



Designation: E2905/E2905M – 19

# Standard Practice for Examination of Mill and Kiln Girth Gear Teeth— Electromagnetic Methods<sup>1</sup>

This standard is issued under the fixed designation E2905/E2905M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

NOTE 1—Throughout the standard, “gear” means gear or pinion unless the gear is specifically identified.

1.1 This practice describes a two-part procedure for electromagnetic evaluation on gear teeth on mill and kiln gear drives and pinions. The first part of this practice details the ability to detect 100 % of surface-breaking discontinuities only in the addendum, dedendum, and root area on both the drive side and non-drive side of the gear tooth using an eddy current array. The second part of the examination is to size or measure accurately the length and depth of any cracks found in these areas using electromagnetic methods. No other practice addresses the use of electromagnetic methods for the detection and sizing of surface-breaking discontinuities on mill and kiln ring gear teeth.

1.2 This practice is used only for crack detection, scuffing, wear patterns, and early signs of macro-pitting. It will not provide a full gear tooth analysis. Visual examination by an experienced gear specialist is the only way to characterize fully the failure modes present, their severity, and consequences. It is imperative that the analysis of the gear teeth is completed at the time of examination. Sending data offsite for analysis later is not recommended as potential failure modes could be missed from lack of in-situ visual examination.

1.3 Two technicians, one gear specialist, and a gear technician are typically required for this practice. One technician guides the probe and the other technician operates the computer/software and analyzes the gear teeth condition.

1.4 It is important that the appropriate method standards, such as Guide E709 and Practice E2261, if the alternating current field measurement approach is used for crack sizing, accompany the technician when performing the examination.

1.5 It is recommended that the technician review the appendices in this practice in advance of starting the job.

1.6 A clean gear is recommended for a complete gear analysis. Depending on the lubrication used, the technician, in discussion with the client, shall determine the appropriate cleaning procedure. If an oil bath lubrication system is used, ensure the gear teeth surfaces are clean. If an asphaltic-based or synthetic-based lubricant is used, refer to the annexes and appendices in this practice.

1.7 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.8 *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.*

1.9 *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:<sup>2</sup>

E709 Guide for Magnetic Particle Testing

E1316 Terminology for Nondestructive Examinations

E2261 Practice for Examination of Welds Using the Alternating Current Field Measurement Technique

E2884 Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays

### 2.2 AIA Standard:<sup>3</sup>

NAS 410 Certification and Qualification of Nondestructive Test Personnel

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.07 on Electromagnetic Method.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, <http://www.aia-aerospace.org>.

\*A Summary of Changes section appears at the end of this standard

### 2.3 ANSI/AGMA Standards:<sup>4</sup>

**AGMA 912-A04** Mechanisms of Gear Tooth Failures—Information Sheet

**AGMA 919-1-A14** Condition Monitoring and Diagnostics of Gear Units and Open Gears

**ASNI/AGMA 1010-F14** Standard for Appearance of Gear Teeth—Terminology of Wear and Failure

**ANSI/AGMA 1012 G-05** Gear Nomenclature, Definition of Terms

**ANSI+AGMA+6014-B15** Annex G

### 2.4 ANSI/ASNT Standards:

**ANSI/ASNT-CP-189** Qualification and Certification of Non-destructive Testing Personnel<sup>4</sup>

**ISO 9712** Qualification and Certification of NDT Personnel<sup>4</sup>

**SNT-TC-1A** Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing<sup>5</sup>

## 3. Terminology

**3.1 Definitions**—For definitions of terms relating to this practice, refer to Terminology **E1316**, Practice **E2261**, and Guide **E2884**. For definitions of general terms relating to gear examinations, refer to Guide **E709**, ANSI/AGMA 1012 G-05, ANSI/AGMA 1010-F14, AGMA 919-1-A14, and ANSI+AGMA+6014-B15.

