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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, ajustage et vérification d'instruments de mesure de la topographie des surfaces

Reference number
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Foreword

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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).

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This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and verification*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 25178 series can be found on the ISO website.

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.

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 chain links E, F and G of the chains of standards on profile surface texture and areal 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.

This document specifies default procedures for the calibration, adjustment and verification of surface topography measuring instruments, 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.

This document 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.

The calibration of an instrument's metrological characteristics enables the verification of the instrument's specifications when the specifications are based on these metrological characteristics. This also enables the comparison of systems of different manufacturers that may be based on different measurement principles.

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.

Calibration is a part of the determination of the overall uncertainty of measurement. The complete evaluation of measurement uncertainty may include other factors such as operator variability, changing environmental influences, the effects of thermal and mechanical stresses on the sample part and other factors that are not accounted for in the instrument calibrations.

Alternative calibration techniques to the defaults given here are equally acceptable, depending on the capabilities of the instrumentation and provided those alternatives have clear traceability paths. 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.

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

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

1 Scope

This document specifies generic procedures for the calibration, adjustment and verification of metrological characteristics that areal topography measuring instruments have in common, as stated in ISO 25178-600.

Because surface profiles can be extracted from surface topography images, most of the methods described in this document can be adapted to profiling instruments.

Instrument-specific issues are not covered by this document. For example, for instruments based on mechanical probing where the probe follows an additional arcuate motion, additional measures are specified in ISO 25178-701.

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

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 25178-600:2019, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 600: Metrological characteristics for areal topography measuring methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
non-measured points
surface locations for which no valid measured values exist

Note 1 to entry: The handling of non-measured points is specified in 6.3.

Note 2 to entry: Non-measured points may be caused by a feature of the measuring instrument or by a defect on the surface of the measurement standard which is outside the range of the instrument.

3.2
spurious data
data that have been qualified as measurable by the measurement principle but deviate significantly from a reasonable value range, based on a priori knowledge

Note 1 to entry: Spurious data may relate to 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 determining their values to be unlikely based on a priori knowledge about both the expected surface and the instrument, or simply by defects and contamination on the surface. Spurious data may appear as outliers or spikes.

Note 2 to entry: Spurious data can be caused by environmental conditions, such as vibration or external light sources, by interaction between the surface and instrument, or simply by defects and contamination on the surface. Spurious data may appear as outliers or spikes.

Note 3 to entry: The handling of spurious data is specified in 6.4.

3.3
measurement noise
N_M
noise added to the output signal occurring during the normal use of the instrument

[SOURCE: ISO 25178-600:2019, 3.1.15, modified — Notes to entry removed.]

3.4
instrument noise
N_I
internal noise added to the output signal caused by the instrument if ideally placed in a noise-free environment

[SOURCE: ISO 25178-600:2019, 3.1.14, modified — Notes to entry removed.]

3.5
***z*-linearity deviation**
l_z
maximum local linearity difference between the line from which the amplification coefficient is derived and the response function

[SOURCE: ISO 25178-600:2019, 3.1.11, modified — Term revised and note to entry removed.]

3.6
instrument transfer function curve
f_{ITF}
curve describing an instrument's height response as a function of the spatial frequency of the surface topography

[SOURCE: ISO 25178-600:2019, 3.1.19, modified — Term revised and notes to entry removed.]

3.7
topography fidelity
T_{FI}
closeness of agreement between a measured surface profile or measured topography and one whose uncertainties are insignificant by comparison

[SOURCE: ISO 25178-600:2019, 3.1.26, modified — Note to entry removed.]

4 Symbols and abbreviated terms

The metrological characteristics for areal topography measuring methods and associated symbols and abbreviated terms are defined in ISO 25178-600. Table 1 contains a list of these metrological characteristics.

Table 1 — List of metrological characteristics for surface texture measurement methods[a]

Metrological characteristic (and clause in this document)	Symbol	Clause and figure in ISO 25178-600:2019 containing definition	Main potential error along (ISO 25178-600:2019, 3.1.2)
Amplification coefficient (6.7)	α_x, α_y, α_z	3.1.10 (Figure 2)	*x*, *y*, *z*
Linearity deviation (6.8)	l_x, l_y, l_z	3.1.11 (Figure 2)	*x*, *y*, *z*
Flatness deviation (6.6)	z_{FLT}	3.1.12	*z*
Measurement noise (6.5)	N_M	3.1.15	*z*
Topographic spatial resolution (6.11)	W_R	3.1.20	*z*
x-y mapping deviations (6.9)	$\Delta_x(x,y)$, $\Delta_y(x,y)$	3.1.13	*x*, *y*
Topography fidelity (6.12)	T_{FI}	3.1.26	*x*, *y*, *z*

NOTE 1 Depending on the measurement application, other axis motion errors (see ISO 230-1, ISO 10360-7 and ISO 10360-8) can also be significant but are not listed here for surface texture measurement.

