



International
Standard

ISO 5463

**Geometrical product specifications
(GPS) — Rotary axis form-
measuring instruments — Design
and metrological characteristics**

*Spécification géométrique des produits (GPS) — Instruments de
mesure de forme à axe rotatif — Caractéristiques de conception
et caractéristiques métrologiques*

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Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
3.1 General terms	2
3.2 Terms relating to probe system	3
4 Design characteristics	3
4.1 General	3
4.2 Types of rotary axis form-measuring instruments	4
4.2.1 General	4
4.2.2 Rotating workpiece instrument	4
4.2.3 Stationary workpiece instrument	6
4.3 Design characteristics of probe	8
4.3.1 Contact probe	8
4.3.2 Other types of probe	9
5 Metrological characteristics	9
5.1 General	9
5.2 Rating operating condition	9
5.2.1 Environmental conditions	9
5.2.2 Operating conditions	10
5.3 Correction of form deviations on material measure	10
5.4 Probe characteristics	10
5.4.1 Reference point	10
5.4.2 Probe error	10
6 Determination of conformity to specification	12
6.1 General	12
6.2 Measurement uncertainty	12
6.3 Decision rule	13
Annex A (normative) Design and metrological characteristics for rotating workpiece instruments	14
Annex B (informative) Artefacts for metrological characteristics	38
Annex C (informative) Dynamic response of the probe	42
Annex D (informative) Incidental machine characteristics “Cresting”	45
Annex E (informative) Other types of probes	46
Annex F (informative) Relationship to the GPS matrix model	48
Bibliography	49

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.

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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).

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 standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain link F of the chains of standards on form, orientation, location and run-out.

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 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 F](#).

See ISO/TR 14253-6 for additional information on the selection of alternative decision rules.

There are different types and variants of rotary axis form-measuring instrument. The metrological characteristics described in this document apply to all types and variants.

Geometrical product specifications (GPS) — Rotary axis form-measuring instruments — Design and metrological characteristics

1 Scope

This document specifies the most important design and metrological characteristics of rotary axis form-measuring instruments.

It is not applicable to coordinate measurement systems as defined by the ISO 10360 series, whether the systems are fitted with a rotary axis or not, except by special agreement.

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 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

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

ISO/TR 14253-6, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 6: Generalized decision rules for the acceptance and rejection of instruments and workpieces*

ISO 14978:2018, *Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment*

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

ISO/IEC Guide 99:2007, *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 1101, ISO 14978 and ISO/IEC Guide 99 and the following 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 General terms

