INTERNATIONAL STANDARD

ISO 10360-5

Third edition
2020-03

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 5: Coordinate measuring machines (CMMs) using single and multiple stylus contacting probing systems using discrete point and/or scanning measuring mode

Spécification géométrique des produits (GPS) — Essais de réception et de vérification périodique des systèmes à mesurer tridimensionnels (SMT) —

Partie 5: MMT utilisant des systèmes de palpage à stylet simple ou à stylets multiples utilisant un mode de mesurage par point discret et/ou par scan

Reference number
ISO 10360-5:2020(E)

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Published in Switzerland

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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).

This third edition cancels and replaces the second edition (ISO 10360-5:2010), which has been technically revised.

It also incorporates with a technical revision the tests contained within ISO 10360-4:2000 and, as such, it cancels and replaces ISO 10360-4:2000.

The main changes to the previous edition are as follows:

— the adoption of new symbology;

— the addition of an optional ring gauge test;

— changes to acceptable test parameters e.g. test sphere diameter;

— changes to Location results evaluation including an “opposing styli” evaluation.

A list of all parts in the ISO 10360 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain link F of the chains of standards on size, distance, 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 about the relation of this document to other standards and the GPS matrix model see Annex G.

The acceptance and reverification tests described in this document are applicable to coordinate measuring machines (CMMs) that use contacting probes, with or without multiple styli or multiple articulated-probe positions, when measuring using discrete point and/or scanning mode.

Experience has shown that the multi-stylus errors calculated using this document are significant and, at times, represent the dominant errors in the CMM. Owing to the virtually infinite variety of modern CMM probing system configurations, the description of the tests specified by this document provides a testing protocol for specification, but the actual test coverage has been limited to provide a practical subset of tests which are intended to reveal typical errors associated with probing configurations in a limited amount of time. 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;

— installations including a scanning probe, capable of being used in a scanning mode;

— multi-probe installations.

It is believed that the procedures given in this document 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, and then by retesting the new configuration set.

The tests in this document are sensitive to many errors, attributable to both the CMM and the probing system, and are intended 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, for example 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 EL tests in ISO 10360-2, because with multiple styli the net CMM travel may be very different from the measured length. See Annex C for more information.

This document complements ISO 10360-7 (CMMs equipped with imaging probing systems), ISO 10360-8 (CMMs with optical distance sensors), ISO 10360-9 (CMMs with multiple probing systems) and ISO 10360-2 (CMMs used for measuring linear dimensions).

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 5: Coordinate measuring machines (CMMs) using single and multiple stylus contacting probing systems using discrete point and/or scanning measuring mode

1 Scope

This document 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; and

— spherical or hemispherical stylus tip(s).

NOTE CMM probing performance tests 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 document applies to CMMs supplied with any of the following:

a) single-stylus probing systems;

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 systems;

e) stylus and probe changing systems;

f) manual (non-driven) and automated CMMs;

g) installations including a scanning probe, capable of being used in a scanning mode.

This document is not applicable to non-contacting probing systems, which require different testing procedures.

The term ‘combined CMM and multi-stylus probing system size error’ has been shortened to ‘multi-stylus size error’ for convenience. This applies in similar cases.

If it is desirable to isolate the probing system performance as far as is practical, the influence of the CMM can be minimized but not eliminated. See Annex C for more information.

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 10360-1, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO 10360-2, *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 verifying conformity or nonconformity with specifications*

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 10360-1, ISO 14253-1, ISO/IEC Guide 99 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/

NOTE 1 This clause contains fifteen definitions (3.7 to 3.9, 3.11 to 3.15, 3.19 to 3.21, 3.23 and 3.25 to 3.27) which supersede eighteen similar definitions in ISO 10360-1:2000, Clause 9. Some of these revised definitions are required to avoid ambiguities which would otherwise have been introduced with this document. Others effectively supersede identical definitions in ISO 10360-1, because the symbols used have been revised and expanded for clarification. The superseded definitions in ISO 10360-1:2000 are 9.3, 9.4 and 9.11 to 9.26.

