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Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 5: CMMs using multiple-stylus 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 stylets multiples

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Contents

Page

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 3.

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 part of ISO 10360 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10360-5 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 machines (CMM)*:

— *Part 1: Vocabulary*

— *Part 2: CMMs used for measuring linear 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 using multiple-stylus probing systems*

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

Annexes A and B of this part of ISO 10360 are for information only.

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 on 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 B.

The acceptance and reverification tests described in this part of ISO 10360 are applicable to CMMs that use more than one stylus, or stylus orientation, when measuring a workpiece.

Experience has shown that 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 multiple styli, probes or articulated-probe positions.

The situations to which they are applicable include

— 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

— multiple-probe installations.

It is believed that the procedures given in this part of ISO 10360 will be helpful in minimizing probing-system uncertainty components for specific measurement tasks, and that the user will be able to reduce errors by removing contributing elements such as long 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 size-measuring test given in ISO 10360-2 (conducted using only one stylus), and in addition to, or instead of, the test of the probing system specified in ISO 10360-2.

Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) —

Part 5:
CMMs using multiple-stylus probing systems

1 Scope

This part of ISO 10360 specifies acceptance and periodic reverification tests of the performance of CMMs having multiple-stylus probing systems, including systems with fixed multiple-styli attached to a single probe (e.g. “star” stylus), multiple-probing systems such as those with a stylus for each of their probes, and systems with articulating probing.

The acceptance test and reverification test specified in this part of ISO 10360 are applicable only to the following:

— CMMs using any type of contact-probing system;

— stylus system configurations able to be prequalified (i.e. where the repeatability of the system operation is sufficient so that a stylus qualification is not required for each use);

NOTE In the case of prequalified configurations, a similar test could be devised for non-repeatable changes of stylus system configurations.

— spherical, hemispherical and disk-shaped styli.

These tests are not applicable to non-contact probing systems, which require special testing procedures outside the scope of this part of ISO 10360.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10360. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10360 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

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

International Vocabulary of Basic and General Terms in Metrology (VIM). BIPM, IEC, IFCC, IUPAC, IUPAP, OIML, 2nd edition, 1993.

3 Terms and definitions

For the purposes of this part of ISO 10360, the terms and definitions given in ISO 10360-1, ISO 14253-1 and VIM apply.

4 Requirements for metrological characteristics

4.1 Errors of indication

The fixed multiple-stylus probing system errors and the articulating probing system errors, MF, MS, ML, and AF, AS, AL, respectively, shall not exceed the corresponding maximum permissible errors (MPE_{MF}, MPE_{MS}, MPE_{ML}, and MPE_{AF}, MPE_{AS}, MPE_{AL}), as stated by:

— the manufacturer, in the case of acceptance tests;

— the user, in the case of reverification tests.

The errors and their corresponding maximum permissible errors are expressed in micrometres.

NOTE Multiple-stylus probing system errors are broadly categorized into form-related (MF, AF), size-related (MS, AS) and location-related (ML, AL) errors. Different combinations of these will be important for the uncertainty of the different measurement tasks.

4.2 Environmental conditions

The limits to be respected for permissible environmental conditions that influence the measurements, such as temperature, air humidity and vibration at the site of installation, shall be specified by

— the manufacturer, in the case of acceptance tests, or

— the user, in the case of reverification tests.

In either case, the user may choose the conditions from within the specified limits.

4.3 Styli

The styli used in the tests specified in clause 5 shall be those approved for use with the CMM, i.e. made of the same material, of the same stylus-shaft diameter and nominal length, and having the same stylus-tip quality. However, it is recognized that the exact stylus lengths used for test procedures might not be available, and therefore a stylus-length variation of 6 mm or 10 % of the nominal length, whichever is the greater, may be used.

4.4 Operating conditions

For the tests specified in clause 5, the CMM shall be operated using the procedures given in the manufacturer's operating manual. Specific areas of the manufacturer's manual to be adhered to include

a) machine start up/warm up cycles,

b) stylus system configuration and assembly,

c) cleaning procedures for stylus tip and reference sphere, and

d) probing system qualification.

All stylus tips and the reference sphere should be cleaned before the probing-system qualification to eliminate residual film which might affect the measurements or test results.

Ensuring approximate thermal equilibrium of the probing system before and during the probing system qualification is critical to the test.

5 Acceptance tests and reverification tests

5.1 Fixed multiple-stylus probing system

5.1.1 Principle

The principle of this test procedure is to measure the form, size and location of a test sphere using five different fixed styli. Each stylus probes 25 points on the test sphere, for a total of 125 points for all five styli.

If a stylus or probe changing system is supplied with the CMM, five changes shall be performed, one before each stylus is used. For each group of 25 points taken with a single stylus, associate a least-squares sphere fit, for a total of five sphere fits.

The ranges of the centre coordinates (X, Y, and Z) of all five spheres are calculated. The largest of these three ranges yields the location error ML. In addition, a least-squares sphere fit using all 125 points is examined for the form and size errors of indication. This analysis yields the size error MS and form error MF.

Since the results of these tests are highly dependent on the stylus system, a series of stylus lengths is considered; only those lengths the CMM manufacturer specifies as applicable to the stylus system shall be tested.

