INTERNATIONAL STANDARD

ISO 12179

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Geometrical Product Specifications (GPS) — Surface texture: Profile method — Calibration of contact (stylus) instruments

Spécification géométrique des produits (GPS) — État de surface: Méthode du profil — Étalonnage des instruments à contact (palpeur)

Reference number
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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 12179 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

Annexes A and B form a normative part of this International Standard. Annexes C and D are for information only.

Introduction

This International Standard is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences the chain link 6 of the chain of standards on roughness, waviness and primary profile.

For more detailed information on the relationship of this standard to the GPS matrix model, see annex D.

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

Geometrical Product Specifications (GPS) — Surface texture: Profile method — Calibration of contact (stylus) instruments

1 Scope

This International 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.

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

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 10012-1:1992, *Quality assurance requirements for measuring equipment — Part 1: Metrological confirmation system for measuring equipment.*

ISO 12085:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Motif parameters.*

ISO 14253-1:1998, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specification.*

ISO/TS 14253-2:1999, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 2: Guide to the estimation of uncertainty of measurement in GPS measurement, in calibration of measuring equipment and in product verification*.

Guide to the expression of uncertainty in measurement (GUM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1st edition, 1995.

International vocabulary of basic and general terms used in metrology (VIM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 2nd edition, 1993.

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 3274, ISO 4287, ISO 14253-1, VIM [some of which are reproduced below (without their notes) for convenience], GUM, and term and definition 3.2, apply.

3.1
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards

[VIM 6.11]

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 (of a measuring instrument)
operation of bringing a measuring instrument into a state of performance suitable for its use

[VIM 4.30]

3.4
(measurement) standard
etalon
material measure, measuring instrument, reference material or measuring system intended to define, realize, conserve or reproduce a unit or one or more values of a quantity to serve as a reference

[VIM 6.1]

NOTE In ISO 5436:1985, "measurement standards" were referred to as "calibration specimens".

3.5
uncertainty of measurement
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[VIM 3.9]

3.6
traceability
property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

[VIM 6.10]

4 Conditions of use

4.1 Components and configurations of the contact (stylus) instrument

The contact (stylus) instrument is comprised of 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/measuring result. Each configuration of the contact (stylus) instrument shall be calibrated separately.

EXAMPLE With a change of probe the contact (stylus) instrument shall be 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.

EXAMPLE Noise, temperature, vibration, air movement, etc.

5 Measurement standards

The following measuring standards are applicable to the calibrations given in clause 6:

- optical flat;
- depth measurement standard (Figure 1): type A according to ISO 5436-1;
- spacing measurement standard (Figure 2): type C according to ISO 5436-1;
- inclined optical flat (Figure 3);
- profile co-ordinate measurement standard (consisting of a sphere or prism): type E according to ISO 5436-1;
- roughness measurement standard (Figure 4): type D according to ISO 5436-1.

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

6 Contact (stylus) instrument metrological characteristics

Only those task-related contact (stylus) instrument metrological characteristics which are relevant for the intended measurements should be selected for calibration. For example, for the measurement of spacing parameters, the vertical profile component need not be calibrated.

6.1 Residual profile calibration

The scratch-free optical flat reproduces the residual profile. For task-related calibrations use the appropriate profile and parameters (for example: the roughness profile with *Ra*, *Rq* or *Rt*; the waviness profile with *Wq* or *Wt*).

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

Dimension in millimetres

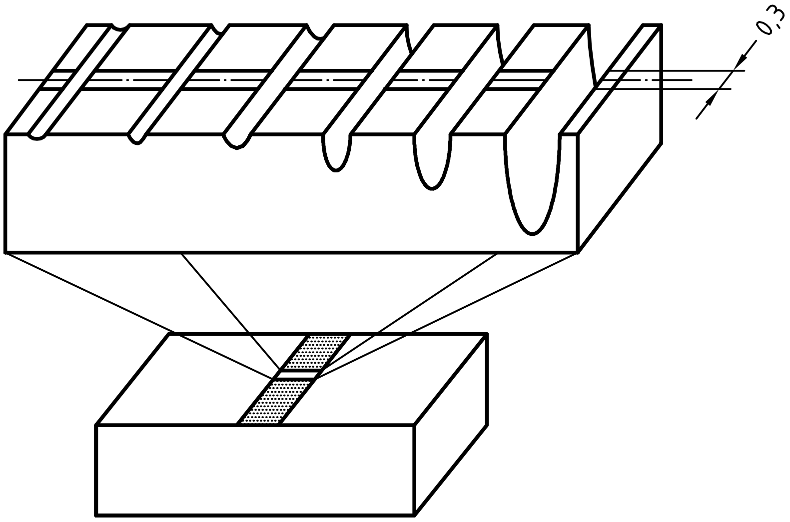

Figure 1 — Example of a depth measurement standard (type A2)

