Designation: E3517/E3517M – 26

Standard Practice for Flaw Sizing using Total Focusing Method[1]

This standard is issued under the fixed designation E3517/E3517M; 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 evaluating length and vertical extent sizes of flaws in metal weldments using the post processing algorithms referred to as total focusing method (Note 1).

NOTE 1—This practice is based on experience with ferrous and aluminum alloys. Other metallic materials can be examined using this practice provided reference standards can be developed that demonstrate that the particular material and weld can be successfully penetrated by an ultrasonic beam.

1.2 This practice describes procedures to determine remaining ligaments associated with flaws in metal weldments.

1.3 This practice uses phased-array ultrasonic systems using either full matrix capture (FMC) or plane wave imaging (PWI) as data acquisition methods.

1.4 This practice does not specify accept-reject criteria.

1.5 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.

1.6 *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.*

1.7 *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 The following documents form a part of this practice to the extent specified herein.

2.2 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing
E1316 Terminology for Nondestructive Examinations
E2491 Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems
E2700 Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays
E2862 Practice for Probability of Detection Analysis for Hit/Miss Data
E2904 Practice for Characterization and Verification of Linear Phased Array Ultrasonic Probes
E3023 Practice for Probability of Detection Analysis for $\hat{a}$ Versus a Data

3. Terminology

3.1 *Definitions:*

3.1.1 Related terminology is defined in Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *delay and sum (DAS), n*—a post-processing reconstruction algorithm that sums delayed pulser-receiver A-scans.

3.2.2 *delay multiply and sum (DMAS), n*—a post-processing reconstruction algorithm that sums delayed pulser-receiver A-scans multiplied by each other with the intent of reducing artifacts due to "partially constructive" interferences.

3.2.3 *full matrix capture (FMC), n*—an FMC data set is a compilation of every element in an array transmitting, and in return also receiving, from all other elements being fired (including itself), such that every combination of all the elements produces an A-scan.

3.2.4 *phase-coherence imaging (PCI), n*—uses phase information rather than amplitude and phase information to evaluate the coherence between the recorded raw A-scans.

3.2.5 *plane-wave imaging (PWI), n*—an acquisition method that consists of firing all the elements of the array simultaneously along several angles, while all the elements receive independently; the transmitted delay law produces a plane wave for PWI, compared to a cylindrical wave for FMC.

[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 www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.6 *point spread function (PSF), n*—the image of a theoretical point scatter at a given location within the ROI—it may be used to determine information about how amplitude, shape, and size of a point reflector varies throughout the inspection region for a focusing system such as used in TFM; PSF is used to determine sensitivity and resolution maps in the ROI.

3.2.7 *region of interest (ROI), n*—the cross-sectional area in which the TFM algorithm is applied to reconstruct an image of the contents of that region.

3.2.8 *TFM envelope, n*—computed by applying the Hilbert transform to elementary A-scan signals prior to applying the TFM to obtain the "envelope" from the magnitude of the summed analytic signals; images are "smoothed" and amplitude fidelity is improved.

3.2.9 *total focusing method (TFM), n*—refers to any number of algorithms that use a summation process for each pixel within the ROI grid to generate an image of the reflecting sources in that region.

4. Summary of Practice

4.1 This practice provides a general description of the procedures to perform flaw sizing for the purposes of fracture-mechanics-based acceptance criteria and to establish true flaw sizes when probability of detection is used to assess procedure reliability.

4.2 Analysis of data using this practice uses two general forms of data acquisition, either FMC or PWI.

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.

4.4 The technique generally relies on using post-processed data to locate flaw tips that are the source of tip-diffraction. When no tip-diffraction signals can be identified, amplitude-drop techniques may be used.

