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Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 5: CMMs using single and multiple stylus contacting probing systems

Spécification géométrique des produits (GPS) — Essais de réception et de vérification périodique des machines à mesurer tridimensionnelles (MMT) —

Partie 5: MMT utilisant des systèmes de palpage à stylet simple et à stylets multiples

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10360-5 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This second edition cancels and replaces the first edition (ISO 10360-5:2000), which has been technically revised, and ISO/PAS 12868:2009.

ISO 10360 consists of the following parts, under the general title *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM)*:

— *Part 1: Vocabulary*

— *Part 2: CMMs used for measuring linear dimensions*

— *Part 3: CMMs with the axis of a rotary table as the fourth axis*

— *Part 4: CMMs used in scanning measuring mode*

— *Part 5: CMMs using single and multiple stylus contacting probing systems*

— *Part 6: Estimation of errors in computing Gaussian associated features*

— *Part 7: CMMs equipped with video probing systems*

— *Part 9: CMMs with multiple probing systems*

The following parts are under preparation:

— *Part 8: CMMs with optical distance sensors*

— *Part 10: Laser trackers for measuring point-to-point distances*

Introduction

This part of ISO 10360 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain link 5 of the chains of standards of size, distance, radius, angle, form, orientation, location, run-out and datums.

For more detailed information on the relation of this part of ISO 10360 to other standards and the GPS matrix model, see Annex E.

The acceptance and reverification tests described in this part of ISO 10360 are applicable to coordinate measuring machines (CMMs) that use contacting probes, with or without multiple styli or multiple articulated-probe positions, when measuring a workpiece.

Experience has shown that the multi-stylus errors calculated using this part of ISO 10360 are significant and, at times, the dominant errors in the CMM. Owing to the virtually infinite variety of modern CMM probing system configurations, the tests specified by this part of ISO 10360 have been limited to providing a testing format only. The tests are intended to provide information on the ability of a CMM to measure a feature or features, using a contacting probe and, when relevant, using multiple styli, multiple probes or multiple articulated-probe positions.

The situations to which they are applicable include

— single-stylus probing systems,

— multiple styli connected to the CMM probe (e.g. a star),

— installations using an articulating probing system (motorized or manual) that can be prequalified,

— installations using a repeatable probe-changing system,

— installations using a repeatable stylus-changing system, and

— multi-probe installations.

It is believed that the procedures given in this part of ISO 10360 will be helpful in identifying CMM system uncertainty components for specific measurement tasks, and that the user will be able to reduce errors by removing contributing elements such as long probe extensions and styli, then retesting the new configuration set.

The tests in this part of ISO 10360 are sensitive to many errors attributable to both the CMM and the probing system, and are to be performed in addition to the length-measuring tests given in ISO 10360-2.

The primary objective is to determine the practical performance of the complete CMM and probing system. Therefore, the tests are designed to reveal measuring errors which are likely to occur when such a combined system is used on real workpieces, e.g. errors generated by the interaction between large probe-tip-offset lengths and uncorrected CMM rotation errors. The errors found here differ from those found in the E_L tests in ISO 10360-2:2009, 6.5, because with multiple styli the net CMM travel may be very different from the measured length. See Annex C for more information.

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 5: CMMs using single and multiple stylus contacting probing systems

1 Scope

This part of ISO 10360 specifies acceptance and periodic reverification tests of CMM performance with contacting probing systems and is only applicable to CMMs using

— any type of contacting probing system,

— a discrete point probing mode, and

— spherical or hemispherical stylus tip(s).

It complements ISO 10360-7, which is the module for CMMs with video probing systems, and ISO 10360-2, which is universal, i.e. not probe-type specific.

NOTE It is the CMM probing performance tests which are specified by the maximum permissible errors (MPEs), due to the impracticality of isolating the performance of the probing system from that of the CMM, even on a small artefact such as a test sphere.