NOTE 2 All the symbols used in this document are listed in Clause 4.

NOTE 3 The definitions in this clause are intended to concisely state the meaning of terms. For metrological characteristics that have numerical values, the complete description of the procedure and derivation of test results in Clause 6 are to be followed in determining values.

NOTE 4 For all definitions and evaluations in this document we assume the form and location values to be zero, i.e. perfect form or zero location distance for a single test sphere. See 6.2.1 for limitations on test sphere calibrated form.

3.1
rated operating condition
operating condition that needs to be fulfilled during measurement in order for a measuring instrument or measuring system to perform as designed

Note 1 to entry: Rated operating conditions generally specify intervals of values for a quantity being measured and for any influence quantity.

Note 2 to entry: Within the ISO 10360 series, the term “as designed” means as specified by MPEs.

Note 3 to entry: If an MPE specification is thought of as a function (where different MPE values could be given for different conditions), then the rated operating conditions define the domain of that function.

[SOURCE: ISO/IEC Guide 99:2007, 4.9, modified — Notes 2 and 3 to entry added.]

3.2
inferred qualification
probing system qualification method where the parameters for each probing system attached to an articulation system are inferred by interpolation, extrapolation or another relevant model, for significantly different angular position(s) from parameters acquired by *empirical qualification* (3.3) at a few angular positions

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

Note 1 to entry: "Reference sphere" is sometimes in industry referred to as "qualification sphere".

3.4
effective diameter
stylus diameter used with the tip correction vector, for compensating stylus centre points to obtain surface points

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

Note 2 to entry: The effective stylus tip diameter may be a parameter established by a probing system qualification.

3.5
multi-stylus probing system
fixed orientation single probe that carries star styli or which through stylus changing can present styli at the relevant orientations to be equivalent to a star stylus

Note 1 to entry: See Figure 6.

3.6
multi-probe system
system in which multiple probes with different fixed orientations are carried simultaneously

Note 1 to entry: See Figure 7.

3.7
multi-stylus form error
$P_{\text{Form.Sph.5×25:}j\text{:Tact}}$
observed form of a test sphere, the measurements being taken with five different styli, each taking 25 points (5 × 25) on the one test sphere using the discrete-point probing mode

Note 1 to entry: See ISO 10360-1:2000, Figure 15.

Note 2 to entry: The symbol P in $P_{\text{Form.Sph.5×25:}j\text{:Tact}}$ indicates that the error is associated with the system performance when local sampling, and the subscript $_{\text{Form}}$ indicates that it is a form error. The subscript $_{\text{Sph}}$ indicates that the test is performed using a sphere as a test artefact. The subscript $_{\text{Tact}}$ indicates that the probing system conforms to Clause 1 of this document (i.e. tactile), thus enabling any alternative probing system to be clearly identified by the use of a different set of characters at * in $P_{\text{Form.Sph.5×25:}j\text{:*}}$.

Note 3 to entry: There are four multi-stylus form errors based on different probing systems and methods of operation. These are designated as follows:

— j = MS, a fixed *multi-stylus probing system* (3.5);

— j = MP, a fixed *multi-probe system* (3.6);

— j = Emp, an articulating probing system using *empirical qualification* (3.3);

— j = Inf, an articulating probing system using *inferred qualification* (3.2).

3.8
multi-stylus size error
$P_{\text{Size.Sph.5×25:}j\text{:Tact}}$
error of indication of the diameter of a test sphere, the measurements being taken with five different styli, each taking 25 points on the one test sphere by a CMM using the discrete-point probing mode

Note 1 to entry: The subscript $_{\text{Size}}$ in $P_{\text{Size.Sph.5×25:}j\text{:Tact}}$ indicates that it is a diameter size error.

Note 2 to entry: Where j is replaced by MS, MP, Emp or Inf as applicable.

3.9
multi-stylus location error
$L_{\text{Dia.5×25:}j\text{:Tact}}$
error of indication of the location of a test sphere as measured using the discrete-point probing mode from five different orientations

Note 1 to entry: The symbol L in $L_{\text{Dia.5×25:}j\text{:Tact}}$ indicates that it is a location error.

