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

Part 13:
Optical 3D CMS

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

Partie 13: SMT optique 3D

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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).

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 chain of standards on size, distance, form, orientation, location and run-out in the general GPS matrix (see Annex H).

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.

This document has two technical objectives:

1) to test the error of indication when measuring a calibrated test length across the global measuring volume of the CMS;

2) to test the errors of indication within a locally intended measuring volume.

These two objectives correspond to:

a) the test performed for a probing system and a moving carrier of the probing system in combination as described in ISO 10360-2, ISO 10360-7, ISO 10360-8, ISO 10360-10, ISO 10360-11[1)] and ISO 10360-12;

b) the test performed dominantly for the probing system as described in ISO 10360-5, ISO 10360-7, ISO 10360-8, ISO 10360-9, ISO 10360-10, ISO 10360-11 and ISO 10360-12.

The benefits of these tests are that the measured result has a direct traceability to the unit of length, the metre, and that it gives information on how the coordinate measuring machine (CMM) or the coordinate measuring system (CMS) performs in similar length measurements.

An optical 3D CMS as specified by this document is a contactless area measuring sensor delivering 3D data in several individual single views by an optical measuring principle and transforming it into a common coordinate system. Typical optical measuring principles are pattern projection, fringe projection and projecting-and-sweeping a scanned line, or similar, delivering single views without assistance of external information related to position and orientation of the objects to be scanned relative to the CMS. Typical registration principles are based on a best fitting of commonly captured position information across at least two different single views by using either or both reference features attached or surface features of the objects to be scanned.

This document is not intended to apply to other types of CMSs, for example:

— tactile CMMs (Cartesian metrological moving carrier), see ISO 10360-2;

— imaging CMMs (Cartesian metrological moving carrier), see ISO 10360-7;

— CMMs equipped with optical distance sensors (Cartesian metrological moving carrier), see ISO 10360-8;

— laser trackers, see ISO 10360-10;

— X-ray CTs, see ISO 10360-11;

— articulated arm CMMs, see ISO 10360-12;

— measuring instruments intended to measure surface characteristics, see the ISO 25178 series;

— optical microscopes;

— hand-held laser-line type scanners.

1) Under preparation. Stage at the time of publication: ISO/DIS 10360-11:2021.

Parties can apply this document to the above or other types of CMSs by mutual agreement.

This document specifies:

— performance requirements that can be assigned by the manufacturer or the user of the CMS;

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

— rules for verifying conformance;

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

NOTE 1 Annex E describes possible limitations with regard to less cooperative surface characteristics, such as colour, glossiness and roughness, and provides a suggested test that can give CMS users an idea of how representative the maximum permissible error would be when measuring their specific industrial part.

NOTE 2 The optical 3D CMS can be moved and positioned by a manually or automated moving unit. The position, orientation or both can be used as additional information for the registration.

NOTE 3 The acceptance and reverification tests are designed to mimic real but simple measurements occurring in practice, subject to the rated operating conditions and the testing procedures. The user is advised to consider the influence of additional or omitted conditions, procedural steps or both when applying the test results according to this document to predict the performance of an actual CMS.

For more detailed information of the relation of this document to other standards and the GPS matrix model, see Annex H.

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

Part 13: Optical 3D CMS

1 Scope

This document specifies the acceptance tests for verifying the performance of an optical 3D coordinate measuring system (CMS) when measuring lengths as stated by the manufacturer. It also specifies the reverification tests that enable the user to periodically reverify the performance of the optical 3D CMS.

This document is applicable to verification of the measuring performance of CMSs if the surface characteristics (e.g. glossiness, colour) of the object to be scanned are restricted and within a cooperative range.

This document does not apply to other types of CMSs, including those covered by the other parts of the ISO 10360 series.

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 10360-1:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

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, *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 and 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/

3.1
optical 3D coordinate measuring system
optical 3D CMS
system performing measurements of spatial coordinates exclusively by optical sensors

3.2
sensor measurement volume
volume of measurement of the sensor realized without movement of the sensor relative to the workpiece fulfilling the specifications stated by the manufacturer

Note 1 to entry: Dimensional indication of sensor measurement volume stated by the manufacturer can significantly differ from that which the sensor shows.

3.3
registration
transformation of coordinate systems that brings single-view coordinates into a unified coordinate system

Note 1 to entry: A transformation is realized for example by a rigid transformation, consisting of either translation, rotation or both.

Note 2 to entry: Each single view holds its own coordinate system and requires a transformation to the unified coordinate system.

Note 3 to entry: The registration is invertible. The inverse registration can be performed by applying the inverse transformation.