5. Significance and Use

5.1 Flaws that are made during manufacturing or that occur during service of a component have the potential to cause the component to fail. NDT methods such as described in Practice E2700 are intended to locate flaws that have the potential to result in component failure. Since not all flaws will result in failure, it is desirable to have a means of assessing the dimensions of flaws so that fracture-mechanics engineering calculations may be used to assess if the component is still fit for service if the flaw is left unrepaired.

5.2 When an NDT procedure is being evaluated for reliability using probability of detection (POD), standards such as Practices E2862 and E3023 can be used. These would require that flaws are intentionally placed in components. POD calculations require a high degree of accuracy of flaw sizes to ensure that the POD correctly indicates the reliability of the NDT procedure.

5.3 TFM has been demonstrated to provide accurate flaw sizes for both vertical extent and ligament to surface. In fine-grained steel, dimensional error can be less than 1 mm.

5.4 Although TFM has, on occasion, been used as a detection method, it can have limitations in that capacity. Without prior knowledge of flaw orientation, multiple combinations of mode-reconstruction are required. As well, the FMC method of data acquisition relies on single elements in transmit and receive mode, which for thicker section may result in weak signals due to attenuation and scatter noise. Using PWI instead of FMC as the acquisition mode can improve the strength of transmitted pulses; however, the resulting plane waves may not always provide the optimum angle to produce the required backscattered signals.

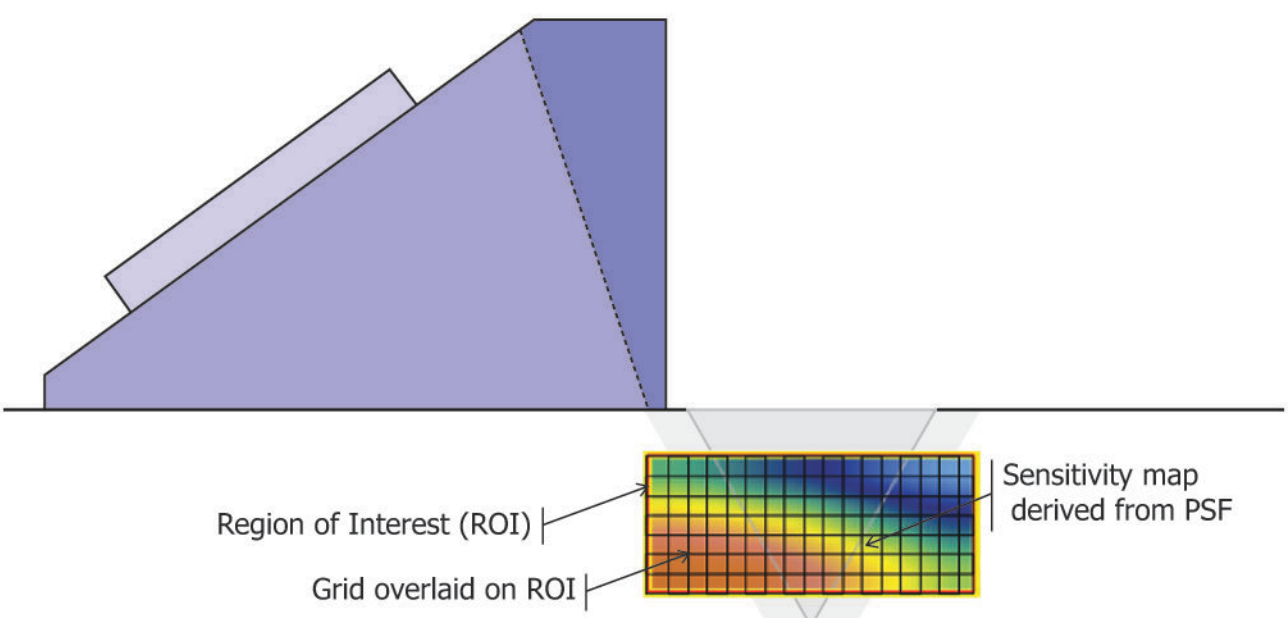

FIG. 1 Region of Interest for TFM Reconstruction