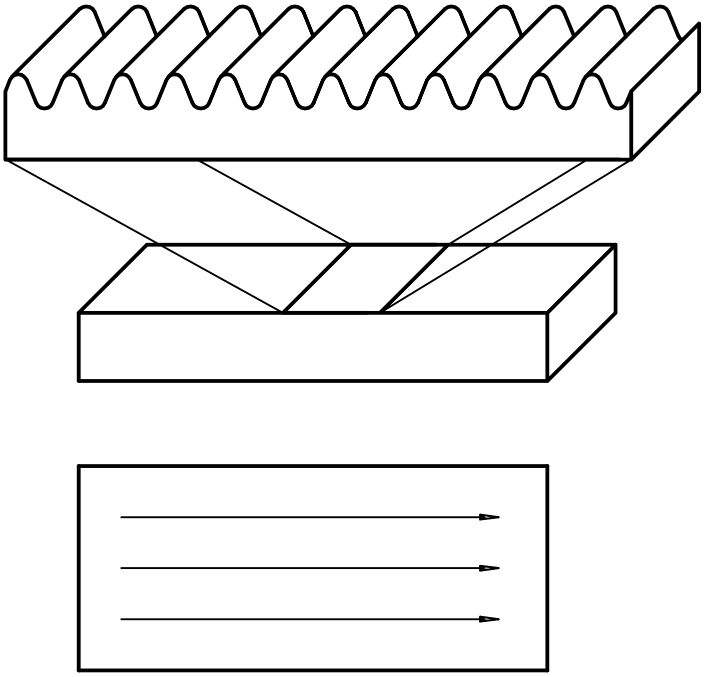

Figure 2 — Example of a spacing measurement standard (type C)