Note 4 to entry: In practice, the transformation parameters are derived first, then the transformations occur either immediately or at a later stage.

Note 5 to entry: A registration can require a person to operate the CMS.

3.4
fusion
operation that merges two or more sets of measured coordinates into a unified set of measured coordinates

Note 1 to entry: Fusions are performed to improve the measurement, e.g. to reduce the dispersion and the mismatch of single views.

Note 2 to entry: Fusions are typically irreversible (not invertible).

Note 3 to entry: A fusion can include any number of elementary operations in combination or in sequence, such as coordinate transformation, averaging, outlier rejection, decimation, convolution and filtration.

Note 4 to entry: The fusion can occur either immediately or at a later stage.

3.5
concatenated measurement volume
volume of measurement of the CMS obtained by movement of the sensor relative to the workpiece and the registration fulfilling the specifications stated by the manufacturer

Note 1 to entry: The concatenated measurement volume can be determined by design of a measuring cabin typically having a cuboid boundary or a three-dimensional size of the intended workpiece.

Note 2 to entry: A concatenated measurement volume can have either a significantly larger volume than the sensor measurement volume or a similar volume to the sensor measurement volume.

3.6
single-view measurement
measurement of spatial coordinates done with an optical sensor without movement relative to the workpiece

Note 1 to entry: Single-view measurement is performed with no movement of the carrier, registration or fusion.

Note 2 to entry: Single-view measurement can include repeated measurements, for example multiple exposures, provided that no movement of the optical sensor relative to the workpiece occurs from the first exposure to the last.

3.7
multiple-view measurement
measurement of spatial coordinates through registration and fusion of multiple single-view measurements in different locations and orientations of the optical sensor relative to the workpiece

3.8
probing form dispersion error
$P_{\mathrm{Form.Sph.}i:j\mathrm{:O3D}}$
smallest width of a spherical shell that encompasses a percentile of all measured data

Note 1 to entry: The symbol "*P*" in $P_{\mathrm{Form.Sph.}i:j\mathrm{:O3D}}$ indicates that the error is associated with the probing system performance; the qualifier "Form.Sph" indicates that it is associated with the probing dispersion error when measuring a sphere; and the qualifier "O3D" indicates that it is associated with an optical 3D CMS. The qualifier "*i*" identifies the percentile of probed points selected for the evaluation: either "D95 %" denoting 95 % of the population or "All" denoting the whole population, i.e. 100 %. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case. Examples of such symbols include $P_{\mathrm{Form.Sph.D95\ \%:SMV.SV:O3D}}$ and $P_{\mathrm{Form.Sph.All:SMV.MV:O3D}}$.

Note 2 to entry: Both percentiles, 95 % and All, are of the measured points according to the rated operating conditions. When these conditions include pre-processing such as prefiltering or meshing, then the percentiles apply to such points after this application.

Note 3 to entry: 5 % of the measured points in the "All" data set is eliminated to determine $P_{\mathrm{Form.Sph.D95\ \%:}j\mathrm{:O3D}}$. Outliers can be eliminated by this operation.

Note 4 to entry: It can be beneficial to evaluate probing errors from point cloud both from "95 %" population and "All" population. A difference in these two test results can reveal influences of smoothing filters or equivalent functions potentially pre-installed as an integral part of the CMS or the associated software, which is not always transparently visible for users of the CMS.

3.9
probing size error
$P_{\mathrm{Size.Sph.}i:j\mathrm{:O3D}}$
error of indication when measuring a calibrated diameter of a test sphere as associated by an unweighted and unconstrained least-squares fit to a percentile of all measured data

Note 1 to entry: The symbol "*P*" in $P_{\mathrm{Size.Sph.}i:j\mathrm{:O3D}}$ indicates that the error is associated with the probing system performance; the qualifier "Size.Sph" indicates that it is associated with the probing size error of a sphere; and the qualifier "O3D" indicates that it is associated with the optical 3D CMS. The qualifier "*i*" identifies the percentile of probing points selected for the evaluation: either from "D95 %" denoting 95 % of the population or "All" denoting the whole population, i.e. 100 %. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case. Examples of such symbols include $P_{\mathrm{Size.Sph.D95\ \%:SMV.SV:O3D}}$ and $P_{\mathrm{Size.Sph.All:SMV.MV:O3D}}$.

Note 2 to entry: Both percentiles, 95 % and All, are of the measured points according to the rated operating conditions. When these conditions include pre-processing such as prefiltering or meshing, then the percentiles apply to such points after this application.

Note 3 to entry: The probing size error is determined by the errors of the sensors (caused by, for example, noise, digitization, image distortion, optical interaction with the surface of the material standard, calibration, faulty algorithms) and of the positioning system.

