INTERNATIONAL STANDARD

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Non-magnetic metallic coatings on metallic and non-metallic basis materials — Measurement of coating thickness — Phase-sensitive eddy-current method

Revêtements métalliques non magnétiques sur des matériaux de base métalliques et non métalliques — Mesurage de l'épaisseur de revêtement — Méthode par courants de Foucault sensible aux variations de phase

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the first edition (ISO 21968:2005), which has been technically revised. The main changes compared with the previous edition are as follows:

— this document has been adapted to the current requirements of ISO/IEC Guide 98-3 (also known as "GUM:1995");

— hints, practical examples and simple estimations of the measurement uncertainty for most important factors have been added;

— repeatability and reproducibility values for typical applications of the method have been added;

— the annex has been expanded with further applications and experimental estimations of factors affecting the accuracy.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Non-magnetic metallic coatings on metallic and non-metallic basis materials — Measurement of coating thickness — Phase-sensitive eddy-current method

1 Scope

This document specifies a method for using phase-sensitive eddy-current instruments for non-destructive measurements of the thickness of non-magnetic metallic coatings on metallic and non-metallic basis materials such as:

a) zinc, cadmium, copper, tin or chromium on steel;

b) copper or silver on composite materials.

The phase-sensitive method can be applied without thickness errors to smaller surface areas and to stronger surface curvatures than the amplitude-sensitive eddy-current method specified in ISO 2360, and is less affected by the magnetic properties of the basis material. However, the phase-sensitive method is more affected by the electrical properties of the coating materials.

In this document, the term "coating" is used for materials such as, for example, paints and varnishes, electroplated coatings, enamel coatings, plastic coatings, claddings and powder coatings.

This method is particularly applicable to measurements of the thickness of metallic coatings. These coatings can be non-magnetic metallic coatings on non-conductive, conductive or magnetic base materials, but also magnetic coatings on non-conductive or conductive base materials.

The measurement of metallic coatings on metallic basis material works only when the product of conductivity and permeability (σ, μ) of one of the materials is at least a factor of two times the product of conductivity and permeability for the other material. Non-ferromagnetic materials have a relative permeability of one.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2064, *Metallic and other inorganic coatings — Definitions and conventions concerning the measurement of thickness*

ISO 4618, *Paints and varnishes — Terms and definitions*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2064, ISO 4618 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
adjustment of a measuring system
set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured

Note 1 to entry: Types of adjustment of a measuring system can include zero adjustment of a measuring system, offset adjustment, and span adjustment (sometimes called gain adjustment).

Note 2 to entry: Adjustment of a measuring system should not be confused with *calibration* (3.2), which is a prerequisite for adjustment.

Note 3 to entry: After an adjustment of a measuring system, the measuring system shall usually be recalibrated.

Note 4 to entry: Colloquially the term "calibration" is frequently, but falsely, used instead of the term "adjustment". In the same way, the terms "verification" and "checking" are often used instead of the correct term "calibration".

[SOURCE: ISO/IEC Guide 99:2007, 3.11 (also known as "VIM"), modified — Note 4 to entry has been added.]

3.2
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Note 1 to entry: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: Calibration should not be confused with *adjustment of a measuring system* (3.1), often mistakenly called "self-calibration", nor with verification of calibration.

Note 3 to entry: Often, the first step alone in the above definition is perceived as being calibration.

[SOURCE: ISO/IEC Guide 99:2007, 2.39 (also known as "VIM")]

4   Principle of measurement

Phase-sensitive eddy-current instruments work on the principle that a high-frequency electromagnetic field generated by the probe system of the instrument will produce eddy currents in the coating on which the probe is placed and in the base material beneath the coating in case this base material is conductive (see Figure 1). These induced currents cause a change of the electromagnetic field surrounding the probe coil system and therefore result in a change of the amplitude and the phase angle of the probe coil impedance. The induced eddy-current density is a function of the coating thickness, the conductivity of the coating material, the used frequency of the probe system and the base metal conductivity. If the thickness of a coating of constant conductivity is increased for a given frequency, the impedance vector describes a so-called local function of the thickness in the impedance plane (see Figure 2). Each point of this local curve connects a phase angle of the impedance vector with the respective coating thickness. Consequently, this impedance angle (phase shift) can be used as a measure of the thickness of the coating on the conductor by means of a calibration with reference standards (see also Annex A).

In order to measure a change of the coil impedance phase angle, the test coil is usually part of a coil system and is coupled with the exciting coil on one ferrite core such as in a transformer (see Figure 1). The changes of phase angle and amplitude due to the impact of the induced eddy currents can be measured, for example, using a lock in amplifier. These values are usually pre-processed by digital means and the resulting thickness is then calculated and displayed.