Designation: E3370 – 23

Standard Practice for Matrix Array Ultrasonic Testing of Composites, Sandwich Core Constructions, and Metals[1]

This standard is issued under the fixed designation E3370; 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 covers procedures for matrix array ultrasonic testing (MAUT) of monolithic composites, composite sandwich constructions, and metallic test articles. These procedures can be used throughout the life cycle of a part during product and process design optimization, on line process control, post-manufacturing inspection, and in-service inspection.

1.2 In general, ultrasonic testing is a common volumetric method for detection of embedded or subsurface discontinuities. This practice includes general requirements and procedures which may be used for detecting flaws and for making a relative or approximate evaluation of the size of discontinuities and part anomalies. The types of flaws or discontinuities detected include interply delaminations, foreign object debris (FOD), inclusions, disbond/un-bond, fiber debonding, fiber fracture, porosity, voids, impact damage, thickness variation, and corrosion.

1.3 Typical test articles include monolithic composite layups such as uniaxial, cross ply and angle ply laminates, sandwich constructions, bonded structures, and filament windings, as well as forged, wrought and cast metallic parts. Two techniques can be considered based on accessibility of the inspection surface: namely, pulse echo inspection for one-sided access and through-transmission for two-sided access. As used in this practice, both require the use of a pulsed straight-beam ultrasonic longitudinal wave followed by observing indications of either the reflected (pulse-echo) or received (through transmission) wave.

1.4 This practice provides two ultrasonic test procedures. Each has its own merits and requirements for inspection and shall be selected as agreed upon in a contractual document.

1.4.1 *Test Procedure A, Pulse Echo (non-contacting and contacting)* is at a minimum a single matrix array transducer transmitting and receiving longitudinal waves in the range of 0.5 MHz to 20 MHz (see Fig. 1). This procedure requires access to only one side of the specimen. This procedure can be conducted by automated or manual means. Automated and manual test results may be analyzed in real time or recorded and analyzed later.

1.4.2 *Test Procedure B, Through Transmission (non-contacting and contacting)* is a combination of two transducers. One transmits a longitudinal wave and the other receives the longitudinal wave in the range of 0.5 MHz to 20 MHz (see Fig. 2). This procedure requires access to both sides of the specimen. Typically, the signal transmitting and signal receiving transducers are perpendicularly aligned with each other. This is normally achieved using a yoke transducer holder arrangement, which attaches the two transducers to a single point but deploys them on opposite sides of the structure. Through transmission inspections are also permitted without the use of a yoke transducer holder. This is due to the capacity for improved manual alignment via the matrix array transducers, whereby the live C-scan display enables visual confirmation of accurate alignment, and facilitates re-alignment if needed. This procedure can be conducted by automated or manual means. Automated and manual test results may be imaged or recorded.

1.5 Other contact methods such as angle-beam techniques using shear waves to characterize welds, or surface-beam techniques using Lamb waves to detect impact damage in composite panel structures are not covered.

1.6 This practice does not specify accept-reject criteria.

1.7 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.8 *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.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[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.

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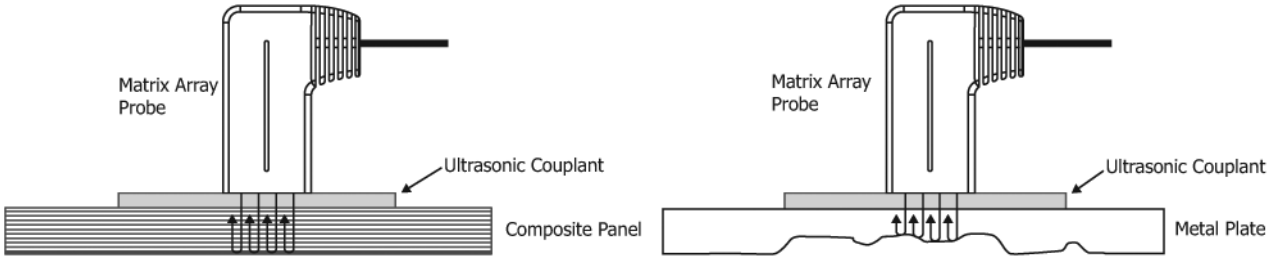

FIG. 1 Test Procedure A, Pulse Echo Apparatus Set-up for a Composite Panel (Left) and Metal Plate (Right) Using One-sided Access

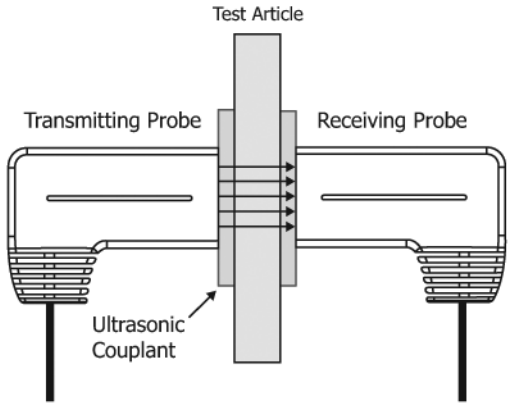

FIG. 2 Test Procedure B, Through Transmission Apparatus Set-up using Two-sided Access

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]

D3878 Terminology for Composite Materials

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E127 Practice for Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks

E494 Practice for Measuring Ultrasonic Velocity in Materials by Comparative Pulse-Echo Method

