standards that cover the determination of resonance frequencies and elastic properties of specific materials by sonic resonance or by impulse excitation of vibration. Test Methods C215, C623, C747, C848, C1198~~and~~, ~~C1198~~E1875~~.~~, and E1876 may differ from this test method in several areas (for example, sample size, dimensional tolerances, sample preparation, calculation details, etc.). The testing of those materials should be done in compliance with the appropriate material-specific standards. Where possible, the procedures, sample specifications, and calculations in this standard are consistent with the other test methods.

1.4 This test method uses test specimens in bar, rod, and disc geometries. The rod and bar geometries are described in the main body. The disc geometry is addressed in Annex A1.

1.5 A modification of this test method can be used for quality control and nondestructive evaluation, using changes in resonant frequency to detect variations in specimen geometry and mass and internal flaws in the specimen. (See 5.5~~).~~.)

1.6 The values stated in SI units are to be regarded as ~~the~~ standard. The non-SI unit values given in parentheses are for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

C215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens
C372 Test Method for Linear Thermal Expansion of Porcelain Enamel and Glaze Frits and Fired Ceramic Whiteware Products by Dilatometer Method
C623 Test Method for Young's Modulus, Shear Modulus, and Poisson's Ratio for Glass and Glass-Ceramics by Resonance
C747 Test Method for Moduli of Elasticity and Fundamental Frequencies of Carbon and Graphite Materials by Sonic Resonance
C848 Test Method for Young's Modulus, Shear Modulus, and Poisson's Ratio For Ceramic Whitewares by Resonance
C1145 Terminology of Advanced Ceramics
C1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature
C1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance
~~D4092 Terminology for Plastics: Dynamic Mechanical Properties~~
E6 Terminology Relating to Methods of Mechanical Testing
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E1875 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Sonic Resonance
E1876 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Impulse Excitation of Vibration
E2001 Guide for Resonant Ultrasound Spectroscopy for Defect Detection in Both Metallic and Non-metallic Parts

2.2 *ISO Standard:*[3]

ISO 14704 Test Method for Flexural Strength of Monolithic Ceramics at Room Temperatures

3. Terminology

3.1 *Definitions:*

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.1 The definitions of terms relating to mechanical testing appearing in Terminology E6 should be considered as applying to the terms used in this test method. The definitions of terms relating to advanced ceramics appearing in Terminology C1145 should be considered as applying to the terms used in this test method. Directly pertinent definitions as listed in Terminologies E6~~,~~ ~~C1145,~~ ~~and~~and C1145 ~~D4092~~are shown in the following paragraphs with the appropriate source given in brackets.

3.1.2 *advanced ceramic, n*—a highly engineered, high-performance, predominately nonmetallic, inorganic, ceramic material having specific functional attributes. **(C1145)**

3.1.3 *dynamic elastic modulus, n*—the elastic modulus, either Young's modulus or shear modulus, that is measured in a dynamic mechanical measurement. **(E1876)**

3.1.4 *dynamic mechanical measurement, n*—a technique in which either the modulus or damping, or both, of a substance under oscillatory load or displacement is measured as a function of temperature, frequency, or time, or combination thereof. **(~~D4092~~E1876)**

3.1.5 *elastic limit* [FL^{-2}],*n*—the greatest stress that a material is capable of sustaining without permanent strain remaining upon complete release of the stress. **(E6)**

3.1.6 *elastic modulus* [FL^{-2}~~]~~],~~,~~*n*—the ratio of stress to strain below the proportional limit. **(E6)**

3.1.7 *Poisson's ratio* (μ) [nd],*n*—the absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

3.1.7.1 *Discussion—*

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

$$\mu = (E/2G) - 1 \tag{1}$$

(E6)

3.1.8 *proportional limit* [FL^{-2}~~]~~],~~,~~*n*—the greatest stress that a material is capable of sustaining without deviation from proportionality of stress to strain (Hooke's law). **(E6)**

3.1.9 *shear modulus (G)* [FL^{-2}~~]~~],~~,~~*n*—the elastic modulus in shear or torsion. Also called modulus of rigidity or torsional modulus. **(E6)**

3.1.10 *Young's modulus (E)* [FL^{-2}~~]~~],~~,~~*n*—the elastic modulus in tension or compression. **(E6)**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *antinodes, n*—two or more locations that have local maximum displacements, called antinodes, in an unconstrained slender rod or bar in resonance. For the fundamental flexure resonance, the antinodes are located at the two ends and the center of the specimen.

3.2.2 *elastic, adj*—the property of a material such that an application of stress within the elastic limit of that material making up the body being stressed will cause an instantaneous and uniform deformation, which will be eliminated upon removal of the stress, with the body returning instantly to its original size and shape without energy loss. Most advanced ceramics conform to this definition well enough to make this resonance test valid.

3.2.3 *flexural vibrations, n*—the vibrations that occur when the displacements in a slender rod or bar are in a plane normal to the length dimension.

3.2.4 *homogeneous, adj*—the condition of a specimen such that the composition and density are uniform, so that any smaller specimen taken from the original is representative of the whole. Practically, as long as the geometrical dimensions of the test specimen are large with respect to the size of individual grains, crystals, components, pores, or microcracks, the body can be considered homogeneous.

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