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Standard Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays[1]

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ε[1] NOTE—Section 2 was corrected editorially in June 2104.

1. Scope

1.1 This guide covers the use of conformable eddy current sensor arrays for nondestructive examination of electrically conducting materials for discontinuities and material quality. The discontinuities include surface breaking and subsurface cracks and pitting as well as near-surface and hidden-surface material loss. The material quality includes coating thickness, electrical conductivity, magnetic permeability, surface roughness and other properties that vary with the electrical conductivity or magnetic permeability.

1.2 This guide is intended for use on nonmagnetic and magnetic metals as well as composite materials with an electrically conducting component, such as reinforced carbon-carbon composite or polymer matrix composites with carbon fibers.

1.3 This guide applies to planar as well as non-planar materials with and without insulating coating layers.

1.4 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.5 *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]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

E2338 Practice for Characterization of Coatings Using Conformable Eddy-Current Sensors without Coating Reference Standards

2.2 *ASNT Documents:*[3]

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

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

2.3 *AIA Standard:*

NAS 410 Certification and Qualification of Nondestructive Testing Personnel[4]

2.4 *Department of Defense Handbook:*

MIL-HDBK–1823A Nondestructive Evaluation System Reliability Assessment

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this guide refer to Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *B-Scan*—a method of data presentation utilizing a horizontal base line that indicates distance along the surface of a material and a vertical deflection that represents a measurement response for the material being examined.

3.2.2 *C-Scan*—a method of data presentation which provides measurement responses for the material being examined in two-dimensions over the surface of the material.

3.2.3 *conformable*—refers to an ability of sensors or sensor arrays to conform to non-planar surfaces without significant effects on the measurement results, or with effects that are limited to a quantifiable bound.

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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. (Replacement standard for MIL-STD-410.)

3.2.4 *depth of sensitivity*—depth to which the sensor response to features or properties of interest exceeds a noise threshold.

3.2.4.1 *Discussion*—The depth of sensitivity is generally smaller than the depth of penetration since it incorporates a comparison between the signal obtained from a feature as well as measurement noise, whereas the depth of penetration refers to the decrease in field intensity with distance away from a test coil.

3.2.5 *discontinuity-containing reference standard*—a region of the material under examination or a material having electromagnetic properties similar to the material under examination for which a discontinuity having known characteristics is present.

3.2.6 *discontinuity-free reference standard*—a region of the material under examination or a material having electromagnetic properties similar to the material under examination for which no discontinuities are present.

3.2.7 *drive winding*—a conductor pattern or coil that produces a magnetic field that couples to the material being examined.

3.2.7.1 *Discussion*—The drive winding can have various geometries, including: 1) a simple linear conductor that is placed adjacent to a one-dimensional array of sensing elements; 2) one or multiple conducting loops driven to create a complex field pattern; and 3) multiple conducting loops with a separate loop for each sensing element.

3.2.8 *insulating shims*—conformable and substantially nonconducting or insulating foils that are used to measure effects of small lift-off excursions on sensor response.

3.2.9 *lift off*—normal distance from the plane of the conformable sensor winding conductors to the surface of the conducting material under examination.

3.2.10 *model for sensor response*—a relation between the response of the sensor (for example, impedance magnitude and phase or real and imaginary parts) and properties of interest (for example, electrical conductivity, magnetic permeability, lift-off, and material thickness) for at least one sensing element and at least one drive winding.

3.2.10.1 *Discussion*—These model responses may be obtained from database tables and may be analysis-based or empirical.

3.2.11 *sensing element*—a means for measuring the magnetic field intensity or rate of change of magnetic field intensity, such as an inductive coil or a solid-state device.

3.2.11.1 *Discussion*—The sensing elements can be arranged in one or two-dimensional arrays. They can provide either an absolute signal related to the magnetic field in the vicinity of the sense element or a differential signal.

3.2.12 *spatial half-wavelength*—spacing between the conductors of a linear drive winding with current flow in opposite directions.

3.2.12.1 *Discussion*—This spacing affects the depth of sensitivity. The spatial wavelength equals two times this spacing. For a circular drive winding, the effective spatial half-wavelength is equal to the drive winding diameter.

3.2.13 *system performance verification*—the use of a measurement of one or more response values, typically physical property values, for a reference part to confirm that the response values are within specified tolerances to validate the system standardization and verify proper instrument operation.

4. Summary of Guide

4.1 The examination is performed by scanning a conformable eddy current sensor array over the surface of the material of interest, with the sensor array energized with alternating current of one or more frequencies. The electrical response from each sensing element of the eddy current sensor array is modified by the proximity and local condition of the material being examined. The extent of this modification is determined by the distance between the eddy current sensor array and the material being examined, as well as the dimensions and electrical properties (electrical conductivity and magnetic permeability) of the material. The presence of metallurgical or mechanical discontinuities in the material alters the measured impedance of the eddy current sense elements. While scanning over the material, the position at each measurement location should be recorded along with the response of each sensing element in the sensor array. The measured responses and location information can then be used, typically in the form of a displayed image (C-scan (3.2.2)) or in the form of a plot (B-scan (3.2.1)), to determine the presence and characteristics of material property variations or discontinuities.

4.2 The eddy current sensor arrays used for the examination are flexible and, with a suitable backing layer, can conform to both flat and curved surfaces, including fillets, cylindrical surfaces, etc. The sensor array can have a variety of configurations. These include: 1) a linear drive conductor that is energized by the instrument alternating current and a linear array of absolute sense elements positioned parallel to the drive conductor; 2) a complex drive conductor that produces a desired field pattern at each sensing element; and 3) individual drive conductors associated with each sensing element. Associated with each sense element are one or more measurement responses that reflect the local material condition at each location over the surface. The sensor arrays may be used with models for the sensor response and appropriate algorithms to convert measured responses for each sensing element into physical properties, such as lift-off, electrical conductivity, magnetic permeability, coating thickness, and/or substrate thickness. Baseline values for these measurement responses or physical properties are used to ensure proper operation during the examination while local variations in one or more of these properties can be used to detect and characterize the discontinuity. For example, although, an impedance magnitude or other sensing element response can be used without a model to determine the presence of a flaw, a measurement of the lift-off at each sensing element location ensures that the sensor is conforming properly to the surface. Also, a position measurement capability, such as a rolling position encoder, can be used to measure location in the scan direction and ensure that sufficient data resolution is achieved. Visual or audio signaling devices may be used to indicate the position of the discontinuity.