E543 Specification for Agencies Performing Nondestructive Testing

E797/E797M Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

E1001 Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves

E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases (Withdrawn 2015)[3]

E1901 Guide for Detection and Evaluation of Discontinuities by Contact Pulse-Echo Straight-Beam Ultrasonic Methods

E1316 Terminology for Nondestructive Examinations

E2375 Practice for Ultrasonic Testing of Wrought Products

E2491 Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems

E2580 Practice for Ultrasonic Testing of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications

2.2 *SAE Standards:*[4]

ARP 5605 Solid Composite Laminate NDI Reference Standards

ARP 5606 Composite Honeycomb NDI Reference Standards

ARP 5089 Composite Repair NDT/NDI Handbook

2.3 *AIA Standard:*[5]

NAS-410 NAS Certification & Qualification of Nondestructive Test Personnel

[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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[5] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

2.4 *ASNT Documents:*[6]

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

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

Nondestructive Testing Handbook, Ultrasonic Testing, 2nd Edition, Vol. 7

2.5 *ISO Standard:*[7]

ISO 9712 NDT–Qualification and Certification of NDT Personnel in the Applicable Product Sector "Aerospace"

2.6 *European Committee for Standardization Document:*[8]

EN 4179 Aerospace Series - Qualification and Approval of Personnel for Non-destructive Testing

2.7 *FAA Circular Advisory:*[9]

AC-65-31B Training, Qualification, and Certification of Nondestructive Inspection Personnel

2.8 *MIL Document:*[10]

MIL-HDBK-1823 Nondestructive Evaluation System Reliability Assessment

3. Terminology

3.1 *Definitions*—Terminology in accordance with Terminologies E1316 and D3878 shall be used where applicable.

3.2 *Definitions of Terms Not Specific to This Standard:*

3.2.1 *defect, n*—see Terminology E1316.

3.2.2 *delamination, n*—see Terminology D3878.

3.2.3 *disbond, n*—see Terminology D3878.

3.2.4 *distance amplitude correction (DAC), n*—see Terminology E1316.

3.2.5 *flaw, n*—see Terminology E1316.

3.2.6 *matrix array transducers, n*—these transducers have an active area divided in two dimensions in different elements. This division can, for example, be in the form of a checkerboard, or sectored rings. Matrix array transducers may either be phased or nonphased. Nonphased matrix array transducers tend not to have discrete piezoelectric elements that pulse and receive individually. They instead achieve a matrix array aperture by either using a crossed electrode architecture or by pulsing from a large single crystal and receiving on a separate two-dimensional array. Due to this architecture, matrix array transducers may not allow beam steering. They are thus typically used for straight beam applications such as inspection of composites and corrosion mapping. Such nonphased matrix array transducers use live C-scan displays, highlighting the inspection region directly beneath the transducers.

3.2.6.1 *Discussion*—For the purpose of this practice, the matrix array transducers used are nonphased.

3.2.7 *phased array transducer, n*—see Terminology E1316.

3.2.8 *pulse echo method, n*—see Terminology E1316.

3.2.9 *sandwich construction, n*—see Terminology D3878.

3.2.10 *through transmission technique, n*—see Terminology E1316.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *flat panel composite, n*—any fiber reinforced composite lay-up consisting of laminate (plies) with one or more orientations with respect to some reference direction that are consolidated by press or autoclave to yield a two-dimensionally flat article of finite thickness.

3.3.2 *time-corrected gain (TCG), n*—time-corrected gain is a method of compensating for a reduction in signal amplitude with increasing range from reflectors of equal area. This is achieved by increasing the system gain with time so that the signals appear of equal amplitude. TCG achieves the same objective as a DAC.

3.3.2.1 *Discussion*—Calibration using TCG is required to ensure that indications have uniform amplitude with depth and position.

4. Summary of Practice

4.1 This practice describes two procedures for detecting bulk defects in monolithic composites, composite sandwich constructions, and metallic parts using ultrasonic longitudinal waves emitted from a two-dimensional matrix array transducer and coupled by contact. Equipment, reference blocks, examination procedures, data evaluation procedures, and documentation are described in detail

4.2 This practice focuses on the advantages and limitations of two-dimensional matrix arrays. Characteristics of phased array transducers such as linear, annular, and "rho-theta" are not discussed.

5. Significance and Use

5.1 The procedures described in this practice have proven utility in the inspecting (*1*) monolithic polymer matrix composites (laminates) for bulk defects, (*2*) metals for corrosion during the service life of the part of interest, (*3*) thickness checks, (*4*) adhesive bonding of metals, composites, and sandwich core constructions, (*5*) coatings, and (*6*) composite filament windings. Both unpressurized, and with suitable precautions, pressurized materials and components are inspected.

5.2 This practice provides guidelines for the application of longitudinal wave examination to the detection and quantitative evaluation of damage, discontinuities, and thickness variations in materials.

5.3 This practice is intended primarily for the testing of parts to acceptance criteria most typically specified in a purchase order or other contractual document, and for testing of parts in-service to detect and evaluate damage.

5.4 MAUT search units provide near-surface resolution and detection of small discontinuities comparable to phased array

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

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

[8] Available from CEN-CENELEC Management Centre, Rue de la Science 23, B-1040 Brussels.

[9] Available from U.S. Department of Transportation Federal Aviation Administration 800 Independence Ave SW, Washington, DC 20591.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.