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Standard Practice for Use of the Ultrasonic Time of Flight Diffraction (TOFD) Technique[1]

This standard is issued under the fixed designation E2373/E2373M; 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 establishes the requirements for developing ultrasonic examination procedures using the ultrasonic technique known as Time-of-Flight Diffraction (TOFD).

1.2 Consistent with ASTM Policy, TOFD may be regarded as an ultrasonic test method whereby the qualities and characteristics of the item tested are evaluated, measured and in some cases identified. Measurements may be subject to precision and bias that may be determined statistically or as a function of some parameter(s) such as wavelength. This practice may be used for applications that would be qualitative and properly addressed as examinations as well as quantitative and more properly addressed as tests.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E164 Practice for Contact Ultrasonic Testing of Weldments

E543 Specification for Agencies Performing Nondestructive Testing

E1065 Practice for Evaluating Characteristics of Ultrasonic Search Units

E1316 Terminology for Nondestructive Examinations

E1324 Guide for Measuring Some Electronic Characteristics of Ultrasonic Testing Instruments

E1961 Practice for Mechanized Ultrasonic Testing of Girth Welds Using Zonal Discrimination with Focused Search Units

2.2 *ASNT Documents:*[3]

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

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

2.3 *Aerospace Industries Association Document:*[4]

NAS-410 Certification and Qualification of Nondestructive Testing Personnel

2.4 *ISO Standard:*[5]

ISO 9712 Non-destructive Testing—Qualification and Certification of NDT Personnel

2.5 *Other Documents:*

Code Case 2235 ASME Boiler and Pressure Vessel Code[6]

EN 583-6 Non-destructive Testing: Ultrasonic Examination. Time-of-flight Diffraction Technique as a Method for Detection and Sizing of Discontinuities

3. Terminology

3.1 *Definitions*—Related terminology is defined in Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *B-scan display*—a sectional view of the plotted inspection data formed by the stacking of A-scans. (Some users refer to stacked A-scans from non-parallel scans as D-scans and reserve those used with parallel scans as B-scans.)

3.2.2 *back-wall echo*—a specular reflection from the backwall of the component being examined (usually assumed to be a plate).

[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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[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.

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[6] Available from the American Society of Mechanical Engineers, ASME International, 22 Law Drive, Box 2900, Fairfield, NJ 07007-2900.

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

3.2.3 *lateral wave*—a compression wave that travels by the most direct route from the transmitting probe to the receiving probe in a TOFD configuration.

3.2.4 *parallel scan*—a scan whereby the probe pair motion is parallel to the ultrasonic beam axis. Also called a B-scan by some users.

3.2.5 *PCS*—abbreviation for probe center spacing. Refers to the distance between the marked exit points of a pair of TOFD probes for a specific application.

3.2.6 *non-parallel or longitudinal scan*—a scan whereby the probe pair motion is perpendicular to the ultrasonic beam axis.

3.2.7 *RF waveforms*—the non-rectified A-scan.

4. Significance and Use

4.1 This practice provides general principles for the application of the Time-of-Flight Diffraction Technique as a tool for detection and sizing of discontinuities.

4.2 TOFD is a nondestructive ultrasonic examination technique that is not based on amplitude response. However, sufficient sensitivity is required to identify indications for evaluation.

4.3 Techniques used are typically applied to welded joints in carbon steel but the principles may be applicable to other applications including other materials with suitable validation procedures agreeable to the contracting parties.

4.4 In addition to a stand-alone ultrasonic detection technique TOFD may be used in conjunction with weld examinations such as those described in Practices E164 and E1961 where it may be used to improve sizing estimates of flaws detected by the manual or mechanized pulse-echo techniques and help discriminate between flaws and geometric reflectors.

4.5 The technique has proven effective on thicknesses from 9 to 300 mm [0.375 to 12 in.]. TOFD has been used on thicknesses outside of this range but special considerations are necessary. Techniques developed outside of this range of thickness shall be demonstrated as capable of meeting the required detection and sizing requirements of the specification used.

5. Basis of Application

5.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

5.2 *Personnel Qualification*

5.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, ISO 9712, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

5.3 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in E543. The applicable edition of E543 shall be specified in the contractual agreement.

5.4 *Procedures and Techniques*—The procedures and techniques to be used shall be as specified in the contractual agreement.

5.5 *Surface Preparation*—The pre-examination surface preparation criteria shall be in accordance with 6.3 unless otherwise specified.

5.6 *Timing of Examination*—The timing of examination shall be in accordance with 6.3 unless otherwise specified.

5.7 *Extent of Examination*—The extent of examination shall be in accordance with 6.3 unless otherwise specified.

5.8 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with Section 8 unless otherwise specified. Since acceptance criteria (for example, for reference radiographs) are not specified in this practice, they shall be specified in the contractual agreement.

5.9 *Re-examination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this standard and if required shall be specified in the contractual agreement.

6. Procedures

6.1 *Introduction:*

6.1.1 TOFD is an ultrasonic examination technique that can provide improved detection and sizing capabilities of discontinuities compared to standard ultrasonic pulse-echo techniques. It uses forward scattered tip diffraction and reflection of transmitted ultrasonic pulses. This document describes the requirements for TOFD equipment and procedures on flat plate surfaces. Guidance for more complex geometries is provided in the Appendix. General guidance on TOFD can also be found in EN 583–6. Acceptance criteria typical and performance demonstration requirements that may be used with TOFD techniques are found in ASME Code Case 2235[7].

6.1.2 Because phase inversions of signals play an important role in the evaluation of TOFD results, all procedures developed using this practice shall require that the equipment presentation use and store RF waveforms.

6.1.3 Whether motorized or manually-operated, probe motion must be encoded for position and probes held in a fixture that maintains correct PCS during scanning. Time based sampling of data collection is not acceptable.

6.1.4 Fig. 1 illustrates the typical probe configuration for a TOFD examination. The figure uses a weld for convenience of references; however, TOFD need not be restricted to just weld examinations.

6.1.5 The lateral wave and back-wall echo signals provide convenient references. For most applications mode converted

[7] Reference to ASME CC2235 is made only as an example of an existing code where the mutually agreed upon acceptance criteria allows TOFD to be applied. This does not suggest that application of ASME CC2235 would be appropriate in all cases. It should be recognized that the high sensitivity of the TOFD technique could result in indications from reflectors in plate materials that meet all plate ultrasonic specification requirements. Such indications should not be considered unacceptable unless they fail to meet the acceptance criteria agreed upon in 8.1.