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Geometrical product specifications (GPS) — Surface texture: Areal —

Part 700: **Calibration, adjustment and verification of areal topography measuring instruments**

Spécification géométrique des produits (GPS) — État de surface: Surfacique —

Partie 700: Étalonnage, réglage et vérification d'instruments de mesure de topographie de surface

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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.

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Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences the chain link F of the chains of standards on areal surface texture and profile surface texture.

The ISO/GPS matrix model given in ISO 14638 gives an overview of the ISO/GPS system of which this document is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to the specifications made in accordance with this document, unless otherwise indicated.

For more detailed information of the relation of this document to other standards and the GPS matrix model, see Annex A.

In the GPS concept the design values of geometric parameters on workpieces and their tolerances are compared with the measurement of those parameters on the corresponding manufactured workpieces and their associated measurement uncertainties. For a reliable result it is therefore necessary to calibrate the measurement instrument involved in this process. Calibration realizes an unbroken traceability chain of the concerned values to worldwide accepted common reference unit values. In this standard calibration strictly means the determination of the measurement deviation from the reference value. In common language calibration is often used for the combination of the operations "calibration" and "adjustment".

This standard describes the calibration, see ISO/IEC Guide 99:2007, 2.39, adjustment, see ISO/IEC Guide 99:2007, 3.11 and verification, see ISO/IEC Guide 99:2007, 2.44, in general for topography measuring instruments.

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Metrological characteristics defined in ISO 25178-600 are connected with results of measurement executed with topography measuring instruments. So, it is necessary to have the instrument in a calibrated state, which guarantees the traceability of the measurement results. The calibration is the basis for possible correction by adjustment of the instrument and the verification after the adjustment. The residual deviation after verification can be used as a contribution to the measurement uncertainty, which enables one to quantify the characteristics in a traceable way.

The metrological characteristics capture all of the factors that can influence a measurement result (influence quantities) and can be propagated appropriately through a specific measurement model to estimate measurement uncertainty. Also, in ISO 25178 parts 60X, influence quantities are defined for each instrument type. These influence quantities are given to show how they affect the metrological characteristics and are not needed for uncertainty estimation if the metrological characteristics are properly used in the measurement model.

This document describes default procedures for instrument calibration, adjustment, and verification when using material measures traceable to the meter through a national metrology institute or qualified laboratory, see ISO/IEC Guide 99:2007, 2.41. Default methods are recommended when no other calibration procedures have been clearly defined.

Alternative calibration techniques with clear traceability path are equally acceptable, depending on the capabilities of the instrumentation, see 5.1 and 5.3.3. Example techniques include those based on an independent realization of the meter using a natural emission wavelength, the value for which has been established with a known uncertainty.

Specific influences caused for example by environmental conditions are not considered. However, these must be considered by the user working under such environmental conditions.

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Geometrical product specifications (GPS) — Surface texture: Areal —

Part 700:
Calibration, adjustment and verification of areal topography measuring instruments

1 Scope

This part of ISO 25178 specifies generic procedures for the calibration, adjustment and verification of areal topography measuring instruments defined in ISO 25178-6, and for the determination of their metrological characteristics. This part of ISO 25178 considers metrological characteristics that topography measuring instruments have in common, notably those described in ISO 25178, Parts 601 to 607. Collectively, those standards encompass both microscope based instruments and point sensing instruments with lateral scanning devices.

This document presents a method to estimate uncertainty for a large range of surfaces, but not all. The range of surfaces will be dependent on the instrument used, see Clause 6.6.2 describing the topography fidelity.

For instrument specific principles, other parts may be developed in the 700 series of ISO 25178.

For example, this document covers only instruments without additional arcuate motion, which may be described in a future revision of the ISO 25178-701.

This document does not include procedures for area-integrating methods, although those are also defined in ISO 25178-6. For example, light scattering belongs to a class of techniques known as area-integrating methods for measuring surface topography.

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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 230-10, *Test code for machine tools — Part 10: Determination of the measuring performance of probing systems of numerically controlled machine tools*

ISO 3274:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 5436-1, *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Measurement standards — Part 1: Material measures*

ISO 5436-2, *Geometrical product specifications (GPS) — Surface texture: Profile method; Measurement standards — Part 2: Software measurement standards*

ISO 8015, *Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules*

ISO 10360-7, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 7: CMMs equipped with imaging probing systems*

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ISO 10360-8, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 8: CMMs with optical distance sensors*

ISO 11952, *Surface chemical analysis — Scanning-probe microscopy — Determination of geometric quantities using SPM: Calibration of measuring systems*

ISO 14253-1, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for verifying conformity or nonconformity with specifications*

ISO 14253-5, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 5: Uncertainty in verification testing of indicating measuring instruments*

ISO 14406:2010, *Geometrical product specifications (GPS) — Extraction*

ISO 14638, *Geometrical product specifications (GPS) — Matrix model*

ISO 14978:2006, *Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 17450-1:2011, *Geometrical product specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