3.10
distortion error

$D_{CC:j:O3D}$

error of indication when measuring a calibrated centre-to-centre distance within the sensor measurement volume either by single-view measurement operation or multiple-view measurement operation

Note 1 to entry: The symbol "*D*" indicates that the error is associated with the geometrical deformation of the sensor within the sensor measurement volume; the qualifier "CC" indicates that the error of indication is of a centre-to-centre distance; and the qualifier "O3D" indicates that it is associated with an optical 3D CMS. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement, while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case. Examples of such symbols include $D_{CC:SMV.SV:O3D}$ and $D_{CC:SMV.MV:O3D}$.

3.11
flat-form distortion error

$D_{Form.Pla.i:j:O3D}$

minimum distance between two parallel planes that encompass a percentile of all data measured on the test flat

Note 1 to entry: The symbol "*D*" indicates that the error is associated with the geometrical deformation of the sensor; the qualifier "Form.Pla" indicates that it is associated with the form error of a plane; and the qualifier "O3D" indicates that it is associated with the optical 3D CMS. The qualifier "*i*" identifies the percentile of probing points selected for the evaluation: either "D95 %" denoting 95 % of the population or "All" denoting the whole population, i.e. 100 %. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case. Examples of such symbols include $D_{Form.Pla.D95\,\%:SMV.SV:O3D}$ and $D_{Form.Pla.All:SMV.MV:O3D}$.

Note 2 to entry: Both percentiles, 95 % and All, are of the measured points according to the rated operating conditions. When these conditions include pre-processing such as prefiltering or meshing, then the percentiles apply to such points after this application.

3.12
volumetric length measurement error in concatenated measurement volume

$E_{Vol:CMV.MV:O3D}$

error of indication when measuring a calibrated test length within the concatenated measurement volume by multiple-view measurement

Note 1 to entry: The symbol "*E*" indicates that the error of indication is of a length in space; the qualifier "Vol" indicates that volumetric geometry errors of the CMS is of interest (not local probing errors); the qualifier "CMV.MV" denotes multiple-view measurement within the concatenated measurement volume; and the qualifier "O3D" indicates that it is associated with an optical 3D CMS.

Note 2 to entry: The multiple-view measurement is to reveal the volumetric length measurement error in the concatenated measurement volume.

Note 3 to entry: A calibrated test length can typically be calibrated by the centre-to-centre distance of a sphere standard. See Annex B for details.

3.13
maximum permissible probing form dispersion error

$P_{Form.Sph.i:j:O3D,MPE}$

extreme value of $P_{Form.Sph.i:j:O3D}$ permitted by specifications as maximum permissible error

Note 1 to entry: The qualifier "*i*" identifies the percentile of probing points selected for the evaluation: either "D95 %" denoting 95 % of the population or "All" denoting the whole population, i.e. 100 %. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case.

3.14
maximum permissible probing size error
$P_{Size.Sph.i:j:O3D,MPE}$
extreme value of $P_{Size.Sph.i:j:O3D}$ permitted by specifications as maximum permissible error

Note 1 to entry: The qualifier "*i*" identifies the percentile of probing points selected for the evaluation: either "D95%" denoting 95 % of the population or "All" denoting the whole population, i.e. 100 %. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case.

3.15
maximum permissible distortion error
$D_{CC:j:O3D,MPE}$
extreme value of $D_{CC:j:O3D}$ permitted by specifications as maximum permissible error

Note 1 to entry: The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case.

3.16
maximum permissible flat-form distortion error
$D_{Form.Pla.i:j:O3D,MPE}$
extreme value of $D_{Form.Pla.i:j:O3D}$ permitted by specifications as maximum permissible error

Note 1 to entry: The qualifier "*i*" identifies the percentile of probing points selected for the evaluation: either "D95 %" denoting 95 % of the population or "All" denoting the whole population, i.e. 100 %. The qualifier "*j*" identifies the measuring conditions of the CMS. "SMV.SV" denotes single-view measurement while "SMV.MV" denotes multiple-view measurement. The measurement is performed within the sensor measurement volume ("SMV") in either case.

3.17
maximum permissible volumetric length measurement error in concatenated measurement volume
$E_{Vol:CMV.MV:O3D,MPE}$
extreme value of $E_{Vol:CMV.MV:O3D}$ permitted by specifications as maximum permissible error

3.18
bi-directional length measurement error in concatenated measurement volume
$E_{Bi:CMV.MV:O3D}$
error of indication when measuring a calibrated test length bi-directionally within the concatenated measurement volume by multiple-view measurement

Note 1 to entry: See Annex A for details of the optional characteristics.