Note 2 to entry: Where j is replaced by MS, MP, Emp or Inf as applicable.

3.10
opposing-styli projected location error on a sphere
$L_{\text{Dia.Proj.Sph.2×25:}j\text{:Tact}}$
error of indication of the location of a test sphere as measured using discrete-point probing from opposing orientations

Note 1 to entry: This gives the user an indication as to the performance of the system when measuring, for example, co-axiality of crank shaft journals using styli from opposing orientations.

Note 2 to entry: Where j is replaced by MS, MP, Emp or Inf as applicable.

3.11
single-stylus form error
$P_{\text{Form.Sph.1×25:SS:Tact}}$
observed form of a test sphere, the measurements being performed by a CMM with a single stylus (SS), using the discrete-point probing mode taking 25 points on a single sphere (1 × 25)

Note 1 to entry: See ISO 10360-1:2000, Figure 15.

Note 2 to entry: The subscript SS in $P_{\text{Form.Sph.1×25:SS:Tact}}$ indicates use of a single stylus.

3.12
single-stylus size error
$P_{\text{Size.Sph.1×25:SS:Tact}}$
error of indication of the diameter of a test sphere, the measurements being performed by a CMM with a single stylus, using the discrete-point probing mode

3.13
scanning mode form error on a sphere
$P_{\text{Form.Sph.Scan:}k\text{:Tact}}$
observed form of a test sphere, the measurements being performed by a CMM with a single stylus, using scanning mode

Note 1 to entry: Where k is replaced by the following designates as applicable: k = PP or NPP depending on system scanning mode, pre-defined path (PP) or not pre-defined path (NPP).

3.14
scanning mode size error on a sphere
$P_{\text{Size.Sph.Scan:}k\text{:Tact}}$
error of indication of the size of a test sphere, the measurements being performed by a CMM with a single stylus, using scanning mode

Note 1 to entry: Where k is replaced by the following designates as applicable: k = PP or NPP depending on system scanning mode, pre-defined path or not pre-defined path.

3.15
scanning mode time

$\tau_{\text{Sph.Scan:}k\text{:Tact}}$
time taken to perform the scanning test

Note 1 to entry: Where *k* is replaced by the following designates as applicable: *k* = PP or NPP depending on system scanning mode, pre-defined path or not pre-defined path.

Note 2 to entry: Time is stated in seconds.

3.16
scanning mode form error on a ring gauge

$P_{\text{Form.Cir.Scan:}k.lo\text{:Tact}}$
observed form of a ring gauge, the measurements being performed by a CMM using scanning mode with a single stylus aligned to the ram axis if l_o = 0 mm, or a single stylus orthogonal to the ram axis with l_o = 150 mm as the default

Note 1 to entry: Where *k* is replaced by the following designates as applicable: *k* = PP or NPP depending on system scanning mode, pre-defined path or not pre-defined path.

Note 2 to entry: Where l_o is replaced with the relevant length of ram axis stylus tip offset in the specification of the manufacturer.

Note 3 to entry: See Annex A for the test definition for this optional test.

Note 4 to entry: Ram axis stylus tip offset l_o in this document is normally equivalent to ram axis stylus tip offset L used in ISO 10360-2. An example where it is different is a horizontal arm machine where the articulated head is mounted vertically.

3.17
scanning mode size error on a ring gauge

$P_{\text{Size.Cir.Scan:}k.lo\text{:Tact}}$
error of indication of the size of a ring gauge, the measurements being performed by a CMM using scanning mode with a single stylus aligned to the ram axis if l_o = 0 mm; or a single stylus orthogonal to the ram axis with l_o = 150 mm as the default unless otherwise specified

Note 1 to entry: Where *k* is replaced by the following designates as applicable: *k* = PP or NPP depending on system scanning mode, pre-defined path or not pre-defined path.

Note 2 to entry: Where l_o is replaced with the relevant length of ram axis stylus tip offset in the specification of the manufacturer.

