भारतीय मानक

Indian Standard

IS 15759 : 2023
ISO 12179 : 2021

ज्यामितीय उत्पाद विशिष्टि (जी.पी.एस.) — सतह की बनावट — प्रोफाइल पद्धति — संपर्क (स्टाइलस) उपकरणों का अंशशोधन

(पहला पुनरीक्षण)

Geometrical Product Specifications (GPS) — Surface Texture — Profile Method — Calibration of Contact (Stylus) Instruments

(First Revision)

ICS 17.040.30

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NATIONAL FOREWORD

This Indian Standard (First Revision) which is identical with ISO 12179 : 2021 ‘Geometrical product specifications (GPS) — Surface texture: Profile method — Calibration of contact (stylus) instruments’ issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on recommendation of the Engineering Metrology Sectional Committee and approval of the Production and General Engineering Division Council.

This standard was originally published in 2007. This revision has been taken to align it with the latest version of ISO 12179 : 2021. This standard applies to the calibration of the metrological characteristics of contact (stylus) instruments for the measurement of surface texture by the profile method as defined in ISO 3274. The calibration is to be carried out with the aid of measurement standards.

The major changes in this revision are as follows:

a) It incorporates technical corrigendum ISO 12179 : 2000/Cor. 1 : 2003.
b) Annex C has been amended.

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appear referring to this standard, they should be read as ‘Indian Standard’; and
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 3274 Geometrical product specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments	IS 15261 : 2002/ ISO 3274 : 1996 Geometrical product specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments	Identical
ISO 5436-1 : 2000 Geometrical product specifications (GPS) — Surface texture: Profile method; Measurement standards — Part 1: Material measures	IS 15423 (Part 1) : 2003 Geometrical product specifications (GPS) — Surface texture: Profile method measurement standards: Part 1 Material measures	Identical
ISO 10012 : 2003 Measurement management systems — Requirements for measurement processes and measuring equipment	IS/ISO 10012 : 2003 Measurement management systems — Requirements for measurement processes and measuring equipment (*First Revision*)	Identical

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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 chain link G of the chain of standards on profile surface texture.

The ISO GPS matrix model is given in ISO 14638, For more detailed information on the relationship of this document to the GPS matrix model, see Annex F. An overview of standards on profiles and areal surface texture is given in Annex E.

This document introduces calibration of contact (stylus) instruments as defined in ISO 3274. The calibration is carried out with the aid of measurement standards.

Indian Standard

GEOMETRICAL PRODUCT SPECIFICATIONS (GPS) — SURFACE TEXTURE — PROFILE METHOD — CALIBRATION OF CONTACT (STYLUS) INSTRUMENTS

(*First Revision*)

1 Scope

This document specifies the calibration and adjustment of the metrological characteristics of contact (stylus) instruments for the measurement of surface texture by the profile method as defined in ISO 3274. The calibration and adjustment is intended to be carried out with the aid of measurement standards.

Annex B specifies the calibration and adjustment of metrological characteristics of simplified operator contact (stylus) instruments which do not conform with ISO 3274.

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

ISO 5436-1:2000, *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Measurement standards — Part 1: Material measures*

ISO 10012, *Measurement management systems — Requirements for measurement processes and measuring equipment*

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 14253-2, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 2: Guidance for the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters*

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

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

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3274, ISO 14253-1, ISO 21920-2, GUM and VIM 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
calibration
operation that, under specified conditions:

a) 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

b) in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

[SOURCE: ISO/IEC Guide 99:2007 (VIM), 2.39, modified — Notes to entry removed.]

3.2
task-related calibration
set of operations which establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument and the corresponding known values of a limited family of precisely defined measurands which constitute a subset of the measuring capabilities of the measuring instrument

3.3
adjustment
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

[SOURCE: ISO/IEC Guide 99:2007 (VIM), 3.11, modified — Notes to entry removed.]

3.4
measurement standard
etalon
realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference

Note 1 to entry: Measurement standards are also referred to as “calibration specimens”.

[SOURCE: ISO/IEC Guide 99:2007 (VIM), 5.1, modified — Examples and Notes to entry removed.]

3.5
measurement uncertainty
uncertainty of measurement
uncertainty
non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

[SOURCE: ISO/IEC Guide 99:2007 (VIM), 2.26, modified — Notes to entry removed.]

3.6
metrological traceability
property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

[SOURCE: ISO/IEC Guide 99:2007 (VIM), 2.41, modified — Notes to entry removed.]

3.7
defect
<material measures> part of the measurement standard's geometrical feature (non-ideal surface) on which the geometrical shape and geometrical dimensions deviate from those on the nominal feature (ideal surface) either by an amount greater than some agreed or stated maximum value, or, in the absence of any such agreed or stated maximum value, by an amount greater than what is typical or characteristic for the processes used in manufacturing the measurement standard

[SOURCE: ISO 25178-73:2019, 3.1.2, modified — Notes to entry removed.]

4 Conditions of use

4.1 Components and configurations of the contact (stylus) instrument

The contact (stylus) instrument comprises the basic equipment, a drive unit, a probe and a profile recorder (see ISO 3274). If the basic equipment is used with several drive units and probes, each of these instrumental combinations (configurations) shall be calibrated separately.

4.2 Calibration of a configuration

The contact (stylus) instrument shall be calibrated when a change is made to the basic elements of the system which intentionally or unintentionally modifies the measured profile or measuring result. Each configuration of the contact (stylus) instrument shall be calibrated separately. For example, with a change of probe, the contact (stylus) instrument is calibrated.

