Designation: E1876 – 22

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

This standard is issued under the fixed designation E1876; 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 elastic 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 geometry) test specimen of that material can be measured. Dynamic Young's modulus is determined using the resonant frequency in either 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 Calculations are valid for materials that are elastic, homogeneous, and isotropic. Anisotropy can add additional calculation errors. See Appendix X1 for details.

1.3 The use of mixed numerical-experimental techniques (MNET) is outside the scope of this standard.

1.4 This test method may be used for determining dynamic Young's modulus for materials of a composite character (particulate, whisker or fiber reinforced) or other anisotropic materials only after the effect of the reinforcement in the test specimen has been considered. Examples of the characteristics of the reinforcement that can affect the measured dynamic Young's modulus are volume fraction, size, morphology, distribution, orientation, elastic properties, and interfacial bonding.

1.4.1 The effect of the character of the reinforcement shall be considered in interpreting the test results for these types of materials.

NOTE 1—The properties of the reinforcement will directly affect measured elastic properties. Data shown in (**1**)[2] indicates the possibility of underestimating the dynamic Young's modulus by as much as 20 % due to anisotropy

1.5 This test method should not be used for establishing accurate dynamic Young's modulus, dynamic shear modulus, or Poisson's ratio for specimens that have cracks, voids, or other major structural discontinuities.

1.6 This test method may be used for determining whether structural discontinuities exist in a specimen by comparing results with a specimen that is defect free.

1.7 This test method shall not be used for establishing accurate dynamic Young's modulus, dynamic shear modulus or Poisson's ratio for materials that cannot be fabricated in uniform rectangular or cylindrical cross section.

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

1.9 *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.*

1.10 *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:*[3]

C372 Test Method for Linear Thermal Expansion of Porcelain Enamel and Glaze Frits and Fired Ceramic Whiteware Products by Dilatometer Method

C1161 Test Method for Flexural Strength of Advanced

[1] This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] 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

Ceramics at Ambient Temperature
C1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance
E6 Terminology Relating to Methods of Mechanical Testing
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions of terms relating to mechanical testing appearing in Terminology E6 and C1198 should be considered as applying to the terms used in this test method.

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

3.1.3 *dynamic mechanical measurement, n*—a technique in which either the modulus or damping, or both, of a substance under oscillatory applied force or displacement is measured as a function of temperature, frequency, or time, or combination thereof.

3.1.4 *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**

3.1.5 *modulus of elasticity* [FL^{-2}], *n*—the ratio of stress to corresponding strain below the proportional limit.

3.1.5.1 *Discussion*—The stress-strain relationships of many materials do not conform to Hooke's law throughout the elastic range, but deviate therefrom even at stresses well below the elastic limit. For such materials, the slope of either the tangent to the stress-strain curve at the origin or at a low stress, the secant drawn from the origin to any specified point on the stress-strain curve, or the chord connecting any two specified points on the stress-strain curve is usually taken to be the "modulus of elasticity." In these cases, the modulus should be designated as the "tangent modulus," the "secant modulus," or the "chord modulus," and the point or points on the stress-strain curve described. Thus, for materials where the stress-strain relationship is curvilinear rather than linear, one of the four following terms may be used:

(a) initial tangent modulus [FL^{-2}], *n*—the slope of the stress-strain curve at the origin.

(b) tangent modulus [FL^{-2}], *n*—the slope of the stress-strain curve at any specified stress or strain.

(c) secant modulus [FL^{-2}], *n*—the slope of the secant drawn from the origin to any specified point on the stress-strain curve.

(d) chord modulus [FL^{-2}], *n*—the slope of the chord drawn between any two specified points on the stress-strain curve below the elastic limit of the material.

3.1.5.2 *Discussion*—Modulus of elasticity, like stress, is expressed in force per unit of area (pounds per square inch, etc.).

3.1.6 *Poisson's ratio,* μ, *n*—the negative of the ratio of transverse strain to the corresponding axial strain resulting from an axial stress below the proportional limit of the material.

3.1.6.1 *Discussion*—Poisson's ratio may be negative for some materials, for example, a tensile transverse strain will result from a tensile axial strain.

3.1.6.2 *Discussion*—Poisson's ratio will have more than one value if the material is not isotropic. **E6**

3.1.7 *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**

3.1.7.1 *Discussion*—Many experiments have shown that values observed for the proportional limit vary greatly with the sensitivity and accuracy of the testing equipment, eccentricity of loading, the scale to which the stress-strain diagram is plotted, and other factors. When determination of proportional limit is required, the procedure and the sensitivity of the test equipment should be specified.

3.1.8 *shear modulus, G* [FL^{-2}], *n*—the ratio of shear stress to corresponding shear strain below the proportional limit, also called *torsional modulus* and *modulus of rigidity*.

3.1.8.1 *Discussion*—The value of the shear modulus may depend on the direction in which it is measured if the material is not isotropic. Wood, many plastics and certain metals are markedly anisotropic. Deviations from isotropy should be suspected if the shear modulus differs from that determined by substituting independently measured values of Young's modulus, *E*, and Poisson's ratio, μ, in the relation:

$$G = \frac{E}{2(1+\mu)}$$

3.1.8.2 *Discussion*—In general, it is advisable in reporting values of shear modulus to state the range of stress over which it is measured. **E6**

3.1.9 *Young's modulus, E* [FL^{-2}], *n*—the ratio of tensile or compressive stress to corresponding strain below the proportional limit of the material. **E6**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *anti-nodes, n*—two or more locations in an unconstrained slender rod or bar in resonance that have local maximum displacements.

3.2.1.1 *Discussion*—For the fundamental flexure resonance, the anti-nodes 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 elastic materials conform to this definition well enough to make this resonance test valid.

3.2.3 *flexural vibrations, n*—the vibrations that occur when the oscillations 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 values of the elastic properties are uniform throughout, so that any smaller specimen taken from the original is representative of the whole.