Note 3 to entry: See Annex A for the test definition for this optional test.

3.18
opposing-styli projected location error on a ring gauge

$L_{\text{Dia.Proj.Cir.Scan:}j\text{:Tact}}$
error of indication of the location of a ring gauge as measured using scanning mode probing from opposing orientations

Note 1 to entry: This gives the user an indication as to the performance of the system when measuring, for example, co-axiality of crank shaft journals using styli from opposing orientations.

Note 2 to entry: Where *j* is replaced by MS, MP, Emp or Inf as applicable.

3.19
maximum permissible multi-stylus form error

$P_{\text{Form.Sph.5×25:}j\text{:Tact,MPE}}$
extreme value of the *multi-stylus form error* (3.7), $P_{\text{Form.Sph.5×25:}j\text{:Tact}}$, permitted by specifications

Note 1 to entry: See Annex D for how this MPE may be expressed.

Note 2 to entry: Where *j* is replaced by MS, MP, Emp or Inf as applicable.

3.20
maximum permissible multi-stylus size error
$P_{Size.Sph.5×25:j:Tact,MPE}$
extreme value of the *multi-stylus size error* (3.8), $P_{Size.Sph.5×25:j:Tact}$, permitted by specifications

Note 1 to entry: See Annex D for how this MPE may be expressed.

Note 2 to entry: Where *j* is replaced by MS, MP, Emp or Inf as applicable.

3.21
maximum permissible multi-stylus location error
$L_{Dia.5×25:j:Tact,MPE}$
extreme value of the *multi-stylus location error* (3.9), $L_{Dia.5×25:j:Tact}$, permitted by specifications

Note 1 to entry: See Annex D for how this MPE may be expressed.

Note 2 to entry: Where *j* is replaced by MS, MP, Emp or Inf as applicable.

3.22
maximum permissible opposing-styli projected location error on a sphere
$L_{Dia.Proj.Sph.2×25:j:Tact,MPE}$
extreme value of the *opposing-styli projected location error on a sphere* (3.10), $L_{Dia.Proj.Sph.2×25:j:Tact}$, permitted by specifications

Note 1 to entry: See Annex D for how this MPE may be expressed.

Note 2 to entry: Where *j* is replaced by MS, MP, Emp or Inf as applicable.

3.23
maximum permissible single-stylus form error
$P_{Form.Sph.1×25:SS:Tact,MPE}$
extreme value of the *single-stylus form error* (3.11), $P_{Form.Sph.1×25:SS:Tact}$, permitted by specifications

Note 1 to entry: See ISO 10360-1:2000, Figure 15.

Note 2 to entry: $P_{Form.Sph.1×25:SS:Tact}$ is specified against an unambiguous description of the probe and stylus make up.

3.24
maximum permissible single-stylus size error
$P_{Size.Sph.1×25:SS:Tact,MPE}$
extreme value of the *single-stylus size error* (3.12), $P_{Size.Sph.1×25:SS:Tact}$, permitted by specifications

Note 1 to entry: $P_{Size.Sph.1×25:SS:Tact,MPE}$ is specified against an unambiguous description of the probe and stylus make up.

3.25
maximum permissible scanning mode form error on a sphere
$P_{Form.Sph.Scan:k:Tact,MPE}$
extreme value of the *scanning mode form error on a sphere* (3.13), $P_{Form.Sph.Scan:k:Tact}$, permitted by specifications

Note 1 to entry: Where *k* is replaced by the following designates as applicable: *k* = PP or NPP depending on system scanning mode, pre-defined path or not pre-defined path.

3.26
maximum permissible scanning mode size error on a sphere
$P_{Size.Sph.Scan:k:Tact,MPE}$
extreme value of the *scanning mode size error on a sphere* (3.14), $P_{Size.Sph.Scan:k:Tact}$, permitted by specifications

Note 1 to entry: Where *k* is replaced by the following designates as applicable: *k* = PP or NPP depending on system scanning mode, pre-defined path or not pre-defined path.