**SLOVENSKI STANDARD**
# oSIST prEN ISO 21968:2018

**01-december-2018**

---

**Nemagnetne kovinske prevleke na kovinskih in nekovinskih osnovnih materialih - Merjenje debeline nanosa prevleke - Metoda vrtinčnih tokov (ISO 21968:2005)**

Non-magnetic metallic coatings on metallic and non-metallic basis materials - Measurement of coating thickness - Phase-sensitive eddy-current method (ISO/DIS 21968:2018)



Nichtmagnetische metallische Überzüge auf metallischen und nichtmetallischen Grundwerkstoffen - Messung der Schichtdicke - Phasensensitives Wirbelstromverfahren (ISO/DIS 21968:2018)



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 (ISO/DIS 21968:2018)

**Ta slovenski standard je istoveten z:** **prEN ISO 21968**

---

**ICS:**

| | | |
|---|---|---|
| 25.220.40 | Kovinske prevleke | Metallic coatings |

**oSIST prEN ISO 21968:2018** **en**

DRAFT INTERNATIONAL STANDARD

# ISO/DIS 21968

ISO/TC **107** Secretariat: **KATS**

Voting begins on: **2018-10-08** Voting terminates on: **2018-12-31**

# 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*

ICS: 25.220.40





This document is circulated as received from the committee secretariat.

**ISO/CEN PARALLEL PROCESSING**

Reference number
ISO/DIS 21968:2018(E)

# Contents

Page





# 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 on 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 the following URL: www.iso.org/iso/foreword.html.



The committee responsible for this document is ISO/107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the firstedition (ISO 21968:2005), which has been technically revised with changes as follows.

— adaption of this document to the current requirements of ISO/IEC Guide 98 3 (GUM:1995);

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

— inclusion of a repeatability and reproducibility values for typical applications of this method;

— expansion of the Annex with further applications, experimental estimations of factors affecting the accuracy;

— editioriel amendments according to the current ISO directives part 2.

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:

1. zinc, cadmium, copper, tin or chromium on steel;

2. 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.

When measuring metallic coatings on metallic basis material, the product of conductivity and permeability ($\sigma, \mu$) of one of the materials should be at least a factor of 2 times the product of conductivity and permeability for the other material. Non-ferromagnetic materials have a relative permeability of 1.

## 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 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles 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 and ISO 4618 and the following apply.

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

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

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

**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: Adjustment of a measuring system can include zero adjustment, offset adjustment, and span adjustment (sometimes called gain adjustment).

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

Note 3 to entry: After an adjustment of a measuring system, the measuring system must 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, 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

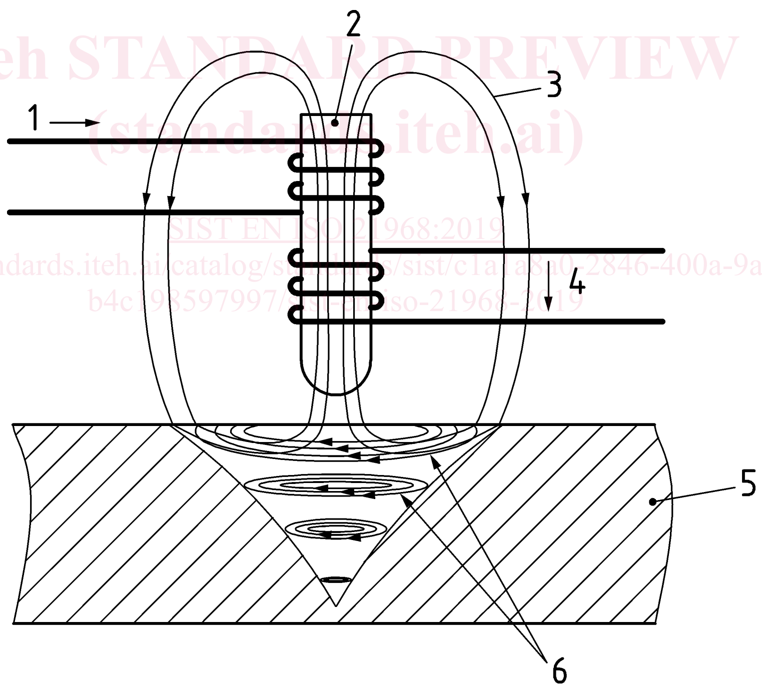
Phase-sensitive eddy current instruments work on the principle that a high frequency electromagnetic field generated by the probe system of the instrument will produce eddy currents in the coating on which the probe is placed and in the base material beneath the coating in case this base material is 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 coupled with the exciting coil on one ferrite core like 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 e.g. using a lock in amplifier. These values are usually pre-processed by digital means and the resulting thickness is then calculated and displayed.