NOTE 2 The maximum measurable slope is an important limitation to be specified for a surface topography measurement instrument. However, users do not need to measure this parameter unless it is part of a measurement model.

[a] Adapted from ISO 25178-600:2019, Table 1.

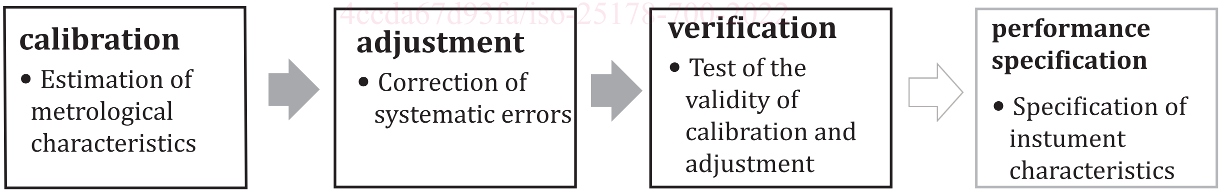
5 Calibration, adjustment and verification of an instrument

5.1 General

This document defines default methods for calibration. It also specifies the general principle for adjustment, verification and determining performance specifications, see Figure 1. Other methods used for calibration shall meet the requirements as specified here and shall be specified.

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

If adjustment is done, verification may be done by a subsequent calibration after adjustment.



NOTE The white arrow indicates the possible subsequent comparison with specifications.

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

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 25178-71 and ISO 25178-72.

NOTE 2 Performance specifications are typically provided by instrument manufacturers.

5.2 Methods for calibration, adjustment and verification

In this document, methods are defined for noise (6.5), flatness deviation (6.6.2), amplification (6.7.2), linearity deviation (6.8.3) and *x-y* mapping deviations (6.9.2). For each of these metrological characteristics a method for the determination of its value is defined. Depending on the characteristics these methods can be used both to calibrate and to verify after adjustment.

No default methods are defined for perpendicularity of the instrument *z*-axis with respect to the *x-y* areal reference (6.10), topographic spatial resolution (6.11) and topography fidelity (6.12).

5.3 Instrument calibration procedure

5.3.1 Calibration by measurement standards

The default procedures all include the use of material measures. Calibrated measurement standards, as defined in ISO 25178-70, 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 (calibrated material measures) 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 and for contact (stylus) instruments in ISO 25178-701:2010, 5.2.1.2.

NOTE 2 Optical flats do not need to be calibrated for the determination of noise as specified in 6.5.

5.3.2 Handling of defects on material measures

Measurement standards without defects should be selected as a first preference. In all cases, however, the possibility of surface defects (in the sense of ISO 25178-73:2019, 3.1.2) shall be addressed when a physical measurement standard is used for calibration tasks. Defects shall be identified or described in accordance with ISO 25178-73:2019, 3.2. Measurement records shall include a statement on the selected response to any encountered surface defects (ISO 25178-73:2019, 3.3), paying attention to the distinction between effective and ineffective defects. If it is not possible to plan valid measurements for a task on a defective standard, that standard shall not be used for that task.

For brevity, such defect-response statements may refer to procedures stated on the calibration certificate of the measurement standard or other suitable documentation from the supplier.

NOTE The supplier of the defective measurement standard will possibly be able to supply an alternative calibration certificate and/or associated measurement procedure that are compatible with the observed defects, allowing valid measurements to be planned without repair or replacement of the standard.

5.3.3 Measurement procedures for calibration with measurement standards

Measurement procedures specified on the calibration certificate of the measurement should be adhered to as closely as possible while using it for the determination of metrological characteristics.

5.3.4 Calibration conditions

Determination of the metrological characteristics shall be performed for each individual instrument and each instrument setup (configuration) used in practice. Environmental conditions shall be similar to working conditions for subsequent measurement activity for that instrument. The selection and configuration of evaluation software shall be the same as that used in practice.

Calibration for determining instrument specification shall be done under documented measurement conditions and these conditions shall be reported (see ISO/IEC 17025:2017, 6.3).

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

EXAMPLE Examples of different setups (configurations):

— use of objective lenses with different magnifications;

— use of different stylus tip radii;

— use of different scanning directions;

— use of different scanning speeds;

— different environmental conditions, such as a significantly different temperature.