3.1.1

rotary axis form-measuring instrument

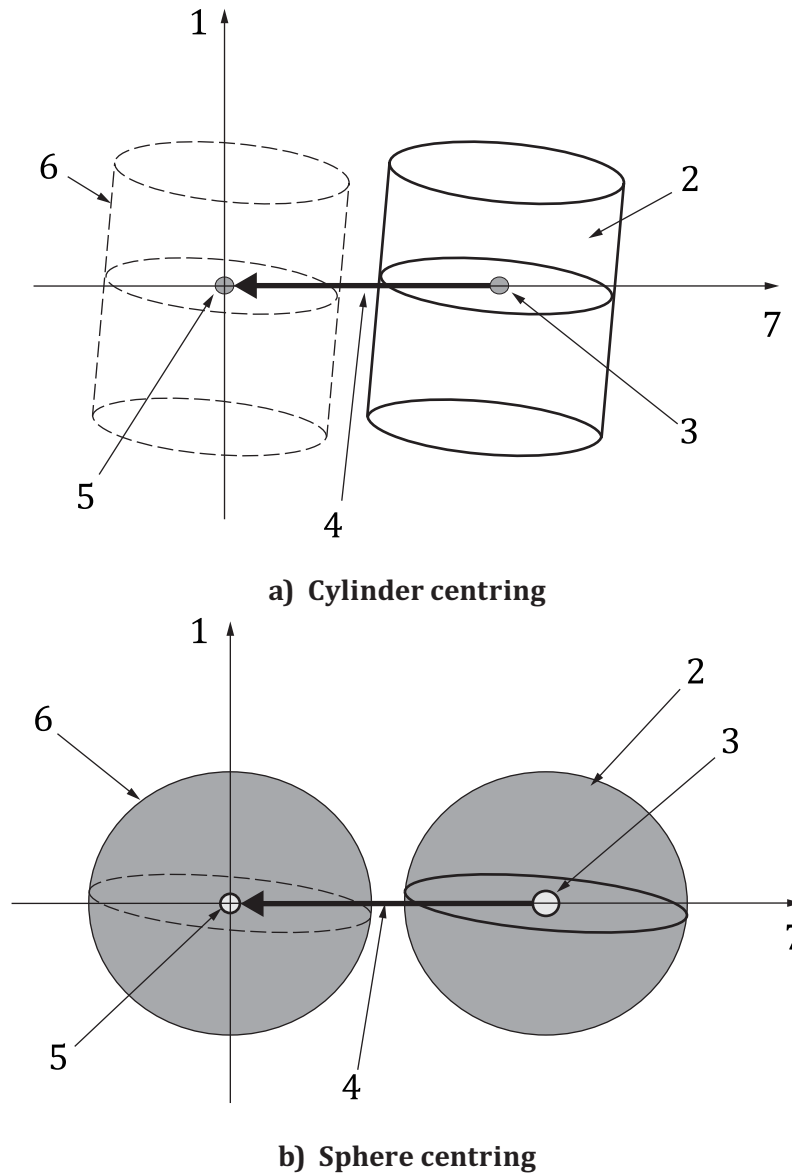
measuring instrument having a rotary axis and quantifying local form deviations from extracted integral surfaces in a cylindrical coordinate system

3.1.2

centring

adjusting, in a plane perpendicular to the axis of rotation, the position of the centre point of the workpiece to be coincident to the axis of rotation of the instrument

Note 1 to entry: See [Figure 1](#).



Key

- | | | | |
|---|------------------------------------|---|---|
| 1 | axis of rotation | 5 | centre point after centring |
| 2 | revolute workpiece before centring | 6 | revolute workpiece after centring |
| 3 | centre point before centring | 7 | orthogonal axis to the axis of rotation |
| 4 | centring displacement | | |

Figure 1 — Centring

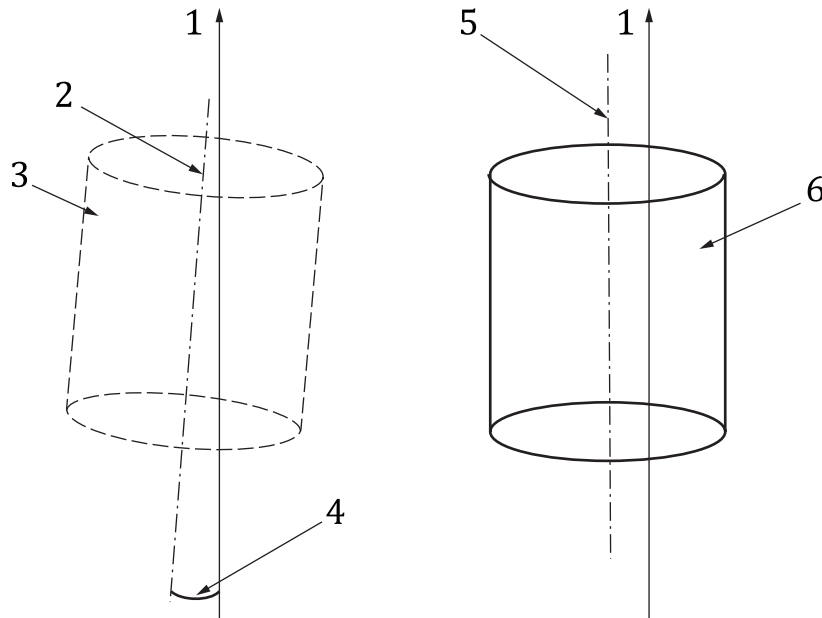
3.1.3

levelling

adjusting the centre line of the workpiece to be parallel to the axis of rotation or adjusting the normal vector to a plane feature of the workpiece to be parallel to the axis of rotation

Note 1 to entry: See [Figure 2](#).