ISO 25178-2:2012, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 2: Terms, definitions and surface texture parameters*

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ISO 25178-3:2012, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 3: Specification operators*

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ISO 25178-6:2010, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 6: Classification of methods for measuring surface texture*

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ISO 25178-70:2013, *Geometrical product specification (GPS) -- Surface texture: Areal -- Material measures*

ISO 25178-71, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 71: Software measurement standards*

ISO 25178-72, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 72: XML file format x3p*

ISO 25178-73:2020, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 73: Terms and definitions for surface defects on material measures*

ISO 25178-600:2020, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 600: Metrological characteristics for areal topography measuring methods*

ISO 25178-601:2010, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 601: Nominal characteristics of contact (stylus) instruments*

ISO 25178-603, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 603: Nominal characteristics of non-contact (phase-shifting interferometric microscopy) instruments*

ISO 25178-604:2013, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 604: Nominal characteristics of non-contact (coherence scanning interferometry) instruments*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3274, ISO 4287, ISO 5436-2, ISO 10360-1, ISO 14406, ISO 14638, ISO 14978, ISO 17450-1, ISO 25178-2, ISO 25178-6, ISO 25178-70, ISO 25178-71, ISO 25178-72, ISO 25178-73 and ISO 25178-600, ISO 25178-601, ISO 25178-603,

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ISO 25178-604 and the following terms and definitions related to the calibration, verification and uncertainty calculation of all areal surface topography measurement principles 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 General metrological definitions

3.1.1
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 is not to be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of calibration.

Note 3 to entry: For the overall calibration of a topography measuring instrument, individual evaluations of the individual metrological characteristics, each with a result and an assigned uncertainty, are needed.

Note 4 to entry: Calibration is performed to establish traceability of a measurement.

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3.1.2
adjustment
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 is not to be confused with calibration, which is a prerequisite for adjustment.

Note 2 to entry: Adjustment is principle specific and typically performed by the instrument manufacturers and therefore no binding rules are given in ISO 25178-700.

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

3.1.3
verification
<topography measuring instruments> provision of objective evidence that a metrological characteristic fulfils stated specifications

Note 1 to entry: Verification procedures are used to demonstrate the validity of the calibration after adjustment.

Note 2 to entry: However, in ISO 17450 (GPS-General Concepts) verification is associated with the measurement results of a manufactured part in relation to its requirement.

3.1.4
performance specification
<topography measuring instruments> explicit set of requirements to be satisfied by a topography measuring instruments

Note 1 to entry: The emphasis here is on a set of characteristics that describe the requested, agreed or claimed behaviour of a topography measuring instrument. Each characteristic is associated with a measurand.

Note 2 to entry: However, in other GPS-documents (e.g. ISO 17450-1, ISO 14638) specifications are associated with requirements on manufactured work-pieces.

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3.1.5
validation
<topography measuring instruments> provision of objective evidence that instruments with specified requirements are adequate for an intended use

EXAMPLE 1 Validation may refer to a modified measurement process to demonstrate that one type of instrument can be used in place of another type of instrument for a particular type of topography measurement.

EXAMPLE 2 Repeatability and reproducibility tests are often used as elements of a validation test.

Note 1 to entry: See also ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*, 2.45[1].

3.2 Measurement related terms and definitions

3.2.1
correction factor
factor used to correct the scaling of a measurement axis

Note 1 to entry: The correction factor is the inverse of the amplification coefficient (see ISO 25178-600, 2020) .

3.2.2
non-measured points
data for which no measured values exist

3.2.3
spurious data
points that have been qualified as measurable by the measurement principle, but deviate significantly from the value, which is the most likely value based on a priori knowledge. Spurious data maybe single points or a small group of points that have been classified as measurable by the measurement instrument. They are identified as spurious data by a priori knowledge about the expected surface with their difference between the expected surface and the measured surface

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Note 1 to entry: For example, spurious data can be outliers or spikes.

Note 2 to entry: Spurious data can be caused by environmental conditions, for example by vibration, sun light, or by interaction of surface and instrument.

4 Symbols and abbreviated terms

The metrological characteristics are defined in ISO 25178-600. The metrological characteristics may show interdependencies.

5 Calibration, adjustment and verification of an instrument

5.1 General

In practice calibration of the instrument refers to a series of operations required to establish the contribution of the metrological characteristics to the measurement uncertainty associated with the instrument measurements. Table 1 contains the full list of metrological characteristics.