6 Determination of the metrological characteristics of the instrument

6.1 General

The metrological characteristics of the instrument that may influence the measurement result and the evaluated measurement uncertainty shall be determined:

— within the measurement volume defined for the intended application;

— at different positions within the measurement volume, if applicable;

— according to an agreed or accepted measurement scheme;

— for different scanning speeds or directions, if applicable.

General measurement schemes are given in the following clauses and more detailed measurement schemes may be specified for each measuring principle.

6.2 Reporting of the measurement conditions

Measurement conditions, relevant instrument settings and environmental conditions may influence the metrological characteristics and shall be reported. Potential disturbances, such as acoustic noise, vibration or lighting conditions, shall be reported but may be described qualitatively.

NOTE 1 Examples of instrument settings and environmental conditions include: temperature; humidity; internal illumination configuration; scan increment; scan speed for scanning instruments (see ISO 25178-604:2013, 2.5.12 and 2.5.13).

NOTE 2 Example phrases for qualitative reporting include “No vibrations or strong vibrations” and “no disturbance by external illumination”; see also 6.5.2.

6.3 Handling of non-measured points

By default, no interpolation and filling of non-measured points within the relevant areas is applied for the determination of the metrological characteristics. However, if interpolation and filling is applied, it shall be reported. Measurements for which a significant number of the points are non-measured should be discarded. Interpolation or other mathematical algorithms shall not change the status of non-measured points to measured points.

6.4 Handling of spurious data and outliers

Depending on a priori knowledge and later applications, spurious data within the region of interest should be removed from the measured points and should be treated in the same way as non-measured points, as specified in 6.3.

6.5 Metrological characteristic: measurement noise, N_M, and instrument noise, N_I

6.5.1 General

The instrument noise is the minimum achievable noise under the most ideal circumstances.

Evaluation of instrument noise shall be performed under the best conditions for the characterization of instrument performance, see ISO 25178-600.

For some instruments, instrument noise cannot be completely separated from other types of measurement noise because the instrument only acquires data while moving. If so, any measured noise includes a dynamic component. See also static noise (ISO 25178-600: 2019, 3.2.6) and dynamic noise (ISO 25178-600: 2019, 3.2.7).

6.5.2 Determination of measurement and instrument noise: application of filters or operators

In applications where filters or operators are used, the measurement noise determination should proceed under the same filter conditions as those used for measurements. The used filters with the applied nesting indices and the used operators shall be reported.

A quantitative statement of measurement noise shall include any filters that may influence the spatial frequencies over which the noise is determined.

An instrument noise specification shall include the relevant data acquisition time, the number of independent data points and any spatial or temporal filters that may influence the spatial frequencies over which the noise is determined (see Reference [19]).

NOTE The S-filter as a low-pass filter reduces the noise but can affect the topographic spatial resolution if this resolution is limited by the lateral sampling. When estimating the noise for the highest lateral resolution, it can be preferable to perform measurements without applying an S-filter.

EXAMPLE In a specification sheet a quantitative statement of instrument noise can be indicated as follows: full measurement area, 1 s data acquisition (at 10 averages per second) and a 3 × 3 pixel median filter.

6.5.3 Determination of measurement and instrument noise: material measures for instrument and measurement noise estimation

The default material measure for instrument noise determination should be one that:

— is compatible with the instrument measurement principle;

— has a smooth and flat surface;

— has surface properties that give an optimum signal-to-noise ratio.

By default, this material measure shall be optically aligned so that a minimum measurement range of the instrument is used. Material measures with an antireflection coating for optical measurements or those causing stick-slip during mechanical measurement may not provide an optimum signal-to-noise ratio. Other types of surfaces can also be used if specified. For example, a minimum amount of roughness may be required for measurement principles such as focus variation microscopy.

The evaluation of the measurement noise is best performed on the surface to be measured on a workpiece under inspection or on a representative sample with similar surface features to the workpiece surface.

EXAMPLE Type AFL material measures as defined in ISO 25178-70 can be used for the instrument noise evaluation.

6.5.4 Determination of measurement and instrument noise: procedure for the determination of measurement noise

6.5.4.1 General

The subtraction method, 6.5.4.3, is the default method for determination of measurement noise of areal measuring instruments.

6.5.4.2 Assessed parameter

The assessed parameter is N_M according to Formula (1) or (3).

6.5.4.3 Estimation of measurement noise by the subtraction method

The default method for the determination of measurement noise is the measurement of a material measure according to 6.5.3, which shall be measured twice at the same location with the shortest possible time difference between the two sequential measurements. The two measured topographies