Note 2 to entry: Levelling is often combined with, or followed by, centring in order to bring the axis of the workpiece to be coaxial with the rotary axis of the instrument.



Key

- | | | | |
|---|--|---|---|
| 1 | axis of rotation | 4 | angular displacement |
| 2 | centre line of revolute workpiece before levelling | 5 | centre line of revolute workpiece after levelling |
| 3 | revolute workpiece before levelling | 6 | revolute workpiece after levelling |

Figure 2 — Levelling

3.2 Terms relating to probe system

3.2.1

stylus

mechanical device consisting of a tip and an arm

4 Design characteristics

4.1 General

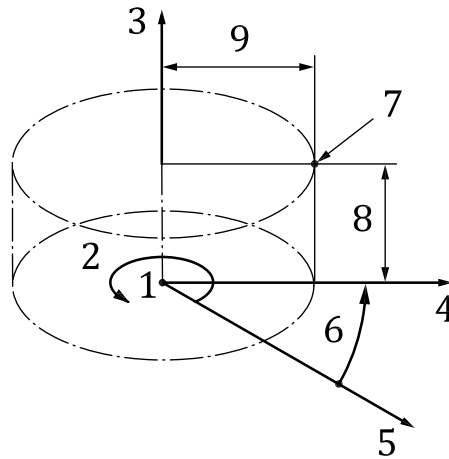
This measuring instrument is primarily constructed to acquire form deviations in cylindrical coordinates through the direct measurement of radial (and axial) deviations. The design characteristics of a rotary axis form-measuring instrument are described generically in [Annex A](#), and depend on its type.

The cylindrical coordinate system is configured with the longitudinal axis nominally coincident with the rotary axis and with a nominally perpendicular transverse axis.

NOTE 1 See [Figure 3](#).

NOTE 2 Displacements measured along the longitudinal axis are designated as H and are measured from a point specified by the manufacturer.

- NOTE 3 Radius, designated as R , is measured from the rotary axis and its basic direction is the transverse axis.
- NOTE 4 Rotation angle, designated as θ , is measured from a line with orientation specified by the manufacturer in the transverse plane.
- NOTE 5 Direction along the rotary axis is called “axial direction” for rotary characteristics.
- NOTE 6 Outward direction around the rotary axis is called “radial direction” for rotary characteristics.
- NOTE 7 Rotating direction around the rotary axis is called “angular direction” for rotary characteristics.



Key

- | | | | |
|---|---|---|---|
| 1 | origin (centre position of rotary bearing) | 6 | rotation angle (angular distance of transverse axis from reference axis) |
| 2 | angular motion | 7 | probing point |
| 3 | axis line of rotation (longitudinal axis) | 8 | longitudinal distance (distance of the probing point from the transverse plane) |
| 4 | transverse axis or radial direction | 9 | radial distance (of the probing point from the rotary axis) |
| 5 | angular reference axis in the transverse plane ($\theta=0$) | | |

Figure 3 — Measuring coordinate system

4.2 Types of rotary axis form-measuring instruments

4.2.1 General

There are a number of different types of rotary axis form-measuring instruments, with variants of each of these types.