The probe and measuring system/display may be integrated into a single instrument.

NOTE 1 Annex C describes the basic performance requirements of the equipment.

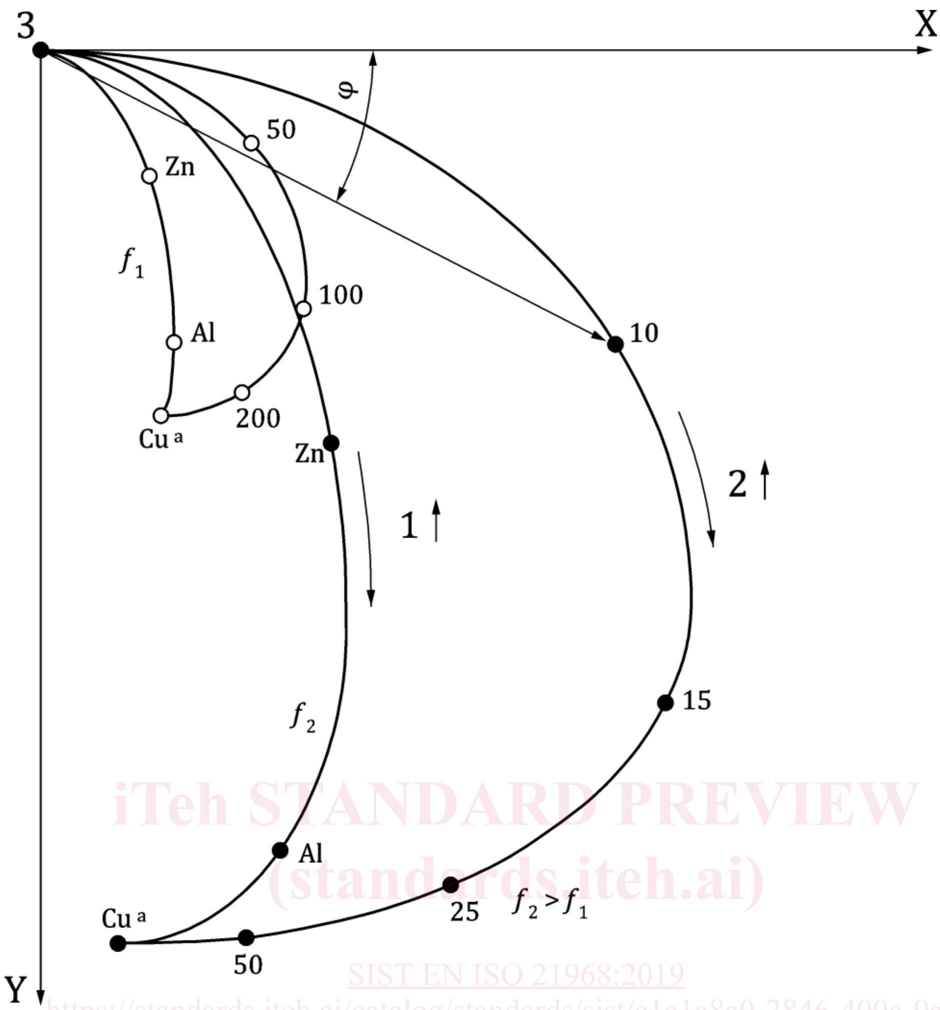
NOTE 2 Factors affecting measurement accuracy are discussed in Clause 5.




**Key**

1 exiciting current
2 ferrit core of probe
3 high frequency alternating magnetic field
4 measured signal U=f(t(φ))
5 induced eddy currents
6 base material (conductive)

**Figure 1 — Phase-sensitive eddy current method**






**Key**

—○— thickness local curve of Cu for the frequence $f_1$

—●— thickness local curve of Cu for the frequence $f_2$

1 conductivity 2 thickness 3 coil air (unaffected)

X real part

Y imaginary part

**Figure 2 — thickness local curve of Cu in the normalized impedance plane for two frequencies $f_1$ and $f_2$**

For each instrument there is a maximum measurable thickness of the coating.

Since this thickness range depends on both the applied frequency of the probe system and the electrical conductivity of the coating, the maximum thickness should be determined experimentally, unless otherwise specified by the manufacturer.