4.3 Place of calibration

The contact (stylus) instrument should be calibrated at the place of use with environmental conditions similar to those present when in use for measurement to take into account external influence factors.

EXAMPLES Noise, temperature, vibration, air movement.

4.4 Defects

Geometrical defects that can be present on the surfaces of material measures and calibration specimens shall be taken into consideration according to ISO 25178-73.

5 Measurement standards

The following measurement standards are applicable to the calibrations given in Clause 6:

— optical flat;

— depth measurement standard (see Figure 1): type A according to ISO 5436-1:2000;

— spacing measurement standard (see Figure 2): type C according to ISO 5436-1:2000;

— inclined optical flat (see Figure 3);

— profile coordinate measurement standard (consisting of a sphere or prism): type E according to ISO 5436-1:2000;

— roughness measurement standard (see Figure 4): type D according to ISO 5436-1:2000.

It is recommended that a profile coordinate measurement standard be used on contact (stylus) instruments where the stylus rotates at least plus and minus one half of a degree when moving through its full range.

NOTE A type C periodic measurement standard is also useful for checking *Ra* as well as for checking *Rsm*.

Dimensions in millimetres

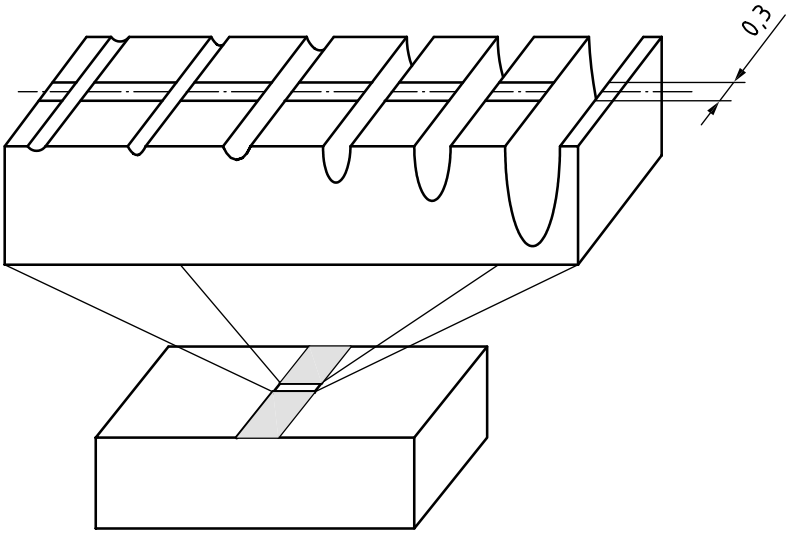


Figure 1 — Example of a depth measurement standard (type A)

Dimensions in millimetres

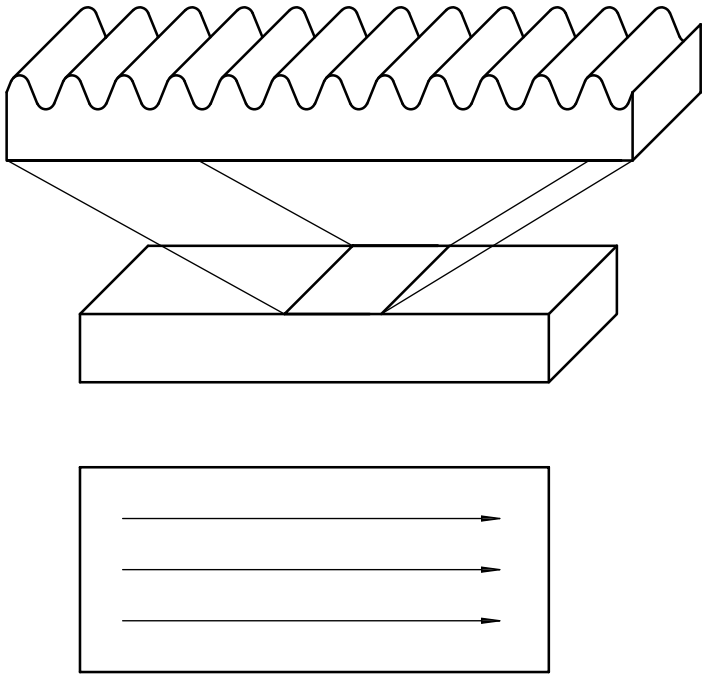


Figure 2 — Example of a spacing measurement standard (type C)