This part of ISO 10360 applies to CMMs supplied with any of the following:

a) single-stylus probing system;

b) multi-stylus probing systems with fixed multiple styli attached to a single probe (e.g. “star” stylus);

c) multiple probing systems such as those with a stylus for each of their probes;

d) systems with articulating probing;

e) stylus and probe changing systems;

f) manual (non-driven) CMMs.

This part of ISO 10360 is not applicable to non-contacting probing systems, which require different testing procedures.

The terms “multi-stylus size error”, etc., should strictly be written “combined CMM and multi-stylus probing-system size error”, etc. For convenience, the wording has been truncated.

If it is desired to isolate the probing-system performance as far as is practical, the influence of the CMM can be minimized. See Annex C for more information.

2 Normative references

The following referenced documents are indispensable for the application 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 10360-1:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO 10360-2:2009, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 2: CMMs used for measuring linear dimensions*

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

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 10360-1, ISO 14253-1, ISO/IEC Guide 99 and the following apply.

NOTE This clause contains eight definitions (3.6 to 3.13) which supersede fourteen similar definitions in Clause 9 of ISO 10360-1:2000. Some of these revised definitions are required to avoid ambiguities which would otherwise have been introduced with this edition of ISO 10360-5. Others effectively supersede identical definitions in ISO 10360-1, because the symbols used have been revised and expanded for clarification. The superseded definitions are 9.3, 9.4 and 9.15 to 9.26.

3.1
inferred probing-system qualification
probing-system qualification method where the parameters for each probing system attached to an articulation system are inferred by interpolation, extrapolation, or other relevant model, for significantly different angular position(s) from parameters acquired by **empirical probing-system qualification** (3.3) at a few angular positions

3.2
angular positioning device qualification
establishment of the parameters of the angular positioning device in an articulating probing system necessary for subsequent **inferred probing-system qualification** (3.1)

3.3
empirical probing-system qualification
probing-system qualification method where the parameters for each probing system attached to an articulation system must be acquired by measurement of the reference sphere at each angular position used

3.4
effective stylus tip diameter
diameter used for the tip correction vector, for compensating measured feature size, etc.

NOTE 1 For the position of the tip correction vector, see ISO 10360-1:2000, Figure 4.

NOTE 2 The effective stylus tip diameter may be a parameter established by a probing-system qualification.

3.5
probing-system pre-qualification
probing-system qualification which is separated from subsequent measurement by probe or stylus change(s), and/or articulating probing-system re-orientation(s)

3.6
multi-stylus form (measurement) error
P_{FTj}
error of indication within which the range of Gaussian radial distances can be determined by a least-squares fit of points measured on a test sphere, the measurements being taken with five different styli on the one test sphere located anywhere in the measuring volume by a CMM using the discrete-point probing mode

See ISO 10360-1:2000, Figure 15.

NOTE 1 The character P in P_{FTj} indicates that the error is associated with the probing-system performance, and the subscript F indicates that it is a form error. The subscript T indicates that the probing system conforms to Clause 1 of this part of ISO 10360 (i.e. tactile), thus enabling any alternative probing system to be clearly identified by the use of a different character at * in P_{F*j}.

NOTE 2 There are four multi-stylus form errors based on different probing systems and methods of operation. These are designated as follows:

j = E, an articulating probing system using empirical qualification;

j = I, an articulating probing system using inferred qualification;

j = M, a fixed multi-stylus probing system;

j = N, a fixed multi-probe system.

NOTE 3 All the symbols used in this part of ISO 10360 are listed in Annex A.

3.7
multi-stylus size error
P_{STj}
error of indication within which the diameter of a test sphere can be determined by a least-squares fit of points, the measurements being taken with five different styli on the one test sphere located anywhere in the measuring volume by a CMM using the discrete-point probing mode

NOTE 1 The subscript S in P_{STj} indicates that it is a size error.

