Designation: E 1312 – 99

Standard Practice for Electromagnetic (Eddy-Current) Examination of Ferromagnetic Cylindrical Bar Product Above the Curie Temperature[1]

This standard is issued under the fixed designation E 1312; 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 eddy-current examination of hot ferromagnetic bars above the Curie temperature where the product is essentially nonmagnetic, but below 2100°F (1149°C).

1.2 This practice is intended for use on bar products having diameters of ½ in. (12.7 mm) to 8 in. (203 mm) at linear throughput speeds up to 1200 FPM (366 MPM). Larger or smaller diameters may be examined by agreement between the using parties.

1.3 The purpose of this document is to provide a procedure for in-line eddy-current inspection of bars during processing for the detection of major or gross surface discontinuities.

1.3.1 The types of discontinuities capable of being detected are commonly referred to as: slivers, laps, seams, roll-ins (scale, dross, etc.), and mechanical damage such as scratches, scores, or indentations.

1.4 This practice does not establish acceptance criteria. They must be specified by agreement between the using parties.

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:*

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *Other Documents:*

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[3]

ANSI/ASNT-CP-189 Standard for Qualification and Certification of NDT Personnel[3]

2.3 *AIA Standard:*

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

3. Terminology

3.1 *Definitions*—Terminology E 1316 shall apply to the terms used in this practice.

4. Summary of Practice

4.1 *Principle*—The major advantage of examining ferromagnetic bar product above the Curie temperature with eddy currents is the enhanced signal-to-noise ratio obtained without the need for magnetic saturation.

4.2 *Sensors*—This examination may be performed with various types or designs of encircling coils or with probe coils that are fixed or rotating.

4.2.1 One or more exciter or sensor coils is used to encircle the bar through which the product to be examined is passed. When the hot bar is in close proximity to the sensing and exciting coils, eddy currents are induced in the hot product by an alternating current. The sensing coil detects the electromagnetic flux related to these currents. Changes or disruptions in the normal flux pattern indicate the presence of discontinuities. This technique is capable of examining the entire circumference without contacting the product.

4.2.2 The surface can also be examined with probe coils having one or more exciters and sensors which are spaced in close proximity to the product surface. The probe is usually small and does not encircle the product, making it necessary to rotate either the probes or the product to obtain 100 % coverage of the circumference. This is essentially a contact technique because the coil is fixtured in a device that rides on the circumference to maintain a fixed distance between the coil and product surface.

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[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E7.07 on Electromagnetic Method.

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[4] Available from the Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, DC 20005.

4.2.3 Discontinuities cause either a change in phase or signal amplitude when detected by the sensing coil. These signals are amplified and processed to activate marking or recording devices, or both. Relative severity of the imperfection can be indicated by the signal amplitude generated by the flux change or the degree of change in phase.

4.2.4 Caution must be exercised in establishing reference standards because flux changes caused by natural discontinuities might differ significantly from those generated by artificial discontinuities.

5. Significance and Use

5.1 The purpose of this practice is to describe a procedure for in-line-eddy-current examination of hot cylindrical bars in the range of diameters listed in 1.2 for large and repetitive discontinuities that may form during processing.

5.2 The discontinuities in bar product capable of being detected by the electromagnetic method are listed in 1.3.1. The method is capable of detecting surface and some subsurface discontinuities that are typically in the order of 0.030 in. (0.75 mm) and deeper, but some shallower discontinuities might also be found.

5.3 Discontinuities that are narrow and deep, but short in length, are readily detectable by both probe and encircling coils because they cause abrupt flux changes. Surface and subsurface discontinuities (if the electromagnetic frequency provides sufficient effective depth of penetration) can be detected by this method.

5.3.1 Discontinuities such as scratches or seams that are continuous and uniform for the full length of cut length bars or extend for extensive linear distances in coiled product may not always be detected when encircling coils are used. These are more detectable with probe coils by intercepting the discontinuity in their rotation around the circumference.

5.3.2 The orientation and type of coil are important parameters in coil design because they influence the detectability of discontinuities.

5.4 The eddy current method is sensitive to metallurgical variations that occur as a result of processing, thus all received signals above the alarm level are not necessarily indicative of defective product.

6. Basis of Application

6.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally recognized nondestructive testing (NDT) personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, 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.

6.2 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

6.3 *Acceptance Criteria*—Since acceptance criteria are not specified in this practice, they shall be specified in the contractural agreement.

7. Apparatus

7.1 *Electronic Apparatus*, should be capable of energizing the test coils or probes with alternating current at selectable frequencies from 400 Hz to 100 kHz. Either manual or remotely operated switches can be used for frequency selection. The equipment should include a detector display (CRT, meters), phase discriminator, filters, modulators, recorders, and alarming/marking devices required for particular applications.

7.2 *Sensors*, whether probe or encircling coils, should operate through a frequency range from 400 Hz to 100 kHz.

7.2.1 The sensor windings must be cooled (such as water jackets) to control the sensor operating temperature and prevent thermal damage to the sensors.

7.2.2 Magnetic or electrostatic shields might be necessary to suppress extraneous electrical transient noise. Electrostatic shields usually float above ground at the sensor and are connected to a cable and then to the preamplifier shield.

