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Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 12:
Articulated arm coordinate measurement machines (CMM)

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

Partie 12: MMT à bras articulés

ICS: 17.040.30

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

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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 10360-12 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

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

— *Part 1: Vocabulary*

— *Part 2: CMMs used for measuring size*

— *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 probing performance with contacting probing system*

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

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

— *Part 8: CMMs with optical distance sensors*

— *Part 9: CMMs with multiple probing systems*

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

— *Part 12: Articulated arm coordinate measuring machines*

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 link 5 of the chains of standards on size, distance, radius, angle, form, orientation, location, run-out and datums. For more detailed information of the relation of this part of ISO 10360 to other standards and the GPS matrix model see Annex I.

The ISO/GPS Masterplan given in ISO/TR 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.

The objective of this part of ISO 10360 is to provide a well-defined testing procedure to (1) enable manufacturers of articulated arm CMMs to provide specification MPEs and (2) to enable users to test articulated arm CMMs to manufacturer specifications using calibrated traceable reference artefacts. The benefits of these tests are that the measured result has a direct traceability to the unit length, the metre, and that they give information on how the articulated arm CMM will perform on similar length measurements.

Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 12: Articulated arm coordinate measurement machines (CMM)

1 Scope

This part of ISO 10360 specifies the acceptance tests for verifying the performance of an articulated arm CMM used for measuring calibrated test lengths as stated by the manufacturer. It also specifies the reverification tests that enable the user to periodically reverify the performance of the articulated arm CMM. It applies to articulated arm CMMs using tactile probes, scanner probes, or both. Details on tests for scanner accessories are given in Annex E.

This International Standard specifies:

— *performance requirements that can be assigned by the manufacturer or the user of the articulated arm CMM,*

— *the manner of execution of the acceptance and reverification tests to demonstrate the stated requirements,*

— *rules for proving conformance, and*

— *applications for which the acceptance and reverification tests can be used.*

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the cited editions apply. 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 test for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO 10360-8:2014, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 8: CMMs with optical distance sensors*

ISO 10360-9:2013, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 9: CMMs with multiple probing systems*

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

ISO/TS 23165:2006, *Geometrical product specifications (GPS) — Guidelines for the evaluation of coordinate measuring machine (CMM) test uncertainty*

3 Terms and Definitions

The definitions in this section 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 shall be followed in determining values.

3.1
articulated arm coordinate measuring machine
system that measures spatial coordinates and comprises (1) open chain of fixed-length segments, (2) joint assemblies interconnecting the segments and attaching them to the stationary environment, and (3) probing system at the free end of the chain

Note 1 to entry The probing system may comprise a rigid probe or a sensing system such as a scanner.

Note 2 to entry Rotary joint assemblies connected to the fixed-length segments are equipped with angular encoders. Cartesian coordinates of each measuring point are calculated from the measured angles and segment lengths.

3.2
joint
rotatable element of an articulated arm CMM

Note to entry There are two types of joints: hinge joints, which cause a hinging movement between adjacent arm segments, and swivel joints, which cause a rotary movement along the direction of an arm segment.

3.3
joint assembly
assembly of elements that interconnect segments of an articulated arm CMM. Usually a joint assembly includes at least a hinge joint and a swivel joint

Note 1 to entry Each joint assembly includes an angle measuring device (rotary encoder).

Note 2 to entry In analogy to the human arm, the three main joint assemblies are designated the shoulder, elbow, and wrist.

Note 3 to entry Current machines have two or three degrees of freedom each for shoulder (a, b), elbow (c, d), and wrist (e, f, g), as shown in Figure 1. Consequently, articulated arm CMMs are referred to as either six or seven axis machines.