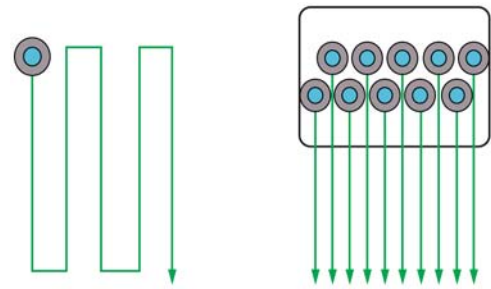
NOTE 2—Different equipment manufacturers may use slightly different terminology. Reference should be made to the equipment manufacturer's documentation for clarification.

### 3.2 Eddy Current Array Method:

**3.2.1 basic concepts of eddy current array, ECA, *n***—eddy current array (ECA) technology provides the ability to measure electronically multiple eddy current sensing coils placed side by side in the same probe assembly.

**3.2.1.1 Discussion**—Example eddy current arrays have distinct drive coils associated with each sense coil or a drive coil with a linear conductor that is parallel to a linear array of sense coils. Depending upon the instrumentation, the response for each sense element can be measured in parallel or a multiplexer can be used to switch between one or more of the sense coils. Typically, a multiplexer is used when the number of sense coils is greater than the number of data acquisition channels for impedance measurement. When using eddy current sensor arrays with multiple drive coils and multiple sensing coils, undesired coupling between the individual coils is likely to take place. It may be necessary to use a multiplexer with a special multiplexing pattern to avoid such undesired coupling. Most conventional eddy current flaw detection techniques can be reproduced with an ECA examination. With the benefits of single-pass coverage, and enhanced imaging capabilities, ECA technology provides a remarkably powerful tool and significant time savings during examinations compared to raster scanning with a single coil probe. (See **Fig. 1**.)

**3.2.1.2 Discussion**—In this standard, the eddy current array is used for crack detection, early signs of macro-pitting,



**FIG. 1 Eddy Current Single Coil Probe Compared to Eddy Current Array Probe Coils**

scuffing, and wear patterns. Although ECA will show wear patterns, the proper method for interpreting contact and wear patterns should be used. Refer to ANSI/AGMA 1010-F14. It describes the appearance of gear tooth failure modes and discusses their mechanisms, with the sole intent of facilitating identification of gear wear and failure. Limitations—The eddy current array will not reveal backlash problems, lubrication issues, tip to root interface, and so forth. Visual interpretation by an expert is the typical method used to analyze these conditions. It is very important that the technician has a clear understanding of analyzing gear teeth failure modes that may be present. Basic eddy current experience does not provide the knowledge required to interpret gear teeth issues or the understanding of ECA. The knowledge of the defect type helps in determining the root causes and the potential solutions, resulting in a higher standard of examination.

**3.2.2 eddy current array probes, *n***—probes can be designed to detect a specific type of discontinuity and to conform to the shape of the part under examination (see **Fig. 2**).

**3.2.2.1 Discussion**—Probes can be designed to detect a specific type of discontinuity and conform to the shape of the gear tooth under examination. Also notice that the center of the root would actually be scanned twice. In this examination, there is no saturation performed. Surface probes are made with coils designed to be driven at relatively high frequencies (typically 50 to 500 kHz). Using higher frequencies results in less penetration of the eddy current field into the test part allowing full coverage of any surface-breaking discontinuities of the component to be examined. In addition, the higher frequencies provide a higher resolution for the detection of smaller defects. For this practice, a surface array probe, with the ability of detecting all surface discontinuities—including cracks, is required for a successful examination.

**3.2.3 reference standard, *n***—shall contain at least one long reference indicator to standardize all the channels of the array at once and also representative defects for flaw characterization during the examination.

**3.2.4 set screws, *n***—conformable and substantially nonconducting set screws on the probe that are used to allow small lift-off adjustments or excursions on surface response.