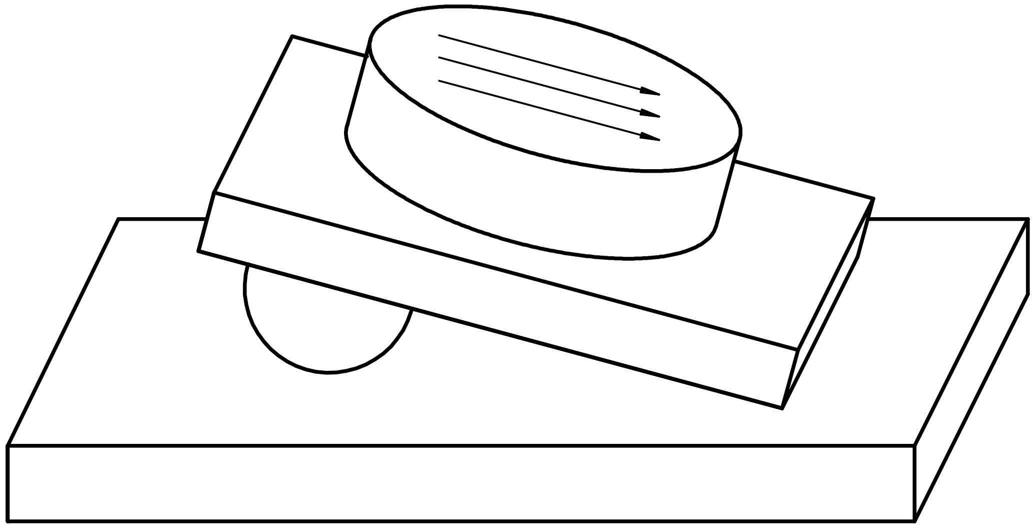

Figure 3 — Example of an inclined optical flat and a measuring plan

Values in millimetres

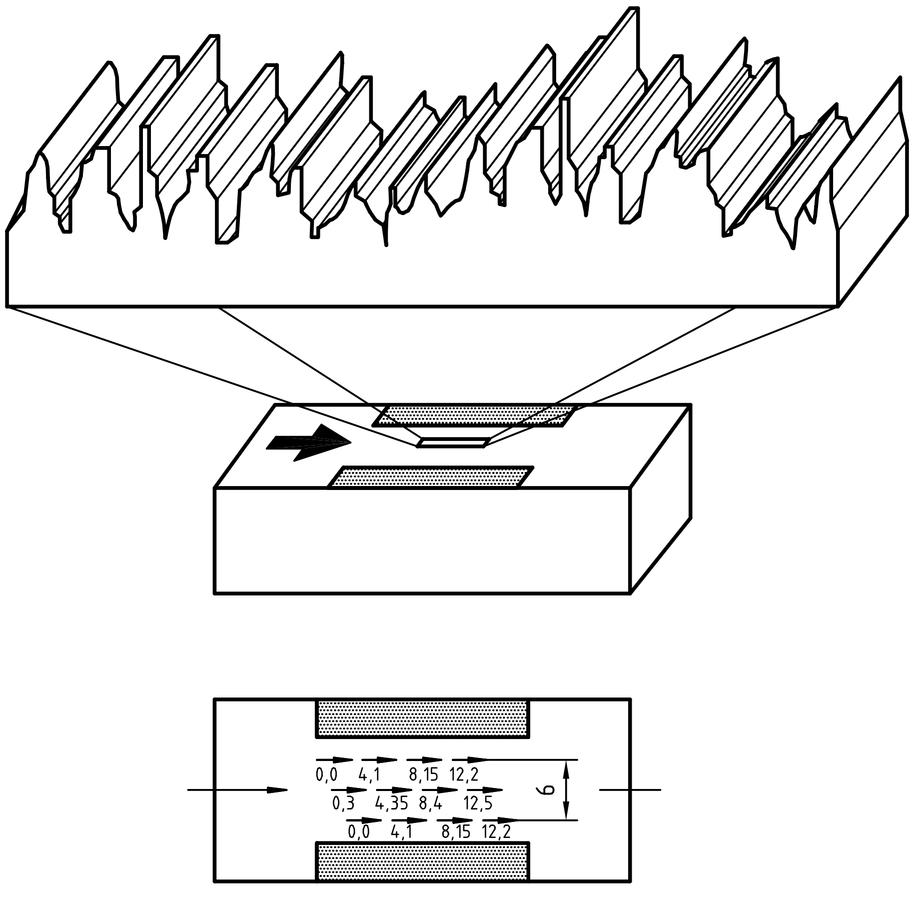

Figure 4 — Example of a roughness measurement standard (type D) and measuring plan

6.2 Vertical profile component calibration

The depth measurement standard reproduces the profile depth in order to measure the error of indication of the vertical profile component.

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

6.3 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.

6.4 Profile co-ordinate system calibration

The inclined optical flat reproduces:

- the least squares best fit angle in degrees;
- the total height of the primary profile, *Pt*, after removal of the least squares best fit straight line;

thus establishing the error of the linked horizontal and vertical co-ordinates (i.e. variation in traverse speed, non-linearities in scales, etc.).

The profile co-ordinate measurement standard reproduces the total height of the primary profile, *Pt*, after removal of the least squares best fit nominal form, thus establishing the co-ordinate system.

6.5 Calibration of the total contact (stylus) instrument

The roughness measurement standards reproduce the:

- arithmetical mean deviation, *Ra*;
- maximum height of profile *Rz*;

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 shall be complied with.

- The residual profile is to 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 to calibrate the measurement standard.

— The best fit procedure (i.e. least squares, minimum zone, etc.), 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*. 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 λc = 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 *Rz* 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*. Record the deviations from the values stated in the calibration certificate.

7.5 Calibration of the profile co-ordinate system

7.5.1 Overall objective

Traverse the inclined optical flat, sphere or prism. Determine *Pt* 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 co-ordinate measurement standard. After removal of the least squares best fit nominal form, determine *Pt*.

Perform measurements on each profile co-ordinate 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 co-ordinate 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.

8 Uncertainty of measurement

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 metrological characteristics (including, as appropriate, measuring plan, filter cut-offs λc and λs, filter types, definition of cut-offs, etc.);

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

— standard uncertainty estimate, u_{i}, of the variation of the metrological characteristic over the area used for calibration (measuring window);

— statement on how the standard uncertainty estimate, u_{i}, was included into 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/TS 14253-2.

The uncertainty of a calibrated metrological characteristic, Q, consists of the two components $u(q)$ and u_{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/TS 14253-2.

The expanded uncertainty U is given by:

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

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 accidental component of the uncertainty, which is calculated from the standard uncertainty estimate. This accidental component, which is caused by the measurement standard, is included in the uncertainty U of the measurement standard. Therefore, this accidental 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, allowed by GUM, to the full ANOVA is to estimate by experience the uncertainty $u(q)$.

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

9 Contact (stylus) instrument calibration certificate

The calibration certificate shall include the items required by ISO 10012-1, 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, etc.);

— 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 co-ordinate measuring 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/TS 14253-2.