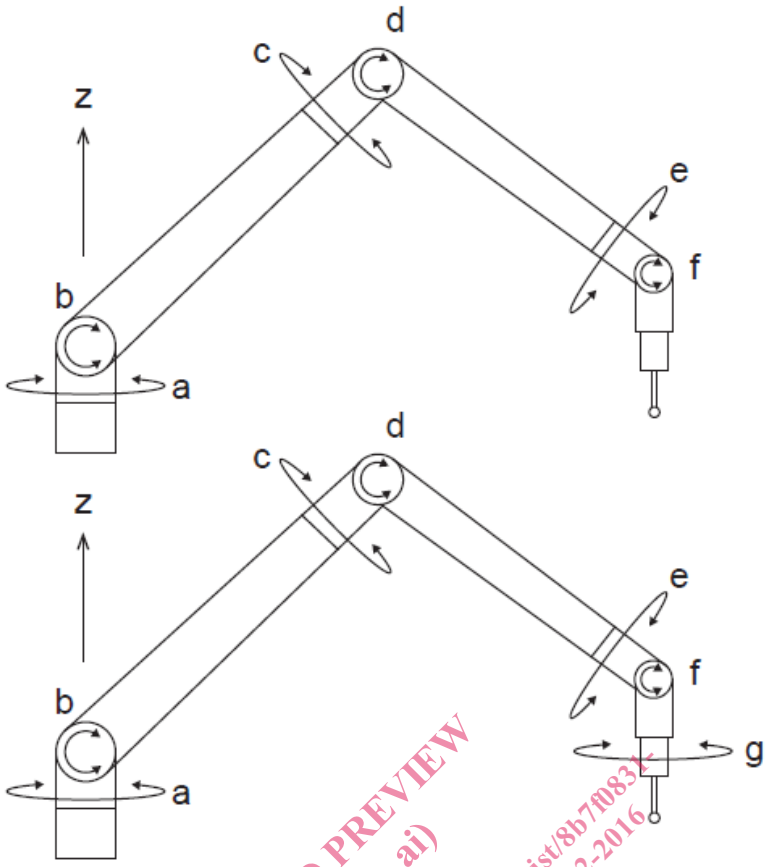

Figure 1 — Articulated arm CMM with six rotary axes (top) and seven rotary axes (bottom)

3.4
measuring range
diameter of the spherical volume within which an articulated arm CMM is capable of measuring

Note 1 to entry Measuring range is specified by the manufacturer.

Note 2 to entry Measuring range is twice the reach of the articulated arm. However, some of the regions that can be reached by the articulated arm may not be within the measuring volume.

3.5
measuring volume
the region in space over which the manufacturer specifies the performance of the articulated arm CMM

Note 1 to entry Measuring volume is restricted by inaccessible zones specified by the manufacturer. For example, there may be an inaccessible zone close to the vertical main axis.

Note 2 to entry Manufacturers may specify more than one measuring volume for a machine, each measuring volume having a separate performance specification.

Note 3 to entry Because of the possibility of binding up a joint when adjacent arm segments are brought close together, the size of the measuring volume may depend on the direction of the probe stylus in relation to the outside of the measuring volume or inaccessible zones within the measuring volume. The manufacturer may specify one or more measuring volumes according to the direction of the probe stylus.

3.6
useful arm length
half the measuring range

3.7
coefficient of thermal expansion (CTE)
α
linear thermal expansion coefficient of a material at 20 ºC

Note to entry The above definition for CTE does not imply that a user is required to make measurements at 20 ^{o}C.

3.8
normal CTE material
material with a CTE between 8 x 10^{-6}/^{o}C and 13 x 10^{-6}/^{o}C
(ISO 10360-2:2009)

Note to entry Some documents may express CTE in units 1/K, which is equivalent to 1/^{o}C.

3.9
kinematic seat
a mechanical seat (nest) that repeatably holds the centre of a spherical surface in a fixed position in space

Note 1 to entry An example of a kinematic seat is a trihedral seat that includes three hardened spheres, each sphere placed on a circle and separated from the other spheres by nominally 120^{o}. Each of the three spheres contacts the surface of a larger sphere (or spherical surface) so as to permit repeatable positioning of the centre of the larger sphere in space.

Note 2 to entry As used in this Standard, a kinematic seat provides constraint for three degrees of freedom rather than six degrees of freedom.

3.10
single point articulation test
test in which articulated arm CMM probe is held within a kinematic seat while the elbow joint is rotated by 180 degrees

Note to entry The single point articulation test is an interim test described in Annex D.

3.11
articulated location error, tactile
$L_{\text{Dia.5x5:Art:Tact.AArm}}$
variation in the centres of the five spheres obtained from performing of the articulated location test when using a tactile probe

Note to entry In the context of this part of the ISO standard, the local abbreviation LDia.5x5:Art is used.

3.12
length measurement error, bidirectional
$E_{\text{Bi:0:Tact.AArm}}$
error of indication when performing a bidirectional point-to-point distance measurement

Note to entry In the context of this part of the ISO standard, the local abbreviation E_{Bi} is used.

3.13
length measurement error, unidirectional
$E_{\text{Uni:0:Tact.AArm}}$
error of indication when performing a unidirectional point-to-point distance measurement

Note 1 to entry Annex B discusses unidirectional and bidirectional measurements.

Note 2 to entry In the context of this part of the ISO standard, the local abbreviation E_{Uni} is used.

3.14
probing form error, tactile
$P_{\text{Form.Sph.1x25::Tact.AArm}}$

error of indication of the range of radii of a spherical material standard of size as determined by a least-squares fit of 25 points measured by a tactile probe

Note to entry In the context of this part of the ISO standard, the local abbreviation $P_{\text{Form.Sph.1x25}}$ is used.

3.15
probing size error, tactile
$P_{Size.Sph.1x25::Tact.AArm}$
error of indication of the diameter of a spherical material standard of size as determined by a least-squares fit of 25 points measured by a tactile probe

Note to entry In the context of this part of the ISO standard, the local abbreviation $P_{Size.Sph.1x25}$ is used.