An explanation of eddy current generation and the calculation of the maximum measurable coating thickness, $t_{max}$, is given in Annex A.

However, in the absence of any other information, the maximum measurable coating thickness, $t_{max}$, can be estimated using formula (1).

$$t_{max} \approx 0{,}8 \cdot \delta_0 \quad (1)$$

where

$\delta_0$ is the standard penetration depth of the coating material (see Annex A).

# 5 Factors affecting measurement uncertainty

## 5.1 Basic influence of the coating thickness

The sensitivity of a probe, i.e. the measurement effect depends on the used frequency, the conductivity of the coating and the base material, and the properties of the probe system. The resulting uncertainty of the thickness depends besides properties of the probe system on the sample materials, e.g. the homogeneity of the coating and base metal conductivity and roughness.

## 5.2 Electrical properties of the coating

The conductivity of the coating but also of the base material determine the induced eddy current density for a given probe system and frequency. Consequently, the coating and base metal conductivity cause the measurement effect for this method. The relationship between coating thickness and the measured value depends strongly on the conductivity of both the coating and base material. Consequently, calibration procedures and measurements shall be made on the same material. Different materials with different conductivities as well as local fluctuations of the conductivity or variations between different samples can cause (more or less) errors in the thickness reading.



## 5.3 Geometry: base material thickness

In case of a conductive base material (base metal) the generation of eddy currents by the coil's magnetic field in the depth of the base metal is obstructed if the base metal thickness is too small. This influence can only be neglected above a certain critical minimum base metal thickness.

Therefore, the thickness of the base metal should always be higher than this critical minimum base metal thickness. An adjustment of the instrument can compensate for errors caused by thin base metal. However, any variation in thickness of the base metal can cause increased uncertainty and errors.

The critical minimum base metal thickness depends on both the probe system (frequency, geometry) and the conductivity of the coating and the base metal. Its value should be determined experimentally, unless otherwise specified by the manufacturer.

NOTE A simple experiment to estimate the critical minimum base metal thickness is described in Annex D.

However, in the absence of any other information, the required minimum base metal thickness, $t_{min}$, can be estimated from Formula (2).

$$t_{min} = 3 \cdot \delta_0 \quad (2)$$

where

$\delta_0$ is the standard penetration depth of the base metal (see Annex A).

In case of a non-conductive and non-magnetic base material the base material thickness does not affect the measurement results and consequently it must not be considered as an influencing factor.

## 5.4 Geometry: edge effects

The induction of eddy currents is obstructed by geometric limitations of the coating (e.g. edges, drills and other). Therefore, measurements made too near to an edge or corner may not be valid unless the instrument has been specifically adjusted for such measurements. The necessary distance in order to avoid an impact of the edge effect depends on the probe system (field distribution).

NOTE 1 A simple experiment to estimate the edge effect is described in Annex D.

NOTE 2 Amplitude-sensitive eddy current instruments as described in ISO 2360 can be substantially more affected by edge effects.

## 5.5 Geometry: surface curvature

The propagation of the magnetic field and consequently the induction of eddy currents are affected by the surface curvature of the coating and the base material. This influence becomes more pronounced with decreasing radius of the curvature and decreasing coating thickness. In order to minimize this influence an adjustment should be performed on a sample with the same geometry.

The influence of surface curvature depends considerably on the probe geometry and can be reduced by reducing the sensitive area of the probe. Probes with very small sensitive areas are often called microprobes.



NOTE 1 There are instruments and probes available that are capable of automatically compensating the sample surface curvature influence if the curvature diameter is known. They can avoid the resulting thickness error.



NOTE 2 A simple experiment to estimate the effect of surface curvature is described in Annex D.

## 5.6 Surface roughness

Measurements are influenced by the surface topography of the coating and can also be influenced by the surface topography of a conductive base metal. Rough surfaces can cause both systematic and random errors. Random errors can be reduced by making multiple measurements, each measurement being made at a different location, and then calculating the average value of that series of measurements.

In order to reduce the influence of roughness, a calibration should be carried out with reference parts with a roughness equivalent to the coated sample.

If necessary, the definition of the average coating thickness that is used should be stated between supplier and client.

NOTE Amplitude-sensitive eddy current measurement as described in ISO 2360 can be more affected by base metal roughness.

## 5.7 Lift-off effect

If the probe is not placed directly onto the coating, the gap between probe and coating (lift-off) will affect the measurement of the metal coating thickness. The strength of the lift-off effect depends on the probe design and the resulting field geometry. By the use of appropriate electronic circuit design