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

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

<sup>5</sup> Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

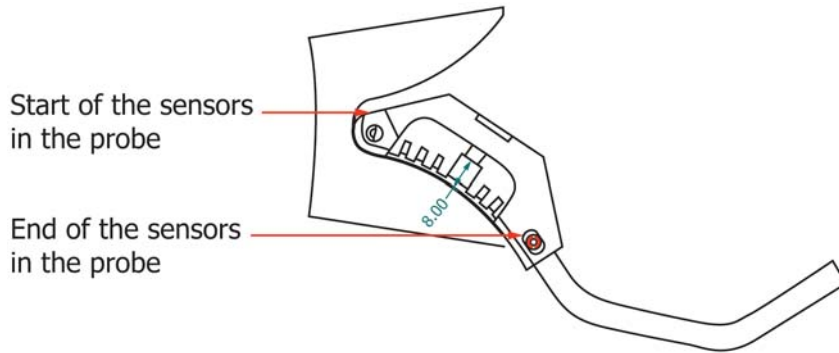


FIG. 2 Coverage of a Flexible Probe—Root, Dedendum, and Addendum

3.2.5.1 *Discussion—Probe Quality*—Probe life varies depending on the environmental conditions within the work area. Some of these environmental factors are temperature, moisture, cleanliness, and the main factor being surface roughness.

#### 4. Summary of Practice

4.1 *Gear-Cleaning Procedure*—Typically, mill operations performs the gear tooth cleaning. However, in some cases, the technicians performing the examination may be required to clean the gear as per [Appendix X2](#). Mill maintenance personnel are responsible for removing the guards for access to the gear teeth. Nondestructive examination (NDE) for mill and kiln girth gear examinations are provided for maintenance and as a part of an overall Reliability Centered Maintenance Program. Visual interpretation is the common method used by gear specialists to analyze gear tooth condition in-situ, such as contact patterns, scuffing, and wear patterns. However, visual examination is not recommended for crack detection. For a thorough visual examination, proper cleaning of the gear teeth is considered mandatory. Another reason for a cleaned gear tooth is that it is very hard for the ECA probe to maintain the geometry of a gear tooth that is covered with lubricant, especially if the lubricant is asphaltic-based or synthetic. If asphaltic or synthetic lubrication is used, refer to [Appendix X2](#) for cleaning procedures.

4.1.1 *ECA*—ECA is used for nondestructively locating and characterizing surface-breaking discontinuities in conducting materials to electrically conductive materials. For use in this practice, the properly designed ECA probe has proven to detect

all surface-breaking discontinuities from 0.76 mm [0.03 in.] and larger on the addendum, dedendum, and root of girth gear teeth. The examination is performed by scanning a conformable eddy current sensor array over the surface of the addendum, dedendum, and root of the gear tooth being examined in one pass. The drive side of the tooth is referred to as the A side and the nondrive side of the tooth is referred to as the B side of the tooth. The measured responses and location information are then used, typically in the form of a displayed image (C-scan), to determine the presence and characteristics of discontinuities.

4.1.2 *Alternating Current Field Measurement Method*—Alternating current field measurement is used if a crack is found. Alternative electromagnetic methods can also be used for sizing cracks.

4.1.3 *Alternating Current Field Measurement for Nondestructive Testing Detection and Sizing of Surface-Breaking Cracks*—It works on all metals, ferrous or nonferrous. A sensor probe is placed on the surface to be examined and an alternating current is induced into the surface. When no defects are present the alternating current produces a uniform magnetic field above the surface. Any defect present will perturb the current, forcing it to flow around and underneath the defect; this causes the magnetic field to become non-uniform and sensors in the alternating current field measurement probe measure these field variations. Two components of this magnetic field are measured—one provides information about the depth or aspect ratio of the defect(s) and the other shows the positions of the defects' ends. The two signals are used to



FIG. 3 Two Cracks on a Tooth Just Above the Root That Were Only Observed Visually After Being Revealed by the ECA Examination; In This Example, the Cracks Were Not Apparent Visually Until MT Was Performed



confirm the presence of a defect and, together with a sizing algorithm, measure its length and depth. The main advantages of alternating current field measurement for this practice are the speed of sizing cracks and that it provides both depth and length information. Defects up to 25 mm [1 in.] in depth can be sized accurately.

4.1.4 *Magnetic Particle Examination*—Magnetic particle is used when an indication is found. It is used to visualize the indication for the technician to make an assessment and document in the report. (See Fig. 3.) It is also used when excessive lift-off prevents the ECA probe from receiving a signal.