3.16
maximum permissible error of articulated location error, tactile
$L_{Dia.5x5:Art:Tact.AArm,MPE}$
extreme value of the articulated location error, tactile, $L_{Dia.5x5:Art:Tact.AArm}$, permitted by specifications

Note to entry In the context of this part of the ISO standard, the local abbreviation $L_{Dia.5x5:Art,MPE}$ is used.

3.17
maximum permissible error of bidirectional length measurement
$E_{Bi:0:Tact.AArm,MPE}$
extreme value of the bidirectional length measurement error, $E_{Bi:0:Tact.AArm}$, permitted by specifications

Note to entry In the context of this part of the ISO standard, the local abbreviation $E_{Bi,MPE}$ is used.

3.18
maximum permissible error of unidirectional length measurement
$E_{Uni:0:Tact.AArm,MPE}$
extreme value of the unidirectional length measurement error, $E_{Uni:0:Tact.AArm}$, permitted by specifications

Note to entry In the context of this part of the ISO standard, the local abbreviation $E_{Uni,MPE}$ is used.

3.19
maximum permissible error of probing form, tactile
$P_{Form.Sph.1x25::Tact.AArm,MPE}$
extreme value of the probing form error for tactile probe, $P_{Form.Sph.1x25::Tact.AArm}$, permitted by specifications

Note to entry In the context of this part of the ISO standard, the local abbreviation $P_{Form.Sph.1x25,MPE}$ is used.

3.20
maximum permissible error of probing size, tactile
$P_{Size.Sph.1x25::Tact.AArm,MPE}$
extreme value of the probing size error for a tactile probe, $P_{Size.Sph.1x25::Tact.AArm}$, permitted by specifications

Note to entry In the context of this part of the ISO standard, the local abbreviation $P_{Size.Sph.1x25,MPE}$ is used.

3.21
rated operating conditions
operating condition that must be fulfilled during measurement in order that a measuring instrument or measuring system 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.

[SOURCE: VIM 3:2008, 4.9]

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

Note 3 to entry When the rated operating conditions are not met in a test according to the ISO 10360, neither conformance nor non-conformance to specifications can be determined.

4 Symbols

For the purpose of this part of ISO 10360, the symbols of Table 1 apply.

Table 1 – Symbols

Global symbols	Local abbreviations	Meaning
$L_{Dia.5x5:Art:Tact.AArm}$	$L_{Dia.5x5:Art}$	Articulated location error, tactile
$E_{Uni:0:Tact.AArm}$	E_{Uni}	Length measurement error, unidirectional
$E_{Bi:0:Tact.AArm}$	E_{Bi}	Length measurement error, bidirectional
$P_{Form.Sph.1x25::Tact.AArm}$	$P_{Form.Sph.1x25}$	Probing form error, tactile
$P_{Size.Sph.1x25::Tact.AArm}$	$P_{Size.Sph.1x25}$	Probing size error, tactile
$E_{Uni:0:Tact.AArm,MPE}$	$E_{Uni,MPE}$	Maximum permissible error of unidirectional length measurement
$E_{Bi:0:Tact.AArm,MPE}$	$E_{Bi,MPE}$	Maximum permissible error of bidirectional length measurement
$P_{Form.Sph.1x25::Tact.AArm,MPE}$	$P_{Form.Sph.1x25,MPE}$	Maximum permissible error for probing form, tactile
$P_{Size.Sph.1x25::Tact.AArm,MPE}$	$P_{Size.Sph.1x25,MPE}$	Maximum permissible error of probing size, tactile
$L_{Dia.5x5:Art:Tact.AArm,MPE}$	$L_{Dia.5x5:Art,MPE}$	Maximum permissible error of articulated location error, tactile

NOTE Local abbreviations are used in this part of the ISO 10360 for the sake of simplicity; however, local abbreviations used in different Part(s) may clash; i.e., the same abbreviation may refer to different complete symbols. Use of abbreviated symbols is not recommended outside the exclusive context of this Part.

5 Environmental and operating conditions

5.1 Environmental conditions

Limits for permissible environmental conditions such as temperature conditions, air pressure, humidity and vibration at the site of installation that influence the measurements 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 under which the testing will be performed within the specified limits (Form 1 in Annex A shows an example method for specifying these conditions). The manufacturer shall provide at a single location in published literature MPE values and operating conditions under which the MPE values are valid.

NOTE If the user wishes to have testing performed under environmental conditions other than the ambient conditions of the test site (e.g. at an elevated or lowered temperature), agreement between parties regarding who bears the cost of environmental conditioning should be obtained.

5.2 Operating conditions

The articulated arm CMM shall be operated by an appropriately trained and skilled operator using the procedures given in the manufacturer's operating manual when conducting the tests given in Clause 6. Specific areas in the manufacturer's manual to be adhered to are, for example:

a) machine start-up/warm-up cycles,

b) machine compensation procedures,

c) location, type, and number of environmental sensors,

d) location, type, and number of thermal workpiece sensors,

e) mounting constraints.