INTERNATIONAL

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

This standard is issued under the fixed designation E2884; 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 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 or layer 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions:* For definitions of terms relating to this guide, refer to Terminology E1316, including Section C on Electromagnetic Testing.

3.1.1 *B-Scan, n*—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.

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

3.1.3 *discontinuity-containing reference standard, n*—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.

3.1.4 *discontinuity-free reference standard, n*—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.

3.1.5 *sensing element, n*—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.

3.1.5.1 *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.

4. Summary of Guide

4.1 The examination is performed by scanning a conformable eddy current sensor array over the surface of the material

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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.

*A Summary of Changes section appears at the end of this standard 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 and the presence of geometric changes in the material, such as coating thickness, layer thickness, or gap thickness between layers, alter 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 (3.1.2)) or in the form of a plot (B-scan (3.1.1)), 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, or substrate thickness, or a combination thereof. 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.

5. Significance and Use

5.1 Eddy current methods are used for nondestructively locating and characterizing discontinuities and geometric property variations in magnetic or nonmagnetic electrically conducting materials. Conformable eddy current sensor arrays permit examination of planar and non-planar materials but usually require suitable fixtures to hold the sensor array near the surface of the material of interest, such as a layer of foam behind the sensor array along with a rigid support structure.

5.2 In operation, the sensor arrays are standardized with measurements in air or a reference part, or both. Responses measured from the sensor array may be converted into physical property values, such as lift-off, electrical conductivity, or magnetic permeability, or a combination thereof. Proper instrument operation is verified by ensuring that these measurement responses or property values are within a prescribed range. Performance verification is performed periodically. Performance verification on a discontinuity-free reference standard or regions of the material being examined that do not contain discontinuities ensures that the electrical and geometric properties, such as electrical conductivity, layer thickness, or lift-off, or a combination thereof, are appropriate for the sensor array. Performance verification on a discontinuity-containing reference standard ensures that the sensor array response to the discontinuity is appropriate.

5.3 The sensor array dimensions, including the size and number of sense elements, and the operating frequency are selected based on the type of examination being performed. The depth of penetration of eddy currents into the material under examination depends upon the frequency of the signal, the electrical conductivity and magnetic permeability of the material, and some dimensions of the sensor array. The depth of penetration is equal to the conventional skin depth at high frequencies but is also related to the sensor array dimensions at low frequencies, such as the size of the drive winding and the gap distance between the drive winding and sense element array. For surface-breaking discontinuities on the surface adjacent to the sensor array, high frequencies should be used where the penetration depth is less than the thickness of the material under examination. For subsurface discontinuities or wall thickness measurements, lower frequencies and larger sensor dimensions should be used so that the depth of penetration is comparable to the material thickness.

5.4 Insulating layers or coatings may be present between the sensor array and the surface of the electrically conducting material under examination. The sensitivity of a measurement to a discontinuity generally decreases as the coating thickness or lift-off, or both, increases. For eddy current sensor arrays having a linear drive conductor and a linear array of sense elements, the spacing between the drive conductor and the array of sense elements should be smaller than or comparable to the thickness of the insulating coating. For other array formats the depth of sensitivity should be verified empirically.

5.5 Models for the sensor response may be used to convert responses measured from the sensor array into physical property values, such as lift-off, electrical conductivity, magnetic permeability, coating thickness, or substrate thickness, or a combination thereof. For determining two property values, one operational frequency can be used. For nonmagnetic materials and examination for crack-like discontinuities, the lift-off and electrical conductivity should be determined. For magnetic materials, when the electrical conductivity can be measured or assumed constant, then the lift-off and magnetic permeability