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Table 1 — List of metrological characteristics for surface topography measurement principles

Metrological characteristic [a]	Symbol	Reference in ISO 25178-600:2018	Main potential error along
Amplification coefficient	$\alpha_x, \alpha_y, \alpha_z$	3.1.10 (see Figure 2)	x, y, z
Linearity deviation	l_x, l_y, l_z	3.1.11 (see Figure 2)	x, y, z
Flatness deviation	z_{FLT}	3.1.12	z
Measurement noise	N_M	3.1.15	z
Topographic spatial resolution	W_R	3.1.20	z
x-y mapping deviations [a]	$\Delta_x(x,y), \Delta_y(x,y)$	3.1.13	x, y
Topography fidelity	T_{Fi}	3.1.26	x, y, z

NOTE The maximum measurable slope is an important limitation to be specified for a topography measuring instruments. However, a user does not need to measure this parameter unless it is part of a measurement model according ISO/IEC Guide 98-3:2008, Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995): 2008, Clause 4.1[2].

[a] Depending on the measurement application, other axis motion errors (see ISO 230-10 and ISO 10360-7 and ISO 10360-8) may also be significant but are not listed here for topography measurements classified as measurable by the measurement instrument. They are identified as spurious point by a priori knowledge about the expected surface with their difference between the expected surface and the measured surface.

This document defines default methods for calibration. It also describes the general principle for adjustment, verification and performance specification, see Figure 1. Other methods used for calibration shall meet the requirements given in the relevant part of ISO 10360 and shall be noted and validated.

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NOTE 1 Determination of the metrological characteristics is not intended to assess the errors due to the calibration and computational algorithms. These algorithms can be verified using software measurement standards, see ISO 5436-2, ISO 25178-71 and ISO 25178-72.

NOTE 2 Performance specifications are typically provided by instrument manufacturers.

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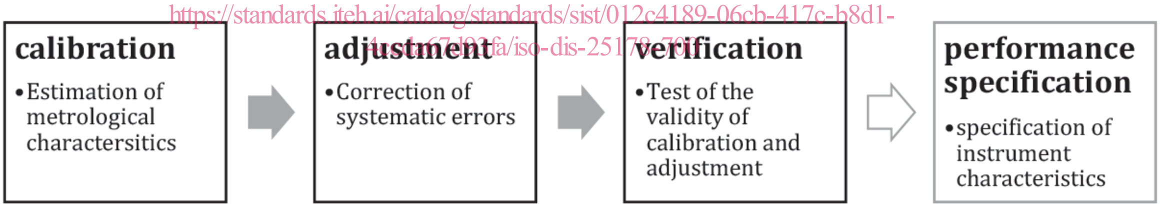

NOTE 1 If no adjustment is necessary, the initial calibration constitutes the verification. In this case the calibration result contributes to the measurement uncertainty calculation.

NOTE 2 If adjustment is done, verification can be done by a subsequent calibration after adjustment. In this case the new result contributes to the measurement uncertainty calculation.

Figure 1 — Flow chart of calibration, adjustment and verification procedure

5.2 Use of the methods for calibration, adjustment and verification

Methods are defined here for amplification, linearity deviation, noise, flatness, and x-y mapping deviations. For each of these metrological characteristics a method for the determination of its value is defined. Dependent on the characteristics these methods can be used both to calibrate and to verify after adjustment.

No defaults are defined for perpendicularity of the instrument z-axis with respect to the x-y areal reference, topographic spatial resolution and the topography fidelity.

NOTE 1 Topography induced influences on measurement uncertainty as the topography fidelity, the instrument transfer function or slope dependencies are listed in Clause 7.

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NOTE 2 The methods for determination of metrological characteristics are described in Clause 6.

5.3 Instrument calibration procedure

5.3.1 Calibration by measurement standards

The use of measurement standards is the default procedure. Calibrated measurement standards, as defined in ISO 25178-70:2014, shall be used during the determination of the metrological characteristics of the instruments. The deviation from the values stated in the calibration certificate shall be recorded, and the uncertainty of the calibration values shall be taken into account. The measurement standards shall be selected by taking into account the characteristics of the surface to be measured.

NOTE 1 The requirements for the material measures are described in ISO 25178-70:2014, Clause 5 and for contact (stylus) instruments in ISO 25178-701:2010, Clause 5.2.1.2.

NOTE 2 Optical flats do not need to be calibrated for the use described in 6.5.1.

5.3.2 Measurement procedures for calibration with measurement standards

Measurement procedures specified on the calibration certificate of the measurement standard should be adhered to whilst using it for the determination of metrological characteristics.

5.3.3 Calibration by other methods

According to ISO/IEC 17025 other procedures for calibration may also be employed. These procedures should be reported and validated.

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5.4 Calibration conditions

Determination of the metrological characteristics shall be performed for each individual instrument and each instrument setup (configuration) used in practice. Stationary environmental conditions shall be similar to typical working conditions. The evaluation software shall be the same as it is used in practice.

Calibration for determining instrument specification should be done under the best available environmental conditions.

NOTE 1 The instrument setup (configuration) is generally application specific.

NOTE 2 Dynamic environmental conditions like vibrations may have a more significant influence on the uncertainty calculation.

EXAMPLE Examples of different setups (configurations):

- Use of objectives with different magnifications
- Use of different stylus tip radii
- Use of different scanning directions
- Use of different scanning speeds
- Different (stationary) environmental conditions, such as temperature

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