Standard Test Method for
Sonic Velocity in Manufactured Carbon and Graphite Materials for Use in Obtaining an Approximate Value of Young's Modulus[1]

This standard is issued under the fixed designation C769; 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 a procedure for measuring the sonic velocity in manufactured carbon and graphite which can be used to obtain an approximate value of Young's modulus.

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

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles

C747 Test Method for Moduli of Elasticity and Fundamental Frequencies of Carbon and Graphite Materials by Sonic Resonance

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI) (the Modern Metric System)

3. Terminology

3.1 *Definitions:*

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

3.1.2 *Young's modulus or modulus of elasticity (E), n*—the elastic modulus in tension or compression.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *end correction time (T_e)*—the non-zero time of flight (correction factor), measured in seconds, that may arise by extrapolation of the pulse travel time, corrected for zero time, back to zero sample length.

3.2.2 *longitudinal sonic pulse*—a sonic pulse in which the displacements are in the direction of propagation of the pulse.

3.2.3 *pulse travel time, (T_t)*—the total time, measured in seconds, required for the sonic pulse to traverse the specimen being tested, and for the associated electronic signals to traverse the transducer coupling medium and electronic circuits of the pulse-propagation system.

3.2.4 *zero time, (T_0)*—the travel time (correction factor), measured in seconds, associated with the transducer coupling medium and electronic circuits in the pulse-propagation system.

4. Summary of Test Method

4.1 The velocity of longitudinal sound waves passing through the test specimen is determined by measuring the distance through the specimen and dividing by the time lapse, between the transmitted pulse and the received pulse.[3,4] Provided the wavelength of the transmitted pulse is a sufficiently small fraction of the sample lateral dimensions, a value of Young's modulus for isotropic graphite can then be obtained using Eq 1 and Eq 2:

$$E = C_v \rho V^2 \tag{1}$$

where:

E = Young's modulus of elasticity, Pa,
ρ = density, kg/m^3,
V = longitudinal signal velocity, m/s, and
C_v = Poisson's factor.

The Poisson's factor, C_v, is related to Poisson's ratio, ν, by the equation:

$$C_v = \frac{(1+\nu)(1-2\nu)}{1-\nu} \tag{2}$$

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[3] Schreiber, Anderson, and Soga, *Elastic Constants and Their Measurement,* McGraw-Hill Book Co., 1221 Avenue of the Americas, New York, NY 10020, 1973.

[4] *American Institute of Physics Handbook* , 3rd ed., McGraw-Hill Book Co., 1221 Avenue of the Americas, New York, NY 10020, 1972, pp. 3–98ff.

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

If Poisson's ratio is unknown, it can be assumed as an approximation in the method. For nuclear graphites, a typical Poisson's ratio of 0.2 corresponds to a Poisson's factor of 0.9.

If the wavelength is not a small fraction of the sample lateral dimensions, and instead is much larger than the specimen lateral dimensions, then the Young's modulus, E is given by Eq 1 with C_v set to one rather than being determined by Eq 2.

5. Significance and Use

5.1 Sonic velocity measurements are useful for comparing materials with similar elastic properties, dimensions, and microstructure.

5.2 Eq 1 provides an accurate value of Young's modulus only for isotropic, non-attenuative, and non-dispersive materials of infinite dimensions. For non-isotropic graphite, Eq 1 can be modified to take into account the Poisson's ratios in all directions. As graphite is a strongly attenuative material, the value of Young's modulus obtained with Eq 1 will be dependent on specimen length. If the specimen lateral dimensions are not large compared to the wavelength of the propagated pulse, then the value of Young's modulus obtained with Eq 1 will be dependent on the specimen lateral dimensions. The accuracy of the Young's modulus calculated from Eq 1 will also depend upon the uncertainty in Poisson's ratio and its impact on the evaluation of the Poisson's factor in Eq 2. However, a value for Young's modulus can be obtained for many applications, which is often in good agreement with the value obtained by other more accurate methods, such as in Test Method C747. The technical issues and typical values of corresponding uncertainties are discussed in detail in STP 1578.[5]

5.3 If the grain size of the carbon or graphite is greater than or about equal to the wavelength of the sonic pulse, the method may not be providing a value of Young's modulus representative of the bulk material. Therefore, it would be recommended to test a lower frequency (longer wavelength) to demonstrate that the range of obtained velocity values are within an acceptable level of accuracy. Significant signal attenuation should be expected when the grain size of the material is greater than or about equal to the wavelength of the transmitted sonic pulse or the material is more porous than would be expected for an as-manufactured graphite.

NOTE 1—Due to frequency dependent attenuation in graphite, the wavelength of the sonic pulse through the test specimen is not necessarily the same as the wavelength of the transmitting transducer.

5.4 If the sample is only a few grains thick, the acceptability of the method's application should be demonstrated by initially performing measurements on a series of tests covering a range of sample lengths between the proposed test length and a test length incorporating sufficient grains to adequately represent the bulk material.

6. Apparatus

6.1 *Driving Circuit,* consisting of an ultrasonic pulse generator.

6.1.1 The user should select a pulse frequency to suit the material microstructure and specimen elastic properties and dimensions being tested. High frequencies are attenuated by carbon and graphite materials and, while typical practicable frequencies lie in the range 0.5 MHz to 2.6 MHz, the user may show that frequencies outside this range are acceptable.

6.2 *Transducer,* input, with suitable coupling medium (see 8.5).

6.3 *Transducer,* output, with suitable coupling medium (see 8.5).

6.3.1 The signal output will depend upon the characteristics of the chosen transducers and pulser-receiver and the test material. It is recommended that the user analyses the input and output frequency spectra to determine optimum conditions. Band pass filters and narrow band transducers may be used to simplify the signal output which could improve the measurement of the time of flight.

6.4 *Computer,* with analogue to digital converter, or oscilloscope, and external trigger from driving circuit.

6.5 See Fig. 1 for a typical schematic setup.

NOTE 2—Some manufacturers combine items 6.1 and 6.4 into a single package with direct time readout. Such apparatus can operate satisfactorily, provided the frequency of the propagated pulse is already known, in order to check that wavelength requirements for the method are satisfied.

7. Test Specimen

7.1 *Selection and Preparation of Specimens*—Take special care to assure obtaining representative specimens that are straight, uniform in cross section, and free of extraneous liquids. The specimen end faces shall be perpendicular to the specimen cylindrical surface to within 0.125 mm total indicator reading.

7.2 *Measurement of Weight and Dimensions*—Determine the weight and the average specimen dimensions to within $\pm 0.2\%$.

7.3 *Limitations on Dimensions*—These cannot be precisely specified as they will depend upon the properties of the material being tested and the experimental setup (for example, transducer frequency). In order to satisfy the theory that supports Eq 1, as a guide, the specimen should have a diameter that is at least a factor five, greater than the wavelength of sound in the material under test. In practice, the length of the specimen will be determined taking account of the comments in 5.3 and 5.4.

7.4 *Limitations on Ultrasonic Pulse Frequency*—Generally speaking, a better accuracy of time of flight will be obtained at higher frequencies. However, attenuation increases at higher frequencies leading to weak and distorted signals.

8. Procedure

8.1 For any given apparatus and choice of coupling medium, it is necessary to follow procedures to quantify the zero time, T_0, and end correction time, T_e, correction factors. T_0 will be dependent upon the type of transducers and their performance over time and should be regularly checked (see