Annex A
(normative)

Calibration of instruments measuring the motifs method parameters

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

A.1 Measurement standards

A.1.1 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.1.2 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.2 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 side 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 5 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

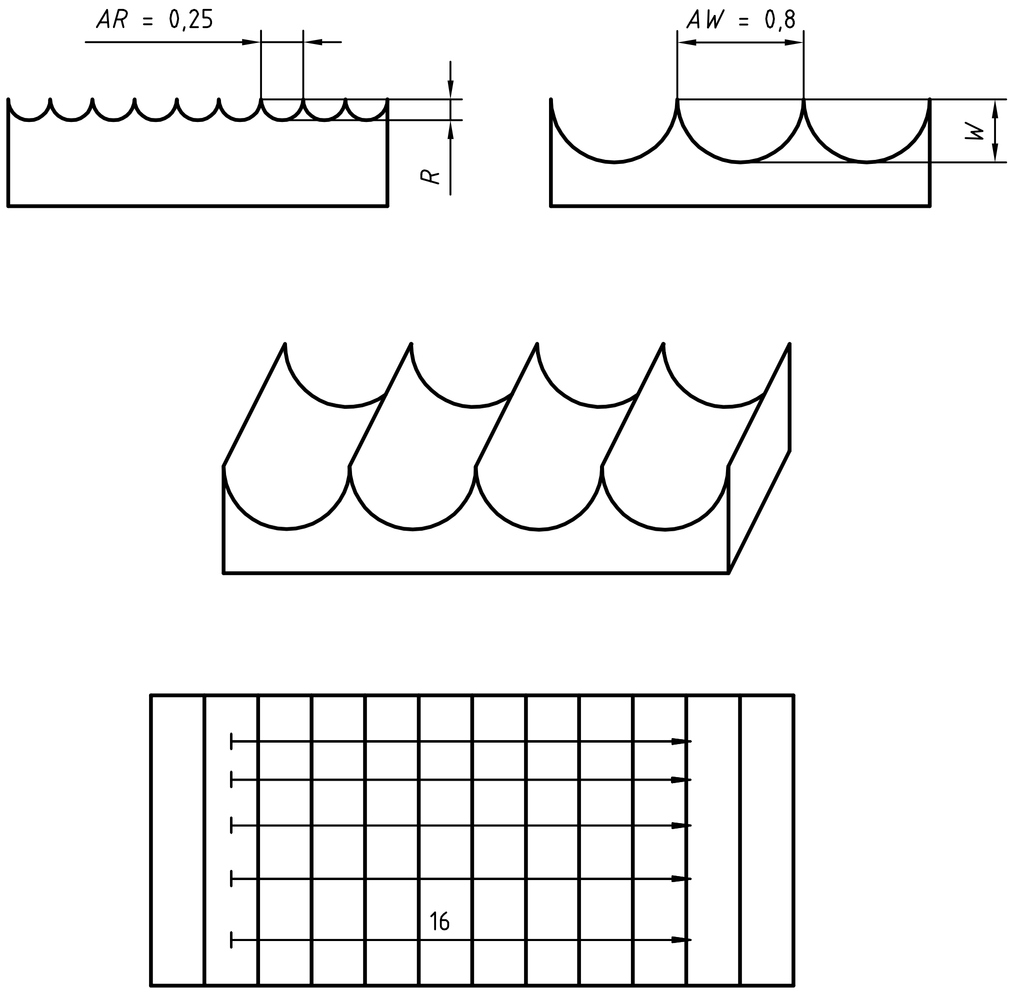

Figure A.1 — Roughness and waviness measurement standards (type C4) and measuring plan

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 achieve 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. Where the specified workpiece or special calibrated workpiece have been calibrated for the specific tasks on an optimum standardised operator instrument for the measurement of surface texture.

NOTE The terminology related to operators is currently under consideration in ISO/TC 213 and may be subject to future changes.

Annex C
(informative)

Example: roughness measurement standard parameter *Ra*

A roughness measurement standard was evaluated, for the parameter *Ra*, five times according to the measuring plan with 12 positions given in Figure 2. Table C.1 gives the individual measured *Ra* values.

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

Table C.1 — Individual *Ra* values, measured according to measuring plan (Figure 2), on a roughness measurement standard (type D)

Individual *Ra* values µm	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 22	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 was assumed that an ANOVA was the appropriate method of analysis. This topic is covered thoroughly in ISO Guide 35. The ANOVA provides estimates of the above variances.