NOTE 2 All the symbols used in this part of ISO 10360 are listed in Annex A.

3.8
multi-stylus location value
P_{LTj}
maximum of the ranges of the X, Y and Z coordinates within which the location of a test sphere can be determined by a least-squares fit of points, the measurements being taken with five different styli on the one test sphere located anywhere in the measuring volume by a CMM using the discrete-point probing mode

NOTE 1 The subscript L in P_{LTj} indicates that it is a location value.

NOTE 2 All the symbols used in this part of ISO 10360 are listed in Annex A.

NOTE 3 All values are absolute.

3.9
single-stylus form error
P_{FTU}
error of indication within which the range of radii can be determined by a least-squares fit of points measured on a test sphere, the measurements being performed by a CMM with a single stylus, using the discrete-point probing mode, with points taken on the test sphere located anywhere in the measuring volume

See ISO 10360-1:2000, Figure 15.

NOTE 1 The character P in P_{FTU} indicates that the error is related primarily to the probing-system performance. The subscript U indicates use of a single (unique) stylus.

NOTE 2 See 3.6 for information on F and T.

NOTE 3 All such characters used in this part of ISO 10360 are listed in Annex A.

NOTE 4 P_{FTU} is identical to P in ISO 10360-2:2001.

3.10
single-stylus size error
P_{STU}
error of indication of the difference between the diameter of a least-squares fit of points measured on a test sphere and its calibrated diameter, the measurements being performed by a CMM with a single stylus, using the discrete-point probing mode, with points taken on the test sphere located anywhere in the measuring volume

NOTE 1 The character P in P_{STU} indicates that the error is related primarily to the probing-system performance. The subscript U indicates use of a single (unique) stylus. The subscript S in P_{STj} indicates that it is a size error.

NOTE 2 All such characters used in this part of ISO 10360 are listed in Annex A.

3.11
maximum permissible multi-stylus form error
$P_{FTj,\,MPE}$
extreme value of the **multi-stylus form error** (3.6), P_{FTj}, permitted by specifications, regulations, etc. for a CMM

NOTE 1 The maximum permissible value of the multi-stylus form error, $P_{FTj,\,MPE}$, can be expressed in one of three forms:

a) $P_{FTj,\,MPE}$ = minimum of $(A + L_P/K)$ and B; or

b) $P_{FTj,\,MPE} = (A + L_P/K)$; or

c) $P_{FTj,\,MPE} = B$

where

A is a positive constant, expressed in micrometres and supplied by the manufacturer;

K is a dimensionless positive constant supplied by the manufacturer;

L_P is the distance in 3D between the centres of the reference sphere and the test sphere, in millimetres;

B is the maximum permissible error $P_{FTj,\,MPE}$, in micrometres, as stated by the manufacturer.

These forms are shown in Figures D.1, D.2 and D.3.

NOTE 2 A maximum permissible error (MPE) as opposed to a maximum permissible limit (MPL) specification is used when the test measurements determine errors; hence, testing an MPE specification requires the use of calibrated artefacts.

NOTE 3 $P_{FTj,\,MPE}$ can be specified by probe-tip-offset length or by the stylus system description.

3.12
maximum permissible multi-stylus size error
$P_{STj,\,MPE}$
extreme value of the **multi-stylus size error** (3.7), P_{STj}, permitted by specifications, regulations, etc. for a CMM

NOTE 1 The maximum permissible value of the multi-stylus size error, $P_{ST_j,\ MPE}$, can be expressed in one of three forms:

a) $P_{ST_j,\ MPE}$ = minimum of $(A + L_P/K)$ and B; or

b) $P_{ST_j,\ MPE} = (A + L_P/K)$; or

c) $P_{ST_j,\ MPE} = B$

where

A is a positive constant, expressed in micrometres and supplied by the manufacturer;

K is a dimensionless positive constant supplied by the manufacturer;

L_P is the distance in 3D between the centres of the reference sphere and the test sphere, in millimetres;

B is the maximum permissible error $P_{ST_j,\ MPE}$, in micrometres, as stated by the manufacturer.

