Designation: C1332 – 18 (Reapproved 2023)

Standard Practice for Measurement of Ultrasonic Attenuation Coefficients of Advanced Ceramics by Pulse-Echo Contact Technique[1]

This standard is issued under the fixed designation C1332; 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 practice describes a procedure for measurement of ultrasonic attenuation coefficients for advanced structural ceramic materials. The procedure is based on a broadband buffered piezoelectric probe used in the pulse-echo contact mode and emitting either longitudinal or shear waves. The primary objective of this practice is materials characterization.

1.2 The procedure requires coupling an ultrasonic probe to the surface of a plate-like sample and the recovery of successive front surface and back surface echoes (refer to Fig. 3). Power spectra of the echoes are used to calculate the attenuation spectrum (attenuation coefficient as a function of ultrasonic frequency) for the sample material. The transducer bandwidth and spectral response are selected to cover a range of frequencies and corresponding wavelengths that interact with microstructural features of interest in solid test samples.

1.3 The purpose of this practice is to establish fundamental procedures for measurement of ultrasonic attenuation coefficients. These measurements should distinguish and quantify microstructural differences among solid samples and therefore help establish a reference database for comparing materials and calibrating ultrasonic attenuation measurement equipment.

1.4 This practice applies to monolithic ceramics and also polycrystalline metals. This practice may be applied to whisker reinforced ceramics, particulate toughened ceramics, and ceramic composites provided that similar constraints on sample size, shape, and finish are met as described herein for monolithic ceramics.

1.5 This practice sets forth the constraints on sample size, shape, and finish that will assure valid attenuation coefficient measurements. This practice also describes the instrumentation, methods, and data processing procedures for accomplishing the measurements.

1.6 This practice is not recommended for highly attenuating materials such as very thick, very porous, rough-surfaced monolithics or composites. This practice is not recommended for highly nonuniform, heterogeneous, cracked, defective, or otherwise flaw-ridden samples that are unrepresentative of the nature or inherent characteristics of the material under examination.

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, health, and 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1331 Practice for Measuring Ultrasonic Velocity in Advanced Ceramics with Broadband Pulse-Echo Cross-Correlation Method

E543 Specification for Agencies Performing Nondestructive Testing

E664/E664M Practice for the Measurement of the Apparent Attenuation of Longitudinal Ultrasonic Waves by Immersion Method

E1316 Terminology for Nondestructive Examinations

E1495/E1495M Guide for Acousto-Ultrasonic Assessment of Composites, Laminates, and Bonded Joints

2.2 *ASNT Documents:*[3]

Recommended Practice SNT-TC-1A for Nondestructive Testing Personnel Qualification and Certification

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

Current edition approved Dec. 1, 2023. Published December 2023. Originally approved in 1996. Last previous edition approved in 2018 as C1332 – 18. DOI: 10.1520/C1332-18R23.

[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 Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

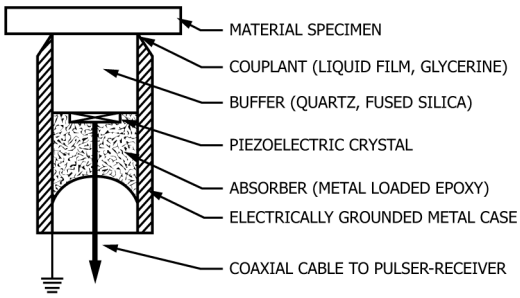

FIG. 1 Cross Section of Buffered Broadband Ultrasonic Probe

2.3 *ISO Standard:*

ISO 9712 Non-destructive Testing – Qualification and Certification of NDT Personnel[4]

2.4 *Aerospace Industries Association Document:*

NAS 410 Certification and Qualification of Nondestructive Testing Personnel[5]

2.5 *Additional references are cited in the text and at end of this practice.*

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *acoustic impedance (Z)*—a property (**1**)[6] defined by a material's density, p, and the velocity of sound within it, v, where $Z = \rho v$.