Let X_{ij} denote the ith value on the jth evaluation. The arithmetic means $\overline{X_i}$, $\overline{X_j}$ and $\overline{X}$ are calculated from the following:

$$\overline{X_i} = \frac{1}{12}\sum_{j=1}^{12} X_{ij}$$

$$\overline{X_j} = \frac{1}{5}\sum_{i=1}^{5} X_{ij}$$

$$\overline{X} = \frac{1}{60}\sum_{i=1}^{5}\sum_{j=1}^{12} X_{ij}$$

Associated with these means are the sum-of-squares S_1, S_2, S_3, and S_4 and calculated from the expressions:

$$S_1 = 60\,\overline{X^2}$$

$$S_2 = 5\sum_{i=1}^{12}(\overline{X_i} - \overline{X})^2$$

$$S_3 = 12\sum_{j=1}^{5}(\overline{X_j} - \overline{X})^2$$

$$S_4 = \sum_{i=1}^{12}\sum_{j=1}^{5}(X_{ij} - \overline{X_i} - \overline{X_j} - \overline{X})^2$$

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	**Degrees of freedom** ν_l	**Mean square** $M_l = \frac{S_l}{\nu_l}$	**Variance estimated by mean square**
Mean	S_1 = 16,774 593 75	1	M_1 = 16,774 593 75	—
Across measurement standard	S_2 = 0,000 804 725	11	M_2 = 7,315 681 8 e−5	$\sigma_M^2 + 5\sigma_R^2$
Between evaluations	S_3 = 0,000 075 196	4	M_3 = 1,879 900 0 e−5	$\sigma_M^2 + 12\sigma_E^2$
Instrument repeatability	S_4 = 0,000 252 648	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, it follows from the last columns of Table C.2:

$$s_R^2 = \frac{(M_2 - M_4)^2}{5}; \; s_R = 3{,}67 \text{ nm}$$

$$s_E^2 = \frac{(M_3 - M_4)^2}{12}; \; s_E = 1{,}04 \text{ nm}$$

$s_M^2 = M_4$; s_M = 2,40 nm

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 $M_2 - M_4$ and $(M_3 - M_4)^2$, respectively, and may be evaluated from the Welch-Satterwaithe formula (see GUM).

$$v_{\text{eff}}(s_R^2) = \frac{(M_2 - M_4)^2}{\frac{M_2^2}{11} + \frac{M_4^2}{44}} = 9{,}3$$

$$v_{\text{eff}}(s_E^2) = \frac{(M_3 - M_4)^2}{\frac{M_3^2}{4} + \frac{M_4^2}{44}} = 1{,}9$$

The calibration certificate gives a nominal value of Ra = 0,529 4 µm with "an uncertainty" of 4 %. Assuming that the 4 % is a plus and minus figure and that the results have a rectangular distribution this gives a standard uncertainty estimate of:

$$u_{\text{cal}} = \frac{0{,}529\ 4\ \mu\text{m} \times 4\ \%}{\sqrt{3}} = 12{,}2\ \text{nm}$$

The calibration certificate state that this uncertainty already includes the variation of the parameter values across the measurement standard so this will not have to be included a second time in the combined standard uncertainty.

The combined standard uncertainty is thus:

$$u_c = \sqrt{s_E^2 + s_M^2 + u_{\text{cal}}^2} = 12{,}5\ \text{nm}$$

and the expanded uncertainty, U, is 0,025 µm with k = 2.

NOTE This example is purely illustrative, the uncertainties calculated must not be taken as typical of those found in practice.

Annex D
(informative)

Relation to the GPS matrix model

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

D.1 Information about this International Standard and its use

This International Standard 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.

D.2 Position in the GPS matrix model

This International Standard is a general GPS standard, which influences the chain link 6 of the chain of standards on roughness, waviness and primary profile in the general GPS matrix, as graphically illustrated in Figure D.1.

Fundamental GPS standards

Global GPS standards

General GPS standards						
Chain link number	**1**	**2**	**3**	**4**	**5**	**6**
Size						
Distance						
Radius						
Angle						
Form of line independent of datum						
Form of line dependent on datum						
Form of surface independent of datum						
Form of surface dependent on datum						
Orientation						
Location						
Circular run-out						
Total run-out						
Datums						
Roughness profile						
Waviness profile						
Primary profile						
Surface imperfections						
Edges						

Figure D.1

D.3 Related standards

The related standards are those of the chains of standards indicated in Figure D.1.

Bibliography

[1] ISO Guide 35, *Certification of reference materials — General and statistical principles.*

[2] ISO/TR 14638:1995, *Geometrical product specifications (GPS) — Masterplan.*

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