Dimensions in millimetres

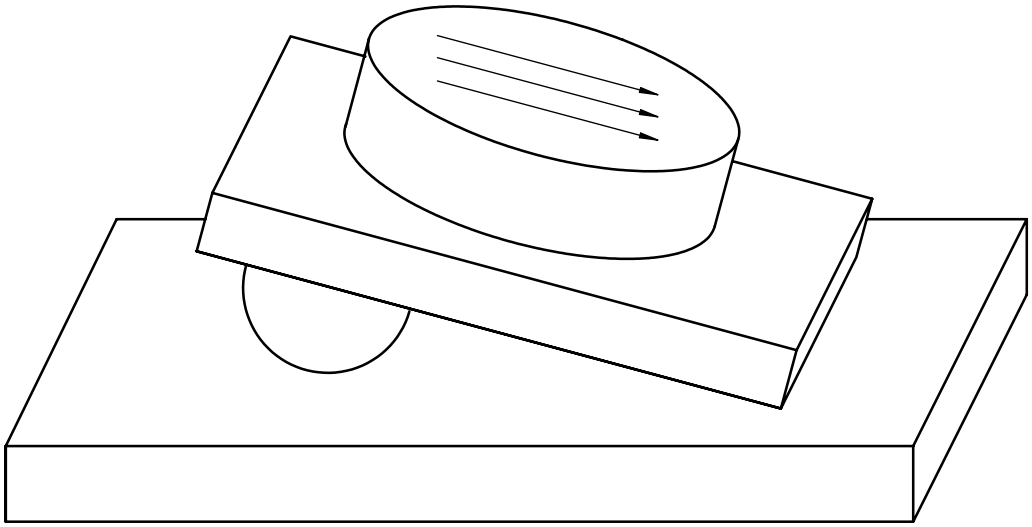


Figure 3 — Example of an inclined optical flat and a measuring plan

Dimensions in millimetres

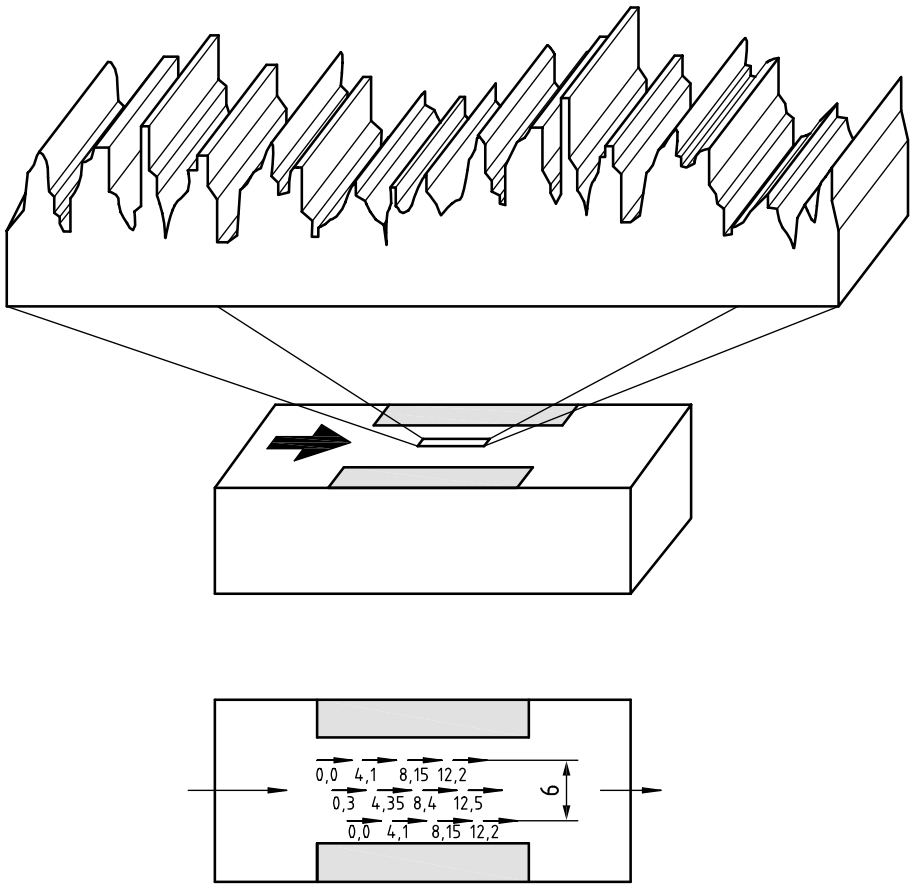


Figure 4 — Example of a roughness measurement standard (type D) and measuring plan

6 Contact (stylus) instrument metrological characteristics

6.1 General

Only those task-related contact (stylus) instrument metrological characteristics which are relevant for the intended measurements should be selected for calibration and adjustment. For example, for the measurement of spacing parameters, the vertical profile component need not be calibrated. Adjustment (if required) of the metrological characteristic shall be carried out after calibration of the metrological characteristic according to the instrument manufacturer's procedures.

6.2 Residual profile calibration

The scratch-free optical flat reproduces the residual profile. For task-related calibrations use the appropriate profile and parameters (e.g. the roughness profile with *Ra*, *Rq* or *Rt;* the waviness profile with *Wa*, *Wq* or *Wt*, see ISO 21920-2).

NOTE By using this approach the effects of external guide straightness, environmental conditions and instrument noise can be established.

6.3 Vertical profile component calibration

The depth measurement standard establishes a profile depth in order to measure the error of indication of the vertical profile component of an instrument.

If no depth measurement standards are available, gauge blocks steps may be used. Care should be taken concerning the uncertainty of the height difference when using gauge blocks steps.

6.4 Horizontal profile component calibration

The spacing measurement standard reproduces the mean width of profile element, *PSm*, in order to measure the error of indication of the horizontal profile component.

6.5 Profile coordinate system calibration

The inclined optical flat reproduces:

— the least-squares-best-fit angle in degrees;

— the total height of the primary profile, *Pt,* see ISO 21920-2, after removal of the least-squares-best-fit straight line,

thus establishing the error of the linked horizontal and vertical coordinates (e.g. variation in traverse speed, nonlinearities in scales).

The profile coordinate measurement standard provides calibration for the total height of the primary profile, *Pt*, after removal of the least-squares-best-fit nominal form, thus establishing the coordinate system.

6.6 Total contact (stylus) instrument calibration

The roughness measurement standard reproduces the:

— arithmetical mean deviation, *Ra*, see ISO 21920-2;

— maximum height of profile, *Rz*, see ISO 21920-2,

thus establishing an overall check of the total contact (stylus) instrument.