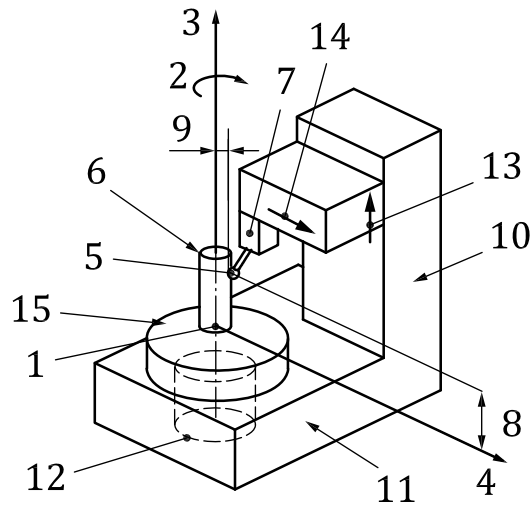
4.2.2 Rotating workpiece instrument

Design characteristics of this type of instrument shall be in accordance with [Annex A](#).

Rotating workpiece instruments include the following variants:

- Vertical axis rotating workpiece instrument on which the workpiece is fixed on a worktable, see [Figure 4](#).
- Horizontal axis rotating workpiece instrument, which is a variant of type a), where the longitudinal axis lies in a horizontal plane, see [Figure 5](#).
- Vertical axis rotating workpiece between centres, which is a variant of type a), where the workpiece is rotated between centres instead of on a worktable.

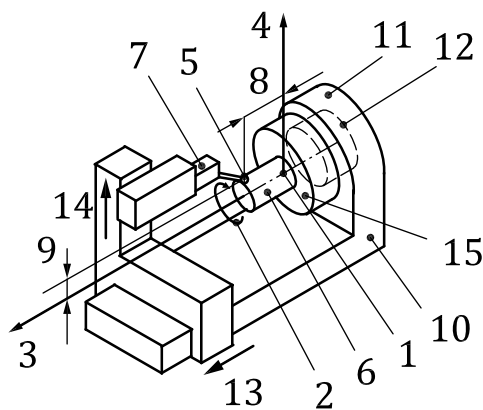
- d) Horizontal axis rotating workpiece between centres, which is a variant of type b), where the workpiece is rotated between centres instead of on a worktable.



Key

- | | | | |
|---|--|----|---|
| 1 | origin of measuring coordinate system | 9 | probing point radius R from rotary axis |
| 2 | angular motion | 10 | column |
| 3 | axis line of rotation | 11 | base |
| 4 | transverse axis | 12 | rotary spindle |
| 5 | probing point | 13 | longitudinal axis motion |
| 6 | workpiece | 14 | transverse axis motion |
| 7 | probe | 15 | worktable |
| 8 | probing point height H from the top plane of the worktable | | |

Figure 4 — Vertical axis rotating workpiece instrument



Key

- | | | | |
|---|--|----|---|
| 1 | origin of measuring coordinate system | 9 | probing point radius R from rotary axis |
| 2 | angular motion | 10 | column |
| 3 | axis line of rotation or longitudinal axis | 11 | base |
| 4 | transverse axis direction | 12 | rotary spindle |
| 5 | probing point | 13 | longitudinal motion |

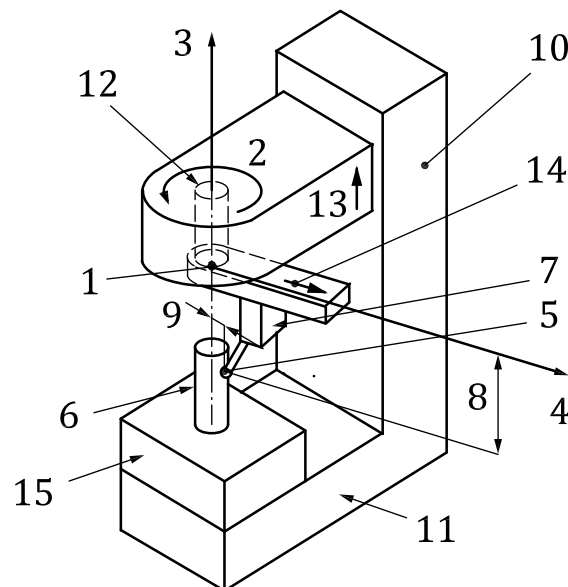
- | | | | |
|---|---|----|------------------------------------|
| 6 | workpiece | 14 | transverse motion |
| 7 | probe | 15 | fixture for workpiece on worktable |
| 8 | probing point height H from worktable top plane | | |