5. Significance and Use

5.1 Visual interpretation of gear teeth condition is different from examining for cracks or early signs of macro-pitting. Visual interpretation is referred to ASNI/AGMA 1010-F14.

5.1.1 The purpose of using an eddy current array for mill girth gear tooth examination is it drastically reduces the examination time; covers a large area in one single pass; provides real-time cartography of the examined region, facilitating data interpretation; and improves reliability and probability of detection (POD). One tooth can be examined in less than 30 seconds.

NOTE 3—In this standard, ECA is used as a discontinuity finding tool (see Fig. 3) and a presentation aid as support once problems are discovered and photographed. Colors and three-dimensional (3D) images (see Fig. 4) that help with visualization are invaluable in such circumstances.

5.1.2 The purpose of using alternating current field measurement is to size surface-breaking cracks electronically.

5.1.3 This practice is a useful tool for a condition-based monitoring program.

5.2 The examination results may then be used by qualified personnel or organizations to assess criticality or probability of failure, or both, or other engineering characteristics (beyond the scope of this practice). This practice is not intended for the

examination of non-surface-breaking discontinuities. Other methods are available to address this if required.

6. Basis of Application

6.1 The following item is subject to contractual agreement between the parties using or referencing this practice.

6.1.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally or internationally recognized 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.

7. Interferences—ECA

7.1 *Curvature of Examination Surface*—For gears or pinions with a pronounced involute profile, a flexible probe is required that can adjust its curvature to the various involute profiles. System performance verification tests should be run to verify lift-off sensitivity by adjusting the set screws in the face of the array probe.

7.2 *Surface Conditions*—Micropitting, macropitting, spalling, and so forth of gear teeth surfaces can be readily scanned with the ECA probe by adjusting the set screws to set a proper lift-off. Gear tooth surfaces shall be clean and free of any asphaltic or synthetic lubricant that could interfere with sliding of the ECA probe along the gear tooth surface.

7.3 *Pressure of the Probe Against Surface Under Examination*—Sliding the probe across the gear tooth is all the pressure that is required.

NOTE 4—The array probe has two set screws that allow for adjusting lift-off.

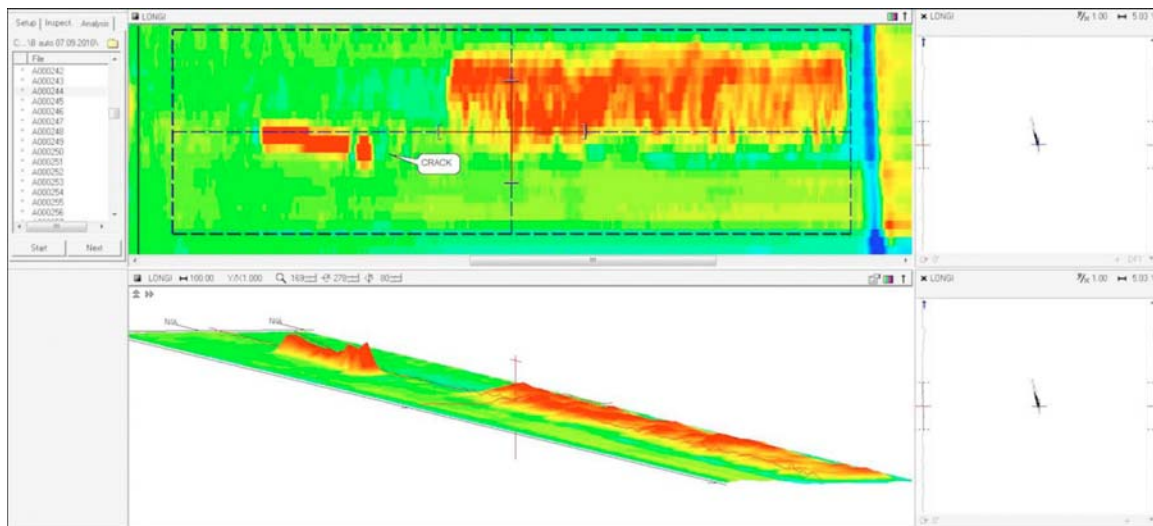


FIG. 4 Two- and Three-Dimensional View