Designation: E 2373 – 04

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

This standard is issued under the fixed designation E 2373; 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 The values stated in SI units are to be regarded as standard. Inch-pound units are provided for information.

1.3 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.

1.4 *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]

E 164 Practice for Ultrasonic Contact Examination of Weldments

E 1065 Guide for Evaluating Characteristics of Ultrasonic Search Units

E 1316 Terminology for Nondestructive Examinations

E 1324 Guide for Measuring Some Electronic Characteristics of Ultrasonic Examination Instruments

2.2 *Other Documents:*

BS 7706 (1993) Guide to Calibration and Setting-up of the Ultrasonic Time-of-Flight Diffraction (TOFD) Technique for Detection , Location and Sizing of Flaws, British Standards Institute, 1993[3]

Code Case 2235 ASME Boiler and Pressure Vessel Code[4]

3. Terminology

3.1 *Definitions*—Related terminology is defined in Terminology E 1316.

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 back-wall of the component being examined (usually assumed to be a plate).

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.

[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 BSI Management Systems, 12110 Sunset Hills Road, Suite 140, Reston VA 20190.

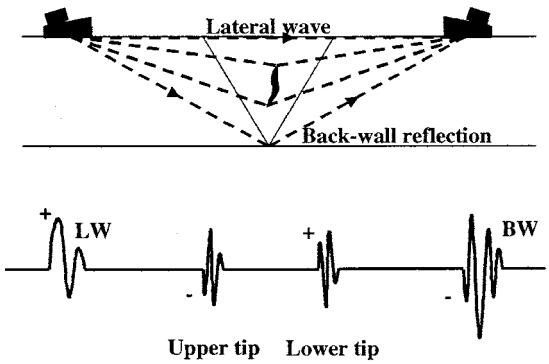
[4] Available from the American Society of Mechanical Engineers, ASME International, 22 Law Drive, Box 2900, Fairfield, NJ 07007-2900.

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 E 164 and E 1961 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.

TOFD Configuration and Signal origins



Non-rectified A-scan presentation is needed to show the phase

FIG. 1

5. Procedures

5.1 *Introduction*:

5.1.1 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 British Standards BS 7706. Acceptance criteria typical and performance demonstration requirements that may be used with TOFD techniques are found in ASME Code Case 2235[5].

5.1.2 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.

5.1.3 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.

5.1.4 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.

5.1.5 The lateral wave and back-wall echo signals provide convenient references. For most applications mode converted signals from flaws are not used and therefore flaw indications are usually recognized as occurring between the lateral wave and back-wall echo signals. Although it is more often the case to use refracted compression mode in the examination piece, some applications may produce better results when the incident angle is greater than the first critical angle, thereby providing a refracted transverse shear mode in the examination piece. When using a refracted compression mode in the examination piece the direct shear and head waves also are generated; however, due to their lower acoustic velocities, shear waves arrive later in time than the back-wall signal.

5.1.6 Fig. 2 is a sketch of a typical presentation for a non-parallel scan of a butt weld in a plate with an imbedded flaw. The right side of Fig. 2 illustrates a waveform extracted from a B-scan display showing the lateral wave, upper tip diffracted, lower tip diffracted and the back-wall echo signals. The left side of Fig. 2 indicates the probe placement with respect to the weld (upper left) and relative motion of the probes (a non-parallel scan is indicated).

5.1.7 Fig. 3 illustrates an actual TOFD scan with five indications (identified on the left) and an extracted A-scan from one of the indications.

5.2 *Written Procedure*—A documented examination strategy or scan plan shall be provided showing probe placement, movement, and component coverage that provides a standardized and repeatable methodology for component acceptance. The scan plan shall also include ultrasonic beam angle(s) used, beam directions with respect to some reference such as a weld centerline, and volume examined.

5.3 *Examination Materials and Surface Preparation*:

5.3.1 TOFD technique can be applied to both metals and nonmetals. Best results are had on fine-grained isotropic materials with low attenuation including some finer grained austenitic alloys and aluminum. With suitable validation procedures, agreeable to the contracting parties, coarser-grained and anisotropic materials may also be examined using TOFD. These usually require additional modifications to frequencies and digital signal processing.

5.3.2 The scanning area shall be clear of weld spatter and other conditions which may interfere with the movement of the probes, the coupling liquid, or the transmission of acoustic energy into the material. Any surface condition such as geometry, coating, and so forth, impeding the ultrasonic examination shall be noted for corrective action prior to scanning.

[5] 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 7.1.