Figure 5 — Horizontal axis rotating workpiece instrument

4.2.3 Stationary workpiece instrument

The stationary workpiece type instruments include the following variants:

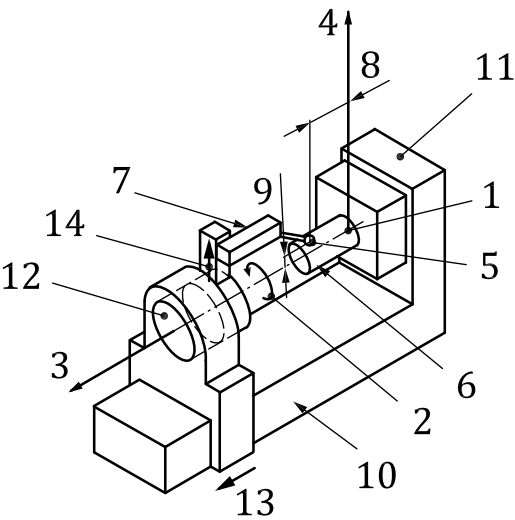
- Vertical axis stationary workpiece instrument on which the stylus turns around the workpiece, which is fixed on a worktable, see [Figure 6](#).
- Horizontal axis stationary workpiece instrument, which is a variant of type a) in which the longitudinal axis lies in a horizontal plane, see [Figure 7](#).
- Horizontal axis stationary workpiece between both centres instrument, which is a variant of b), where the workpiece is held between centres instead of in a workpiece fixture.
- Hole insertion with stationary workpiece instrument, a variant of a type where the instrument works inside a fixed cylindrical hole on a workpiece, see [Figure 8](#).



Key

- | | | | |
|---|---|----|---|
| 1 | origin of measuring coordinate system | 9 | probing point distance R from rotary axis |
| 2 | angular motion | 10 | column |
| 3 | axis line of rotation | 11 | base |
| 4 | transverse axis | 12 | rotary spindle |
| 5 | probing point | 13 | longitudinal axis motion |
| 6 | workpiece | 14 | transverse axis motion |
| 7 | probe | 15 | worktable |
| 8 | probing point height H from the origin at the transverse axis | | |

Figure 6 — Vertical axis stationary workpiece instrument



Key

1	origin of measuring coordinate system	8	probing point height H from the origin at the transverse axis
2	angular motion	9	probing point distance from rotary axis
3	axis line of rotation or transverse axis	10	base
4	longitudinal axis	11	column
5	probing point	12	rotary spindle
6	workpiece	13	transverse axis motion
7	probe	14	adjusting radius

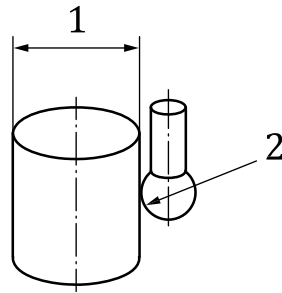
Figure 7 — Horizontal axis stationary workpiece instrument



- Figure 8 — Hole insertion with stationary workpiece instrument**

4.3.1 Contact probe

The default geometry of a stylus tip is a sphere (see [Figure 9](#)).

**Key**

1 diameter of cylindrical workpiece

2 tip radius of sphere stylus in any direction

Figure 9 — Sphere stylus tip geometry**4.3.2 Other types of probe**

There are many different types of probe, which may have limitations on the types of materials that can be measured. For rotary axis form-measuring instruments equipped with other probes, the manufacturer can state each of the specifications (see [Annex E](#)).

5 Metrological characteristics**5.1 General**

The metrological characteristics, other concepts and principles that are common across types and variants are described below. Because the verification of the metrological characteristics may vary dependent on instrument type and variant, testing and verification are described in [Annex A](#) relating to the instrument type and variant. The testing and verification shall be carried out as specified in [Annex A](#). The material measures for these tests are described in [Annex B](#).