Note 2 to entry: The symbol "*E*" indicates that the error is of a length in space; the qualifier "Bi" indicates that the local probing errors are included (bi-directional probing); the qualifier "CMV.MV" denotes multiple-view measurement within the concatenated measurement volume; and the qualifier "O3D" indicates that it is associated with an optical 3D CMS.

Note 3 to entry: The multiple-view measurement is to reveal the volumetric length measurement error in the concatenated measurement volume.

3.19
maximum permissible bi-directional length measurement error
$E_{Bi:CMV.MV:O3D,MPE}$
extreme value of $E_{Bi:CMV.MV:O3D}$ permitted by specifications as maximum permissible error

4 Symbols

$P_{\text{Form.Sph.}i:j:\text{O3D}}$	probing form dispersion error
$P_{\text{Size.Sph.}i:j:\text{O3D}}$	probing size error
$D_{\text{CC:}j:\text{O3D}}$	distortion error
$D_{\text{Form.Pla.}i:j:\text{O3D}}$	flat-form distortion error
$E_{\text{Vol:CMV.MV:O3D}}$	volumetric length measurement error in concatenated measurement volume
$E_{\text{Bi:CMV.MV:O3D}}$	bi-directional length measurement error in concatenated measurement volume
$P_{\text{Form.Sph.}i:j:\text{O3D,MPE}}$	maximum permissible probing form dispersion error
$P_{\text{Size.Sph.}i:j:\text{O3D,MPE}}$	maximum permissible probing size error
$D_{\text{CC:}j:\text{O3D,MPE}}$	maximum permissible distortion error
$D_{\text{Form.Pla.}i:j:\text{O3D,MPE}}$	maximum permissible flat-form distortion error
$E_{\text{Vol:CMV.MV:O3D,MPE}}$	maximum permissible volumetric length measurement error in concatenated measurement volume
$E_{\text{Bi:CMV.MV:O3D,MPE}}$	maximum permissible bi-directional length measurement error
D95 %	95 % percentile of the population
All	whole population (i.e. 100 % percentile)
SMV.SV	single-view measurement within the sensor measurement volume
SMV.MV	multiple-view measurement within the sensor measurement volume
CMV.MV	multiple-view measurement within the concatenated measurement volume

5 Rated operating conditions

5.1 Environmental conditions

Limits for permissible environmental conditions (e.g. temperature conditions, air humidity, vibration and ambient lighting at the site of installation that influences 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 is performed within the manufacturer's specified limits given in the CMS data sheet.

The user is responsible for providing the environment enclosing the CMS as specified by the manufacturer in the data sheet. If the environment does not meet the specifications, then the maximum permissible errors cannot be required to be verified.

5.2 Operating conditions

5.2.1 General

For all the tests described in this document, the optical 3D CMS shall be operated according to the rated operating conditions and the default settings stated by the manufacturer.

If any of the conditions and settings are not specified, the user is free to choose.

The manufacturer may specify extra specifications for special operating conditions and settings at its discretion.

Specific areas in the manufacturer's manual to be adhered to include:

1) machine start-up or warm-up cycles;

2) qualification of the CMS;

3) achievement of thermal stability of the CMS;

4) location, type, number of thermal sensors when these are at least partially applicable;

5) software filters;

6) surface characteristics of the material standards such as colour, roughness, glossiness, light scattering characteristics;

7) default procedures and settings for data registration and data fusion;

8) pre-installed smoothing function;

9) concatenated measurement volume if applicable.

NOTE The CMS qualification can include a number of adjustments and parameter settings, such as those related to the geometry in a sub-system assembly, the illumination, the optical sensing and the numerical filtration.

5.2.2 Material and surface characteristic of material standards

The material used for the material standards shall be stated by the manufacturer. Different materials have different optical characteristics such as reflection factor, optical penetration depth (volume scattering), colour or scattering characteristics, which can influence the test values. The roughness of the material standard shall be negligibly small compared to the maximum permissible error.

Material, surface characteristics and colour of the material standards shall be described in the technical documentation of the instrument that is available to the (potential) user. If the material, the surface characteristics of the material standard or both are not specified then the user is free to choose.

If a specific surface preparation, such as usage of powder spraying or similar, is explicitly stated in the technical data sheet, the surface preparation shall be used in the tests.

NOTE 1 Material standards can be made of diverse materials, such as ceramics or steel.

NOTE 2 Assessment of optical characteristics of the surface to be measured is described in Annex E.

Reference standards used for system qualification shall not be used for the tests described in this document.

The length of each material standard shall be calibrated and the calibration uncertainty shall be taken into account according to ISO 14253-1, when verifying conformity by acceptance or reverification tests.