These forms are shown in Figures D.1, D.2 and D.3.

NOTE 2 A maximum permissible error (MPE) as opposed to a maximum permissible limit (MPL) specification is used when the test measurements determine errors; hence, testing an MPE specification requires the use of calibrated artefacts.

NOTE 3 $P_{ST_j,\ MPE}$ can be specified by probe-tip-offset length or by the stylus system description.

3.13
maximum permissible limit of the multi-stylus location value
$P_{LT_j,\ MPL}$
extreme value of the **multi-stylus location value** (3.8), P_{LT_j}, permitted by specifications, regulations, etc. for a CMM

NOTE 1 The maximum permissible limit of the multi-stylus location value, $P_{LT_j,\ MPL}$, can be expressed in one of three forms:

a) $P_{LT_j,\ MPL}$ = minimum of $(A + L_P/K)$ and B; or

b) $P_{LT_j,\ MPL} = (A + L_P/K)$; or

c) $P_{LT_j,\ MPL} = B$

where

A is a positive constant, expressed in micrometres and supplied by the manufacturer;

K is a dimensionless positive constant supplied by the manufacturer;

L_P is the distance in 3D between the centres of the reference sphere and the test sphere, in millimetres;

B is the maximum permissible limit $P_{LT_j,\ MPL}$, in micrometres, as stated by the manufacturer.

These forms are shown in Figures D.1, D.2 and D.3.

NOTE 2 A maximum permissible limit (MPL) as opposed to a maximum permissible error (MPE) specification is used when the test measurements are not errors; hence, testing an MPL specification does not require the use of artefacts with a relevant calibration.

NOTE 3 $P_{LT_j,\ MPL}$ can be specified by the probe-tip-offset length or by the stylus system description.

3.14
maximum permissible single-stylus form error
$P_{FTU,\ MPE}$
extreme value of the **single-stylus form error** (3.9), P_{FTU}, permitted by specifications, regulations, etc. for a CMM

See ISO 10360-1:2000, Figure 15.

NOTE 1 $P_{FTU,\ MPE}$ can be specified by probe-tip-offset length or by the stylus system description.

NOTE 2 $P_{FTU,\ MPE}$ is identical to MPE_P in ISO 10360-2:2001.

4 Symbols

For the purpose of this document, the symbols of Table 1 apply.

Table 1 — Symbols

Symbol	Meaning
A	Positive constant, expressed in micrometres and supplied by the manufacturer, used to express a maximum permissible limit or error
K	Dimensionless positive constant supplied by the manufacturer, used to express a maximum permissible limit or error
L_P	Distance in 3D between the centres of the reference sphere and the test sphere, in millimetres
B	Maximum permissible error (e.g. $P_{FTj,\ MPE}$) or limit (e.g. $P_{LTj,\ MPL}$), in micrometres, as stated by the manufacturer
R	Gaussian radial distance
l	Fixed multi-stylus probing-system stylus length
l_U	Single-stylus length
l_O	Fixed multi-probe-tip-offset length
l_A	Articulating probing-system probe-tip-offset length
X, Y, Z	Centre coordinates
E_0	Length measurement error with minimal probe-tip-offset length
$E_{0,\ MPE}$	Maximum permissible error of length measurement with minimal probe-tip-offset length
E_L	Length measurement error with probe-tip-offset length L
$E_{L,\ MPE}$	Maximum permissible error of length measurement
$j = E$	Articulating probing system using empirical qualification
$j = I$	Articulating probing system using inferred qualification
$j = M$	Fixed multi-stylus probing system
$j = N$	Fixed multi-probe system
P_{FTE}	Multi-stylus form error, P_{FTj}
P_{FTI}	
P_{FTM}	
P_{FTN}	