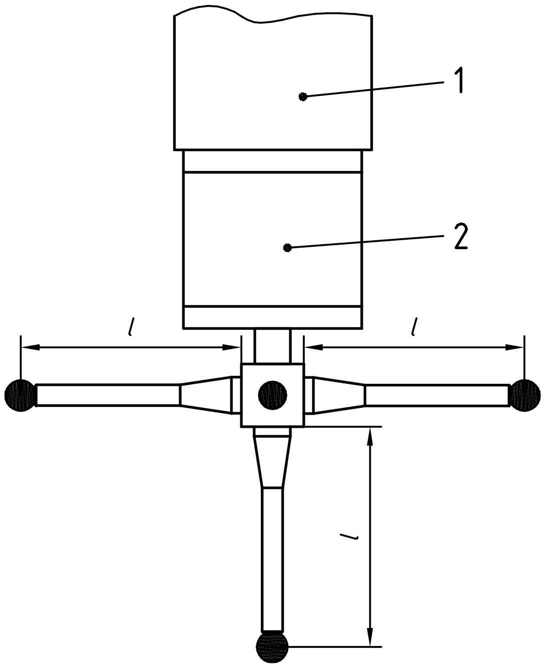
The choice of the location of the test sphere can significantly affect the test results.

5.1.2 Measuring equipment

The material standard of size, the test sphere, shall have a diameter not less than 10 mm and not greater than 30 mm. The test sphere shall be calibrated for size and form. The CMM qualification sphere shall not be used as the test sphere.

5.1.3 Procedure

5.1.3.1 Construct a “star” stylus system composed of one stylus parallel to the axis of the probe and four styli in a plane perpendicular to the axis, each oriented 90° with respect to those adjacent to it. The distance from the probe to the styli connection point shall be the minimum distance possible using the stylus components normally supplied with the CMM (see Figure 1).



Key

1 Ram

2 Probe

NOTE For clarity, only four of the five styli, and only three shafts, are visible.

Figure 1 — Fixed multiple-stylus probing system of stylus length *l*

The applicable values of stylus length, *l*, shall be equal and specified by the CMM manufacturer, and shall be chosen from the following values: 10 mm, 20 mm, 30 mm, 50 mm, 100 mm, 200 mm and 400 mm (see Figure 2). Only those lengths specified by the CMM manufacturer as applicable to the stylus system shall be tested. The stylus components shall be those approved for use with the CMM probing system, unless otherwise specified.

5.1.3.2 Qualify each of the five styli in accordance with the CMM manufacturer's normal operating procedures.

5.1.3.3 The spherical material standard, i.e. the test sphere, should be displaced from the location of the reference sphere used for the probing system qualification in both the X and Y directions a distance at least equal to the largest stylus length used in the tests (see Figure 2). Measure the test sphere using 25 points with each stylus, for a total of 125 points.

The points should be well distributed on the test sphere, covering at least a hemisphere. The recommended point-sampling strategy for a vertical stylus consists of: a point on the test sphere "pole"; four points equally spaced and located 22,5° from the pole; eight points equally spaced, rotated 22,5° from the previous group and located 45° from the pole; four points equally spaced, rotated 22,5° from the previous group and located 67,5° from the pole; eight points equally spaced, rotated 22,5° from the previous group and located 90° from the pole.

For horizontal styli, a similar sampling strategy should be used, with the "pole" defined by the direction of the stylus.

If a stylus- or probe-changing system is supplied with the CMM, five changes shall be performed, each stylus being changed once. However, if fewer than five probe or styli stations are available in the changing system, the maximum number shall be used, with some styli or probes exchanged more than once to achieve a total of five changes.

	MPE_{MF} µm	MPE_{MS} µm	MPE_{ML} µm
Fixed multiple stylus l = 10 mm			
Fixed multiple stylus l = 20 mm			
Fixed multiple stylus l = 30 mm			
Fixed multiple stylus l = 50 mm			
Fixed multiple stylus l = 100 mm			
Fixed multiple stylus l = 200 mm			
Fixed multiple stylus l = 400 mm			

Figure 2 — Sample fixed multiple-stylus probing system specification sheet

5.1.4 Data analysis

5.1.4.1 Associate a least-squares sphere fit for each group of 25 points taken with a single stylus, for a total of five sphere fits. Calculate the range of the centre coordinates (X, Y, and Z) of all five spheres. The largest of these three ranges yields the location error *ML*.

5.1.4.2 Associate a least-squares sphere fit on all 125 points taken with all five styli. Record the deviation of the sphere fit diameter from the calibrated value of the material standard of size to give the fixed multiple-stylus probing system size error *MS*. Similarly, record the range of radii of the 125 points with respect to the least-squares sphere centre, i.e. the sphere form, to give the fixed multiple-stylus probing system size error form error *MF*.

5.1.5 Repeat the steps given in 5.1.3.1 to 5.1.4.2 for each value of l permitted by the CMM manufacturer.

5.2 Articulating probing systems

5.2.1 Principle

The principle of these tests is to measure the form, size and location of a test sphere using five different angular positions of an articulating probing system (see Figure 3). At each angular position 25 points are measured on the test sphere, for a total of 125 points using all five positions.

If a stylus- or probe-changing system is supplied with the CMM, five changes shall be performed, one before each of the angular positions used. Associate a least-squares sphere fit with each group of 25 points taken at an angular position, for a total of five sphere fits.

The ranges of the centre coordinates (X, Y, and Z) of all five spheres are calculated. The largest of these three ranges yields the location error, *AL*. In addition, a least-squares sphere fit using all 125 points is examined for the form and size errors of indication. This analysis yields the size error *AS* and form error *AF*.

Since the results of these tests are highly dependent on the probe extension length, a series of different extension lengths is considered; only those lengths the CMM manufacturer specifies as applicable to the articulating probing system shall be tested.

The choice of the location of the test sphere can significantly affect the test results.