



Designation: C747 – 23

Standard Test Method for Moduli of Elasticity and Fundamental Frequencies of Carbon and Graphite Materials by Sonic Resonance¹

This standard is issued under the fixed designation C747; 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*

1.1 This test method covers determination of the dynamic elastic properties of isotropic and near isotropic carbon and graphite materials 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 or cylindrical) test specimen of that material can be measured. Dynamic Young's modulus is determined using the resonant frequency in the flexural or longitudinal 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.

1.2 This test method determines elastic properties by measuring 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. **Annex A1** contains an alternative approach using continuous excitation.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

¹ This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.F0 on Manufactured Carbon and Graphite Products.

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1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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.*

2. Referenced Documents

2.1 ASTM Standards:²

- C215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens
- C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles
- C885 Test Method for Young's Modulus of Refractory Shapes by Sonic Resonance
- C1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature
- D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
- E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
- E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
- E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this test method, refer to Terminology D4175.

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.

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

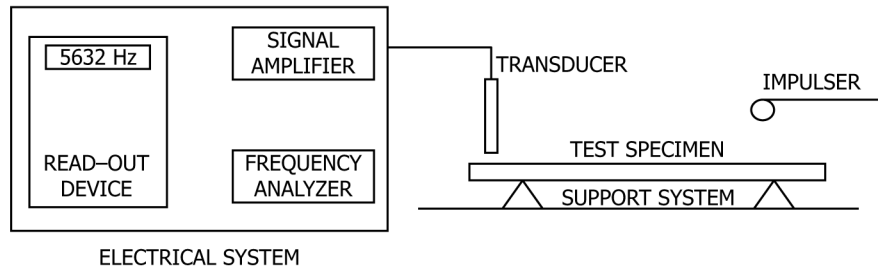


FIG. 1 Block Diagram of Typical Test Apparatus

3.1.2 *antinodes*, *n*—two or more locations that have local maximum displacements in an unconstrained slender rod or bar in resonance.

3.1.3 *elastic modulus*—the ratio of stress to strain, in the stress range where Hooke’s law is valid.

3.1.4 *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.

3.1.5 *homogeneous*, *adj*—in carbon and graphite technology, 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.

3.1.6 *in-plane flexure*, *n*—for rectangular parallelepiped geometries, a flexure mode in which the direction of displacement is in the major plane of the test specimen.

3.1.7 *isotropic*, *adj*—in carbon and graphite technology, having an isotropy ratio of 0.9 to 1.1 for a specific property of interest.

3.1.8 *longitudinal vibrations*—when the oscillations in a slender rod or bar are in a plane parallel to the length dimension, the vibrations are said to be in the longitudinal mode.

3.1.9 *nodes*, *n*—one or more locations in a slender rod or bar in resonance having a constant zero displacement. For the fundamental flexural resonance of such a rod or bar, the nodes are located at 0.224 *L* from each end, where *L* is the length of the specimen.

3.1.10 *out-of-plane flexure*, *n*—for rectangular parallelepiped geometries, a flexure mode in which the direction of displacement is perpendicular to the major plane of the test specimen.

3.1.11 *Poisson’s ratio* (μ), *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. Young’s Modulus (*E*), shear modulus (*G*), and Poisson’s ratio (μ) are related by the following equation:

$$\mu = (E / 2 G) - 1 \quad (1)$$

3.1.12 *resonant frequency*, *n*—naturally occurring frequencies of a body driven into flexural, torsional, or longitudinal vibration that are determined by the elastic modulus, mass, and

dimensions of the body. The lowest resonant frequency in a given vibrational mode is the fundamental resonant frequency of that mode.

3.1.13 *shear modulus*, *n*—the elastic modulus in shear or torsion, also called modulus of rigidity or torsional modulus.

3.1.14 *torsional vibrations*, *n*—the vibrations that occur when the oscillations in each cross-sectional plane of a slender rod or bar are such that the plane twists around the length dimension axis.

3.1.15 *transverse vibrations*, *n*—when the oscillations in a slender rod or bar are in a horizontal plane normal to the length dimension, the vibrations are said to be in the transverse mode; this mode is also commonly referred to as the flexural mode when the oscillations are in a vertical plane.

3.1.16 *Young’s modulus*, *n*—the elastic modulus in tension or compression.

4. Summary of Test Method

4.1 This test method measures the fundamental resonant frequency of test specimens of suitable geometry (bar or rod) by exciting them mechanically by a singular elastic strike with an impulse tool. A transducer (for example, contact accelerometer or non-contacting microphone) senses the resulting mechanical vibrations of the specimen and transforms them into electric signals. Specimen supports, impulse locations, and signal pick-up points are selected to induce and measure specific modes of the transient vibrations. The 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.

5. Significance and Use

5.1 This test method may be used for material development, characterization, design data generation, and quality control purposes.

5.2 This test method is primarily concerned with the room temperature determination of the dynamic moduli of elasticity and rigidity of slender rods or bars composed of homogeneously distributed carbon or graphite particles.

5.3 This test method can be adapted for other materials that are elastic in their initial stress-strain behavior, as defined in Test Method E111.