7 Calibration

7.1 Preparation for calibration

Before calibration, the contact (stylus) instrument shall be checked to determine if it operates correctly as described in the manufacturer's operating instructions. The condition of the stylus tip shall also be checked according to the manufacturer's instructions.

For contact (stylus) instruments, the following requirements apply:

— The residual profile shall be evaluated.

— The plane of the depth measurement standard shall be aligned to the reference surface in the best possible way.

— All measurement standards shall be aligned properly, for example the plane of the roughness measurement standard shall be aligned to within 10 % of the measuring gauge range but not more than 10 µm over the evaluation length.

— In task-related calibrations, roughness measurement standards shall be used with the appropriate roughness, comparable to the roughness of the surface to be measured.

— Measurements shall be taken in the middle of the vertical measuring range of the probe each time.

— A sufficient number of measurements shall be taken on each measurement standard for the required measurement uncertainty (see Clause 8). Repeated measurements are usually necessary due to the inhomogeneity of the measurement standard, the variability of the measurement procedure and the repeatability of the contact (stylus) instrument.

— The conditions used to measure the measurement standard shall be compatible with those used previously to calibrate the measurement standard.

— The best-fit procedure (i.e. least squares, minimum zone) used in the calibration of the measurement standard shall be used.

7.2 Evaluation of the residual profile

Traverse the optical flat. Determine the residual profile and calculate the surface texture parameters *Pt* and *Pq*, see ISO 21920-2.

For task-related calibration, calibrate in accordance with the measuring conditions for each required measurement. For example, when measuring a roughness measurement standard, a cut-off wavelength λ_c = 0,8 mm and a cut-off ratio of 300:1, making a total evaluation length of 4 mm, are used. The measured values of *Ra* and/or *Rz*, see ISO 21920-2, shall be indicated in the calibration certificate for the instrument.

7.3 Calibration of the vertical profile component

7.3.1 Overall objective

Traverse the groove(s) of the depth measurement standard. From the primary profile determine the respective deviations from the value stated in the appropriate calibration certificate.

7.3.2 Procedure

Measure the groove(s) in profile sections within the calibrated area of the measurement standard (see Figure 1). Traverse the groove(s) individually and determine the depth of the groove(s) according to the calibration procedure supplied with the depth measurement standard. State the deviation of the

(mean) value [obtained from the measured value(s)] from the figure given in the calibration certificate of the depth measurement standard.

Alternatively, if a depth measurement standard is not available, wring two gauge blocks, juxtaposed, onto an optical flat. Traverse across both gauge blocks and determine the respective height difference from the total profile. State the deviation in the measured height difference from the difference in heights calculated from the values stated in the calibration certificates of the gauge blocks.

7.4 Calibration of the horizontal profile component

7.4.1 Overall objective

Traverse the spacing measurement standard. Determine the respective deviations from the wavelength parameters stated in the calibration certificate.

7.4.2 Procedure

Perform measurements on the spacing measurement standard, distributed over the measurement surface. An example of a measuring plan is given in Figure 2. Calculate the arithmetical mean for the primary parameter *PSm*, see ISO 21920-2. Record the deviations from the values stated in the calibration certificate.

7.5 Calibration of the profile coordinate system

7.5.1 Overall objective

Traverse the inclined optical flat, sphere or prism. Determine *Pt*, see ISO 21920-2, of the respective deviations from the least-squares-best-fit of the form of the specimen.

7.5.2 Procedure

Perform measurements on each inclination measurement standard using the traverse length and nominal angle of inclination as indicated in the calibration certificate. The measurements shall be distributed over the measurement surface as shown in the measuring plan (see Figure 3). Calculate the profile depth after removal of the least-squares-best-fit line and the arithmetical mean of the least-squares-best-fit angle. Record the largest profile depth and the mean angle of inclination.

Traverse the profile coordinate measurement standard. After removal of the least-squares-best-fit nominal form, determine *Pt*.

Perform measurements on each profile coordinate measurement standard using the traverse length given in the calibration certificate, distributed over the measurement surface.

Calculate the profile depths after removal of the least-squares-best-fit nominal form. Record the largest profile depth.

NOTE Spheres and prisms are commonly used as profile coordinate measurement standards.

7.6 Calibration of the total contact (stylus) instrument

7.6.1 Overall objective

Traverse the roughness measurement standard. From the roughness profile determine the respective deviations from the roughness parameters stated in the respective calibration certificate.

7.6.2 Procedure

Carry out measurements on each roughness measurement standard, distributed over the measurement surface.

An example of a measurement plan is given in Figure 4. Calculate the arithmetical mean for each roughness parameter. Record the deviations from the values stated in the calibration certificate.

7.7 Other calibrations

Calibration of instruments measuring parameters of the motifs method (ISO 12085) shall be carried out as specified in Annex A.

Calibration of simplified operator instruments for the measurements of surface texture shall be carried out as specified in Annex B.

8 Measurement uncertainty

8.1 Information from the calibration certificate for a measurement standard

The following information is taken from the calibration certificate for a measurement standard:

— full definition of the measurand (including, as appropriate, measuring plan, filter cut-offs λ_c and λ_s, filter types, definition of cut-offs);

— uncertainty, U_{ct}, of the stated values of the measurand with the coverage factors used and details of the metrological traceability of the metrological characteristics (see ISO 14253-2);

— standard uncertainty estimate, u, of the variation of the measurand over the area used for calibration (measuring window);

— statement on how the standard uncertainty estimate, u, was included in the calculation of U_{ct}.