3.1.2 *attenuation coefficient (α)*—decrease in ultrasound intensity with distance expressed in nepers (Np) per unit length, herein, $\alpha = [\ln(I_0/I)]/d$, where α is attenuation coefficient, d is path length or distance, I_0 is original intensity, and I is attenuated intensity (**2**).

3.1.3 *attenuation spectrum*—the attenuation coefficient, α, expressed as a function of ultrasonic frequency, f, or plotted as α versus f, over a range of ultrasonic frequencies within the bandwidth of the transducer and associated pulser-receiver instrumentation.

3.1.4 *back surface*—the surface of a test sample which is opposite to the front surface and from which back surface echoes are returned at normal incidence directly to the transducer.

3.1.5 *bandwidth*—the frequency range of an ultrasonic probe, defined by convention as the difference between the lower and upper frequencies at which the signal amplitude is 6 dB down from the frequency at which maximum signal amplitude occurs. The frequency at which the maximum occurs is termed the *center frequency* of the probe or transducer.

3.1.6 *broadband transducer*—an ultrasonic transducer capable of sending and receiving undistorted signals over a broad bandwidth, consisting of thin damped piezoelectric crystal in a buffered probe (search unit).

3.1.7 *buffered probe*—an ultrasonic search unit as defined in Terminology E1316 but containing a delay line or buffer rod to which the piezoelement, that is, transducer consisting of a piezoelectric crystal, is affixed. The buffer rod separates the piezoelement from the test sample (see Fig. 1).

3.1.8 *buffer rod*—an integral part of a buffered probe or search unit, usually a quartz or fused silica cylinder that provides a time delay between the excitation pulse from the piezoelement and echoes returning from a sample coupled to the free end of the buffer rod.

3.1.9 *free surface*—the back surface of a solid test sample interfaced with a very low density medium, usually air or other gas, to assure that the back surface reflection coefficient equals 1 to a high degree of precision.

3.1.10 *frequency (f)*—number of oscillations per second of ultrasonic waves, measured in megahertz, MHz, herein.

3.1.11 *front surface*—the surface of a test sample to which the buffer rod is coupled at normal incidence (designated as test surface in Terminology E1316).

3.1.12 *inherent attenuation*—ultrasound energy loss in a solid as a result of scattering, diffusion, and absorption. This standard assumes that the dominant inherent losses are due to Rayleigh and stochastic scattering (**2**) by the material microstructure, for example, by grains, grain boundaries, and micropores. Measured ultrasound energy loss which, if not corrected, may include losses due to diffraction, individual macroflaws, surface roughness, couplant variations, and transducer defects.

3.1.13 *reflection coefficient (R)*—measure of relative intensity of sound waves reflected back into a material at an interface, defined in terms of the acoustic impedance of the material in which the sound wave originates (Z_0) and the acoustic impedance of the material interfaced with it (Z_i), where $R = [(Z_i - Z_0)/(Z_i + Z_0)]^2$.

3.1.14 *test sample*—a solid coupon or material part that meets the constraints needed to make the attenuation coefficient measurements described herein, that is, a test sample or part having flat, parallel, smooth, preferably ground/polished opposing (front and back) surfaces and having no discrete flaws or anomalies that are unrepresentative of the inherent properties of the material.

3.1.15 *transmission coefficient (T)*—measure of relative intensity of sound waves transmitted through an interface, defined in terms of the acoustic impedance of the material in which the sound wave originates (Z_0) and the acoustic impedance of the material interfaced with it (Z_i), where $T = (4Z_iZ_0)/(Z_i + Z_0)^2$ so that $R + T = 1$.

3.1.16 *wavelength (λ)*—distance that sound (of a particular frequency) travels during one period (during one oscillation), λ = v/f, where v is the velocity of sound in the material and where velocity is measured in cm/μs, and wavelength in cm, herein.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[5] Available from Aerospace Industries Association of America, Inc., 1250 Eye St. NW, Washington, DC, 20005.

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