A rotary axis form-measuring instrument can be used to measure many types of geometrical features. The instrument may, therefore, have many different metrological characteristics. The supplier of a rotary axis form-measuring instrument shall specify the maximum permissible error (MPE) of each metrological characteristic. These MPEs apply when the instrument is used in accordance with the rated operating conditions stated by manufacturer or supplier and the manufacturer's recommendations.

NOTE The manufacturer or supplier does not need to specify MPE values for metrological characteristics that are not included in the instrument functions or in the required measurements on the target workpiece.

The probe error is presented in [5.4](#), separately from [Annex A](#), due to its potential contributor to all other metrological characteristics of a rotary axis form-measuring instrument.

The length unit of metrological characteristics is micrometres, by default.

5.2 Rating operating condition**5.2.1 Environmental conditions**

Limits for permissible environmental conditions that influence the measurements (e.g. temperature conditions, humidity, vibration and ambient lighting at the site of installation) shall be specified by:

- the manufacturer, in the case of acceptance tests;
- the user, in the case of reverification tests.

In both cases, the user is free to choose the environmental conditions within the specified limits given in the instrument data sheet under which testing to this document will be performed.

The user is responsible for providing the environmental conditions as stated by the manufacturer in the data sheet. If the environment is not within the rated operating conditions, then conformity or nonconformity decision cannot be made unless the rated operating condition are met.

5.2.2 Operating conditions

The instrument shall be operated using the procedures given in the manufacturer's operating manual when conducting the tests given in [Annex A](#).

5.3 Correction of form deviations on material measure

As discussed in [Annex B](#), many of the measurement standards needed for verifying conformity to specification should have small form deviations. The form deviations contribute to the measurement uncertainty of the test values. To reduce the contribution of the form deviations on the material measure to the test uncertainty, this document allows correction of the form deviations.

NOTE The following methods are typically used for correction of the form deviation of the measurement standards:

- a) compensation of the calibrated profile method;
- b) reversal error separation method (see ISO 230-7 and references [21],[22],[25] and [27]);
- c) multi-step error separation method; (see references [23],[24],[25],[27],[28] and [32]).

5.4 Probe characteristics

5.4.1 Reference point

Where applicable, the probe used for form measurements shall be provided with user-accessible means for setting the probe to zero or to the reference point. The metrological characteristics described in this document apply when the probe is properly set in accordance with the manufacturer's recommendations, and the reference point is considered fixed when verifying the metrological characteristics.

5.4.2 Probe error

5.4.2.1 General

The probe error (E_p) is the error of indication when the probe is in contact with a material measure, for any angular motion of the material measure or of the stylus depending on the type of the rotary axis form-measuring instrument. The probe error is calculated as the signed deviation of the probe indication from the calibrated reference value of a material measure.

The MPE of probe error shall be specified in at least one measuring range stated by the manufacturer or supplier.

NOTE 1 The probe error can include the sensitivity error, the linearity error, the instrumental drift, the resolution or digital step, the repeatability, the measurement noise, the hysteresis error and the dynamic response (see [Annex C](#)).

NOTE 2 The probe error is a contributor to all metrological characteristics of the instrument.