8.2 The uncertainty of the values measured during calibration of a measuring instrument using a measurement standard

The uncertainty of the values measured during calibration shall be estimated according to the method contained in ISO 14253-2.

The uncertainty of a calibrated metrological characteristic, Q, consists of the two components $u(q)$ and $u_{\text{a.}}$

— $u(q)$ is the sample standard uncertainty estimate of the realized quantity;

— u_{a} is the uncertainty of the adjustment (correction of the systematic errors in the metrological characteristics) estimated according to the method given in ISO 14253-2.

The expanded uncertainty, U, is given by:

$$U = k \times \sqrt{u(q)^2 + u_{\text{a}}^2}$$

where k is the coverage factor.

When the uncertainty is calculated, it should be noted that the surface of the measurement standard or step height is not perfectly uniform, so measurement results scatter. This results in an additional component of the uncertainty, which is calculated from the standard uncertainty estimate. This additional component, which is caused by the measurement standard, is included in the uncertainty, U, of the measurement standard. Therefore, this sample-related component shall not be added to the

component *u(q).* An illustrative example, using a full analysis of variance (ANOVA), is given in Annex C to illustrate this point.

An alternative to the full ANOVA, permitted by GUM, is to estimate by experience the uncertainty *u(q).*

Guidance on the calculation of the uncertainty of calibrated values is given in ISO 14253-2.

9 Contact (stylus) instrument calibration certificate

The calibration certificate shall include the items required by ISO 10012 and the following:

— the components of the full combined contact (stylus) instrument (manufacturer type, serial number);

— the measurement standards used (identification number);

— a reference to the calibration procedure;

— the sets of measuring conditions covered (i.e. measuring range, traverse speed, length traversed, transmission band of measurement, stylus tip radius);

— the results of the measurement of the residual profile using the optical flat;

— the results of the measurement using the depth measurement standard and spacing measurement standard and deviations from the respective values of the metrological characteristics;

— the results of the measurement using the inclined optical flat and *Pt* after least-squares-best-fit line removal;

— if applicable, the measurement results using the profile coordinate measurement standard and *Pt* after least-squares-best-fit nominal form removal;

— the place of measurement and its environmental conditions which influence the calibration; sources for this information include the instructions of the instrument manufacturer and the supplier of the measurement standard;

— expanded uncertainty of measurement and documentation of the uncertainty budget according to ISO 14253-2.

10 General information

The concept diagram is given in Annex D.

For an overview of profile and areal standards in the GPS matrix model, see Annex E.

The relation to the GPS matrix model is given in Annex F.

Annex A
(normative)

Calibration of instruments measuring parameters of the motifs method

A.1 General

This annex describes procedures for the calibration of instruments measuring parameters of the motifs method. The motif parameters are defined in ISO 12085.

A.2 Measurement standards

A.2.1 General

The instruments measuring motifs method parameters R, AR, W and AW are calibrated with measurement standards type C4 according to ISO 5436-1 (see Figure A.1).

A.2.2 Surface parameters

The measurement standards type C4 reproduce:

— measurement standards with spacings of 0,25 mm: mean depth of roughness motifs, R, and mean spacing of roughness motifs, AR.

— measurement standards with spacings of 0,8 mm: mean depth of waviness motifs, W, and mean spacing of waviness motifs, AW.

A.3 Calibration

a) Take a stylus tip of 2 µm radius, checked with an electron microscope.

b) Set the conventional limits of motifs *A* and *B* values to the default values *A* = 0,5 mm and *B* = 2,5 mm.

c) Align the direction of the measurement in the best possible way with the measured surface, and parallel to the longer of the measurement standard.

d) Select the smallest possible measuring range.

e) Set the measuring range in the middle of the length of the measurement standard.

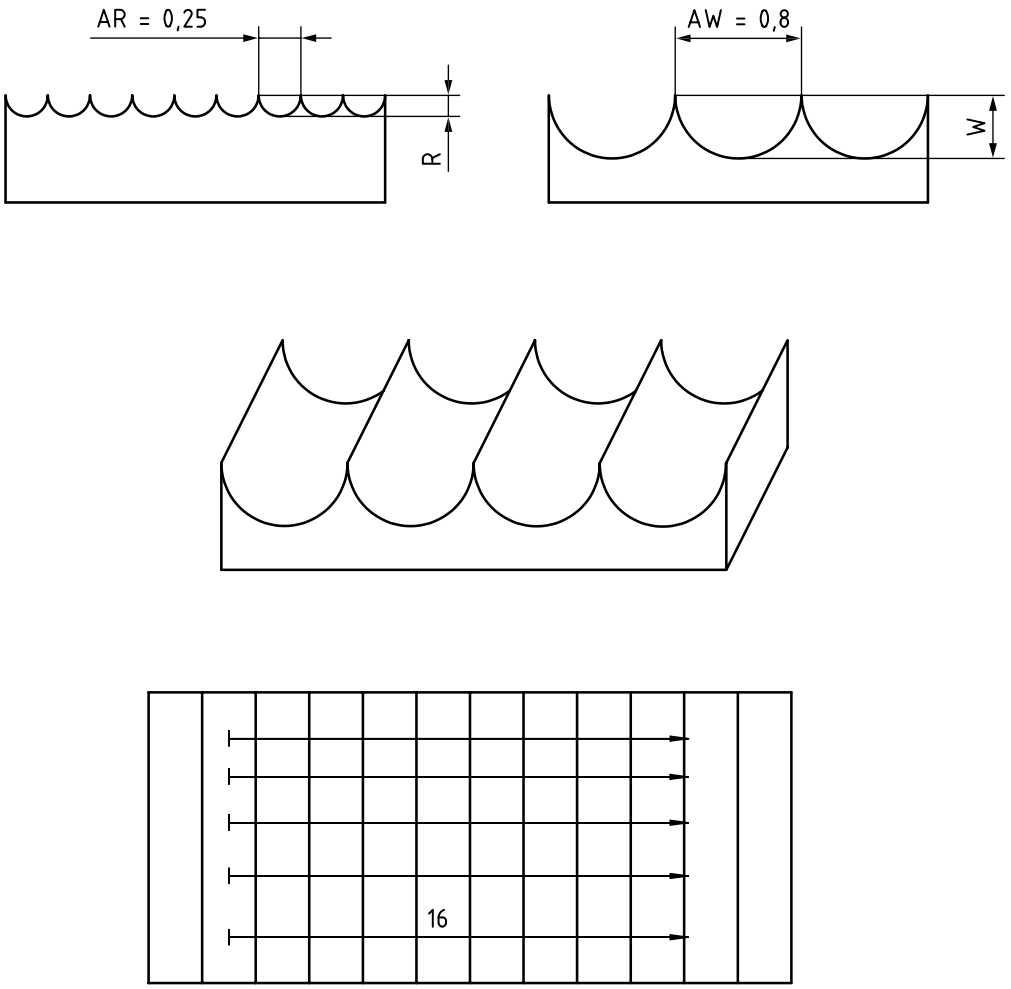
f) Set the measuring length to 16 mm in order to begin and end the measurement in a valley.