7.2.3 Constant spacing, ranging from 1⁄16 in. (1.6 mm) to 1⁄4 in. (6.4 mm) between the sensors and product surface is obtained with positioning mechanisms usually equipped with product guiding devices to prevent mechanical damage to the sensors.

7.3 *Transport Mechanism*—A conveyor or other type of mechanical device should be employed to pass the product through or past the sensors. It should operate at production (or system) speeds with a minimum vibration of the sensors or product, and should maintain alignment of the sensors and product within the specified tolerances. Some systems may require the transport to rotate either the bar, the sensors, or both.

7.3.1 The mechanical tolerances for restraining the longitudinal centerline of the product relative to the coils are critical to obtain an effective electromagnetic examination. Nonuniform sensitivity, the generation of erroneous signals or poor signal-to-noise ratios result when the product and encircling coil are not concentric or the probe coil clearance changes during examination. Therefore, the system passline mechanisms must be properly designed and maintained to achieve the spatial arrangement defined in 7.2.3. Product rolling tolerances, product straightness, and conveyor alignment or roll wear are factors that may influence sensor and product spatial relations. The system sensitivity profile predicated on the passline capabilities can be determined by utilizing the standardization procedure in 8.4.

7.4 *Reference Standard*—It is impractical to use a reference standard heated to the same temperature as the material being examined because of reoxidation, furnace time, etc. Therefore, a material with nonmagnetic properties, such as 304 stainless steel, is substituted. It should be of the same diameter as the material being examined and of sufficient length to span the transport system rolls while passing through or past the sensors at the same speed and under the same conditions as the product. The standard usually has one of the following types of artificial discontinuities on the circumference.

7.4.1 Holes drilled are either partially or completely through the diameter.

7.4.2 Notches should be inserted on the circumference by electric discharge machining, milling, or other methods. They may be either transverse or parallel to the longitudinal axis of the bar. Notch depths are usually given as a percentage of the diameter.

7.4.3 The dimensions of holes or notches (hole diameter and depth, notch width length, depth) are either specified or agreed to between the using parties to establish sensitivity levels and/or acceptance criteria.

7.4.4 The notches or holes should be placed on the circumference and along the bar longitudinal axis with sufficient spacing to ensure that each is detected without interference from a neighbor.

8. System Standardization

8.1 Fabricate the reference standard in accordance with the specification.

8.2 Pass the standard through the system at speeds and conditions simulating production examination.

8.2.1 Adjust the apparatus to obtain a signal-to-noise ratio that allows the operator to differentiate between the signals from the system ambient noise and those produced by discontinuities. Although the minimum recommended signal-to-noise ratio is 2:1, system reliability improves as this ratio increases.

8.2.2 The amplitude or phase may be adjusted to trigger an alarm from each artificial imperfection as it passed by the sensors.

8.3 After the sensitivity adjustments are completed, the standard should be traversed through the coils or probes simulating production conditions several times.

8.3.1 If the artificial discontinuities are located near one of the ends, the standard also should be passed through the system by reversing the leading and trailing ends.

8.3.2 The system alarm or markers, or both, should indicate every specified artificial discontinuity during each pass.

8.3.3 The electronic apparatus should include a suppression circuit to prevent system response from the ends of the standard and cut-to-length bar product.

8.4 The capability of the passline mechanism to maintain the correct distance between the bar surface and coils can be determined by passing the standard through the system at production speeds a minimum of four times with the product rotated 90 degrees after each pass. If more passes are used, the angular rotation should be reduced accordingly. The responses obtained from the artificial discontinuity can be used to plot a sensitivity profile to determine if previously established tolerances are satisfied.

8.4.1 An alternative method is to fabricate the standard with four or more duplicate artificial discontinuities distributed equally around the circumference and separated sufficiently along the longitudinal axis to produce signals without interference from a neighbor. In this case, the standard must be passed through the system one time at production speeds.

8.5 If acceptable by specification and/or agreement between the purchaser, manufacturer or supplier, electronically generated signals simulating responses from artificial discontinuities may be used to adjust the sensitivity or to standardize the system.

9. Procedure

9.1 Standardization should be performed near the start of each working period (or diameter, grade, etc., change) and rechecked at 4 h or more frequent intervals.

9.1.1 If improper system function occurs, all material that passed through the system since the last satisfactory standardization should be re-examined. Because bar product is not reheated and recoiled, electromagnetic inspection of recoiled or cut length cold bars is the only practical method for re-examination. However, different results may be obtained because of changes in metallurgical characteristics between hot and cold product with the exception of austenitic steels.

9.2 Pass all the material through the system for examination at the sensitivity levels adjusted in accordance with Section 8.

9.3 Any piece with discontinuities producing responses above the alarm level should be marked and set aside for further evaluation or disposition, or both.

9.4 No equipment adjustments should be made except during standarization (or standardization checks) or whenever the apparatus is not performing correctly.

10. Keywords

10.1 artificial discontinuity; curie temperature; electrical transient noise; electronically generated signal; encircling coil; ferromagnetic cylindrical bar; flux change; in-line-eddy-current examination; magnetic or electrostatic shield; phase; sensor coil; signal amplitude; suppression circuit; system reliabilty; transport mechanism