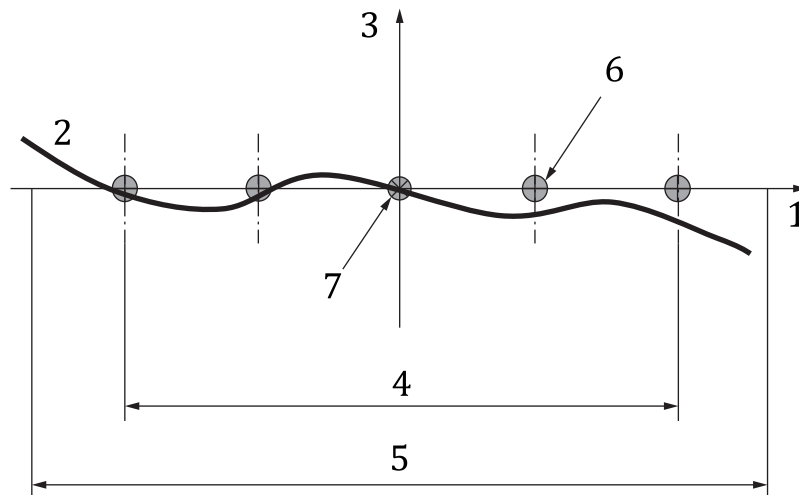
The sensitivity shall be adjusted following the manufacturer's recommendations prior to the probe error test.

5.4.2.2 Test method

5.4.2.2.1 Test points and range

The verification test of probe errors shall be carried out with five or more test points. The test points shall be well distributed, as evenly as practicable, throughout the measuring range of the probe (see [Figure 10](#)). The test points shall cover at least the central 75 % of the measuring range of the probe.

The reference point of the probe shall be at the centre (zero point) of its measuring range. This reference point shall be located on the reference plane of the standard and be one of the test points.



Key

- | | | | |
|---|---------------------|---|--------------------------|
| 1 | actual displacement | 5 | measuring range of probe |
| 2 | probe error curve | 6 | test point |
| 3 | probe error | 7 | reference point |
| 4 | test range | | |

Figure 10 — Analysis of probe error

5.4.2.2.2 Test direction and location

The user is free to choose the probing direction (horizontal or vertical) for the probe error verification test, if not stated otherwise by the manufacturer.

5.4.2.3 Measurement standard and testing procedure

When testing conformity to specifications, sufficient testing shall be used to establish confidence in the results and the tester may choose suitable instruments or measurement standards from those described in [Annex B](#). The instrument or measurement standard used shall cover the range to be tested.

If each target step of displacement has a different probing position, the probing positions should be set along an accurate (rotary, longitudinal or transverse) traversing motion. Probe error shall be calculated from the measured length difference of each displacement. Typical procedures of each instrument and material measures are also shown in [Annex B](#).

5.4.2.4 MPE function

5.4.2.4.1 General

Maximum permissible probe error, $E_{p,MPE}$, is a two-sided MPE function as shown in ISO 14978:2018, 7.2.

5.4.2.4.2 Proportional value MPE functions

Upper limit MPE:

$$E_{P,MPE} = + (a + |L \times b|)$$

Lower limit MPE:

$$E_{P,MPE} = - (a + |L \times b|)$$

5.4.2.4.3 Constant value MPE functions

Upper limit MPE:

$$E_{P,MPE} = + a$$

Lower limit MPE:

$$E_{P,MPE} = - a$$

5.4.2.4.4 Proportional value MPE functions with probe range

Upper limit MPE:

$$E_{P,MPE} = + (a + |L \times b|) / (\text{probe range})$$

Lower limit MPE:

$$E_{P,MPE} = - (a + |L \times b|) / (\text{probe range})$$

where

a are positive constants stated by the manufacturer;

b is a dimensionless positive constant stated by the manufacturer;

L is the actual displacement in micrometres ($L = 0$ at the reference point)

The MPE of the probe error can also be indicated as a percentage of the measuring span stated by the manufacturer when the MPE is intended to indicate using constant value. The MPE of the probe error can also be indicated as a percentage with proportional measuring span.

6 Determination of conformity to specification**6.1 General**

All errors of indication associated with the metrological characteristics shall conform to the specified MPE values.

6.2 Measurement uncertainty

Evaluation of measurement uncertainty shall be performed in accordance with ISO/IEC Guide 98-3. When determining conformity with specification, the measurement uncertainty associated with a test value (the test value uncertainty) shall be evaluated in accordance with ISO 14253-5. Additional guidance is available in ISO 14978:2018, Annex D.