g) Carry out five parallel measurements on each calibration measurement standard, randomly distributed in the width of the measurement standard (in order to avoid wear of a measurement standard always measured in the same place).

h) Determine the mean value and the standard deviation of the five measurements of the parameter R, AR or W, AW. The mean values of R and W allow calibration of the vertical amplification. The mean values of AR and AW allow calibration of the horizontal amplification. The standard deviations of these values are influenced by the repeatability of the apparatus and the homogeneity of the calibrated standard. They shall be taken into account in the calculation of uncertainty of measurement.

i) Measurement standards type D of ISO 5436-1 can also be used in the same way to validate the algorithm of the motif method, if it is not possible to input soft gauges into the measuring chain of the apparatus.

Dimensions in millimetres



Measurement standards with spacings of 0,25 mm: calibrate mean depth of roughness motifs, R, and mean spacing of roughness motifs, AR.

Measurement standards with spacings of 0,8 mm: calibrate mean depth of waviness motifs, W, and mean spacing of waviness motifs, AW.

Figure A.1 — Roughness and waviness measurement standards (type C4) and measuring plan

Annex B
(normative)

Calibration of simplified operator instruments for the measurements of surface texture

A simplified operator instrument for the measurement of surface texture is an instrument that is not intended to implement the standardised operator instrument as defined in ISO 3274.

NOTE ISO 3274 only refers to contact (stylus) instruments with independent reference guides, and so simplified operator instruments include the important class of contact (stylus) instruments with skids.

A key characteristic of simplified operator instruments is that the uncertainty contribution from the instrument is also a function of the imperfections of the measured workpiece. Thus, before using a simplified operator instrument for the measurement of surface texture it is mandatory to establish correlation with the standardized operator instrument to assess this special uncertainty contribution. There are two main approaches to achieving this:

a) Know the nature of the imperfections in advance in order to be able to assess the uncertainty contributions to the measurement uncertainty.

b) Task-related calibration using a specified workpiece or special calibrated workpiece, with the same imperfections which interact with the simplified operator measuring equipment in the same way as the workpiece in the measurement task, and where the specified workpiece or special calibrated workpiece have been calibrated for the specific tasks on an optimum standardized operator instrument for the measurement of surface texture.

Annex C
(informative)

Example: roughness measurement standard parameter *Ra*

A roughness measurement standard was measured for the parameter *Ra* to check the calibration of a stylus instrument. The roughness specimen was measured five times according to the measuring plan with 12 positions given in Figure 2. Table C.1 gives the individual measured *Ra* values.

NOTE 1 These values are simulated to illustrate the statistical techniques involved.

Table C.1 — Individual *Ra* values, measured according to measuring plan (Figure 4), on a roughness measurement standard (type D)

Individual *Ra* values	Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4	Evaluation 5	Mean
Value 1	0,524 7	0,526 1	0,522 9	0,525 2	0,528 7	0,525 52
Value 2	0,524 0	0,528 3	0,526 6	0,532 3	0,526 0	0,527 44
Value 3	0,533 0	0,533 2	0,528 6	0,531 9	0,530 9	0,531 52
Value 4	0,531 1	0,534 2	0,530 6	0,533 4	0,531 3	0,532 12
Value 5	0,521 6	0,520 4	0,522 1	0,526 2	0,520 0	0,522 06
Value 6	0,527 2	0,528 5	0,529 1	0,525 4	0,526 6	0,527 36
Value 7	0,525 6	0,534 0	0,529 5	0,533 2	0,529 1	0,530 28
Value 8	0,534 6	0,530 4	0,533 8	0,536 2	0,532 7	0,533 54
Value 9	0,519 1	0,520 7	0,523 2	0,526 2	0,526 2	0,523 08
Value 10	0,524 7	0,530 3	0,531 5	0,529 5	0,524 6	0,528 12
Value 11	0,532 8	0,530 7	0,530 1	0,531 0	0,527 9	0,530 50
Value 12	0,534 7	0,533 9	0,528 6	0,538 4	0,531 7	0,533 46
Mean	0,527 76	0,529 23	0,528 05	0,530 74	0,527 98	0,528 75

The random effects contributing to the observed variability of the measurements are:

a) variation of the *Ra* value across the roughness measurement standard;

b) variation of the *Ra* value between evaluations;

c) repeatability of the contact (stylus) instrument.

Each of these random effects is assumed to have associated with it an unknown variance, denoted by σ_R^2, σ_E^2 and σ_M^2, respectively, where index *R* stands for roughness measurement standard (variation across roughness measurement standard); index *E* stands for evaluation (between evaluation effects); and index *M* stands for contact (stylus) instrument [repeatability of the contact (stylus) instrument].

It is assumed that an ANOVA is the appropriate method of analysis. This topic is covered in ISO Guide 35.

Let $\bar{X}_{ij}$ denote the *i*-th value on the *j*-th evaluation. The arithmetic means $\bar{X}_i$, $\bar{X}_j$ and $\bar{X}$ are calculated from Formulae (C.1) to (C.3):

$$\bar{X}_i = \frac{1}{5}\sum_{j=1}^{5} X_{ij} \qquad \text{(C.1)}$$

$$\bar{X}_j = \frac{1}{12}\sum_{i=1}^{12} X_{ij} \tag{C.2}$$

$$\bar{X} = \frac{1}{60}\sum_{i=1}^{12}\sum_{j=1}^{5} X_{ij} \tag{C.3}$$

Associated with these means are the sum-of squares S_1, S_2, S_3 and S_4, calculated from Formulae (C.4) to (C.7):

$$S_1 = 60\bar{X}^2 \tag{C.4}$$

$$S_2 = 5\sum_{i=1}^{12}(\bar{X}_i - \bar{X})^2 \tag{C.5}$$

$$S_3 = 12\sum_{j=1}^{5}(\bar{X}_j - \bar{X})^2 \tag{C.6}$$

$$S_4 = \sum_{i=1}^{12}\sum_{j=1}^{5}(X_{ij} - \bar{X}_i - \bar{X}_j + \bar{X})^2 \tag{C.7}$$

A summary of the ANOVA is given in Table C.2.

Table C.2 — Summary of ANOVA

Source of variability	Sum of squares S_l µm^2	Degrees of freedom v_l	Mean square $M_l = \frac{S_l}{v_l}$ µm^2	Variance estimated by mean square
Mean	S_1 = 16,774 593 75	1	M_1 = 16,774 593 75	–
Across measurement standard	S_2 = 0,000 804 722	11	M_2 = 7,315 681 8 e-5	$\sigma_M^2 + 5\sigma_R^2$
Between evaluations	S_3 = 0,000 075 197	4	M_3 = 1,879 900 0 e-5	$\sigma_M^2 + 12\sigma_E^2$
Instrument repeatability	S_4 = 0,000 252 651	44	M_4 = 0,574 200 0 e-5	σ_M^2

Denoting the estimates of σ_R^2, σ_E^2 and σ_M^2 by s_R^2, s_E^2 and s_M^2, respectively, Formulae (C.8) to (C.10) follow from the last columns of Table C.2.

$$s_R^2 = \frac{(M_2 - M_4)}{5} = 3{,}67 \tag{C.8}$$

$$s_E^2 = \frac{(M_3 - M_4)}{12} = 1{,}04 \tag{C.9}$$

$$s_M^2 = M_4 = 2{,}40 \tag{C.10}$$

The degrees of freedom of s_M^2 is 44, the degrees of freedom of M_4. The degrees of freedom of s_R^2 and s_E^2 are the effective degrees of freedom of $(M_2 - M_4)^2$ and $(M_3 - M_4)^2$, respectively, and can be calculated from the Welch-Satterthwaite formula in Formulae (C.11) and (C.12) (see GUM):

$$v_{eff}\left(s_R^2\right) = \frac{(M_2 - M_4)^2}{\frac{M_2^2}{11} + \frac{M_4^2}{44}} = 9{,}3 \tag{C.11}$$

$$v_{eff}\left(s_E^2\right) = \frac{(M_3 - M_4)^2}{\frac{M_3^2}{4} + \frac{M_4^2}{44}} = 1{,}9 \tag{C.12}$$

The calibration certificate for the roughness standard provides a value Ra = 0,529 4 µm with an expanded uncertainty of 1 % (5,3 nm), using a coverage factor of k = 2.

Assuming a standard uncertainty of 0,8 % in the amplification factor (u_A) for the instrument (obtained from the manufacturer), the combined standard uncertainty for the mean value of Ra over the 60 measurements of the standard, is shown in Formulae (C.13):

$$u_c = \sqrt{\left(\frac{S_M^2}{60} + \frac{S_E^2}{5} + \frac{S_R^2}{12} + u_A^2\right)} = 4{,}4 \tag{C.13}$$

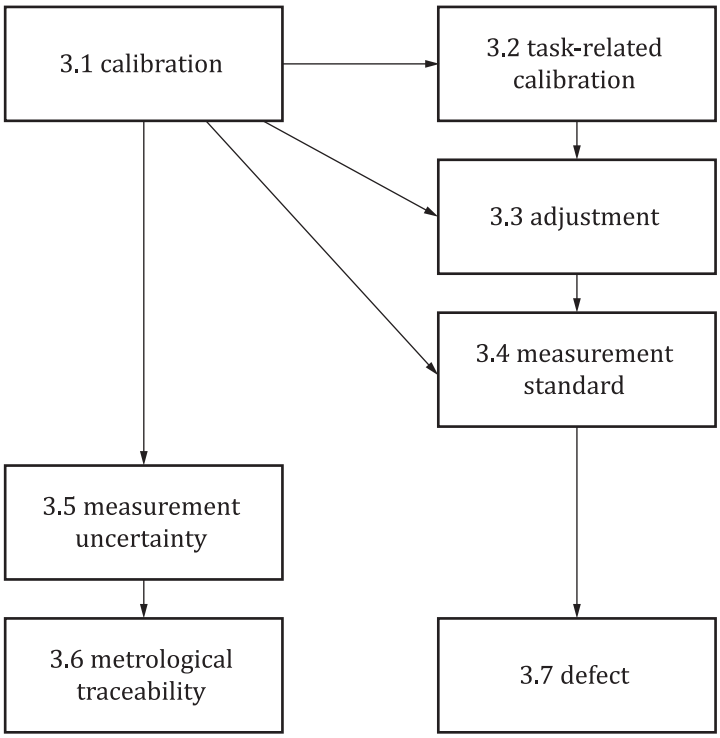
With a coverage factor of k = 2, the uncertainty (U) for the current measurement is 8,8 nm. Because the difference is only 0,65 nm between the calibrated value of 0,529 4 µm and measured value of 0,528 75 µm of the roughness standard – much less than their combined expanded uncertainties – the measured result provides a verification of the calibration of the instrument.

NOTE 2 This example is purely illustrative; the uncertainties calculated are not to be taken as typical of those found in practice.

Annex D
(informative)

Concept diagram

The following is the concept diagram for ISO 12179.



Annex E
(informative)

Overview of profile and areal standards in the GPS matrix model

An overview of standards on profiles and areal surface texture is given in Table E.1.

Table E.1 — Surface texture standards

	Chain links						
	A	B	C	D	E	F	G
	Symbols and indications	Feature requirements	Feature properties	Conformance and non-conformance	Measurement	Measurement equipment	Calibration
Profile surface texture	ISO 21920-1	ISO 21920-2	ISO 21920-3 ISO 16610-2x ISO 16610-3x ISO 16610-4x	ISO 14253 series		ISO 25178-6[a] ISO 25178-6xx[a]	ISO 25178-7x[a] ISO 25178-7xx[a] ISO 12179
Areal surface texture	ISO 25178-1	ISO 25178-2	ISO 25178-3 ISO 16610-6x ISO 16610-7x ISO 16610-8x	ISO 14253 series		ISO 25178-6 ISO 25178-6xx	ISO 25178-7x ISO 25178-7xx

[a] Some areal standards are mentioned here as they are relevant to profile measuring instruments.

Annex F
(informative)

Relation to the GPS matrix model

F.1 General

For full details about the GPS matrix model, see ISO 14638.

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. The default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated.

F.2 Information about this document and its use

This document applies to the calibration of contact (stylus) instruments for the measurement of surface texture by the profile method as defined in ISO 3274. The calibration is to be carried out with the aid of measurement standards as defined in ISO 5436-1

F.3 Position in the GPS matrix model

This document is a general ISO GPS standard which influences chain link G of the chain of standards on profile surface texture, as graphically illustrated in Table F.1.

Table F.1 — Position in the GPS matrix model

	Chain links						
	A	**B**	**C**	**D**	**E**	**F**	**G**
	Symbols and indications	Feature requirements	Feature properties	Conformance and non-conformance	Measurement	Measurement equipment	Calibration
Size							
Distance							
Form							
Orientation							
Location							
Run-out							
Profile surface texture							•
Areal surface texture							
Surface imperfections							

F.4 Related International Standards

The related International Standards are those of the chain of standards indicated in Table F.1.

Bibliography

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

[2] ISO 12085, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Motif parameters*

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

[4] ISO Guide 35, *Reference materials — Guidance for characterization and assessment of homogeneity and stability*

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
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	IS 15371 (Part 1) : 2023/ISO 14253-1 : 2017 Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment: Part 1 Decision rules for verifying conformity or nonconformity with specifications (*First Revision*)	Identical
ISO 14253-2 Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 2: Guidance for the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification	IS 15371 (Part 2) : 2018/ISO 14253 -2 : 2011 Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment: Part 2 Guidance for the estimation of uncertainty in GPS measurement, in calibration	Identical
ISO 21920-2 Geometrical product specifications (GPS) — Surface texture : Profile — Part 2: Terms, definitions and surface texture parameters	IS 18432 (Part 2) : 2023/ISO 21920-2 : 2021 Geometrical product specifications (GPS) — Surface Texture: Profile: Part 2 Terms, definitions and surface texture parameters	Identical
ISO 25178-73 Geometrical product specifications (GPS) — Surface texture: Areal — Part 73: Terms and definitions for surface defects on material measures	IS 18431 (Part 73) : 2023/ ISO 25178-73 : 2019 Geometrical product specifications (GPS) — Surface texture: Areal: Part 73 Terms and definitions for surface defects on material measures	Identical
ISO/IEC Guide 99 International vocabulary of metrology — Basic and general concepts and associated terms(VIM)	IS/ISO/IEC Guide 99 : 2007 International vocabulary of metrology — Basic and general concepts and associated terms (VIM)	Identical

The technical committee has reviewed the provisions of the following International Standard referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard

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

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*Second Revision*)’

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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