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Coordinate metrology —

Part 2:
Performance assessment of coordinate measuring machines

Métrologie par coordonnées —

Partie 2: Évaluation des performances des machines à mesurer tridimensionnelles

Reference number
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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.

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.

International Standard ISO 10360-2 was prepared by Technical Committee ISO/TC 3, *Limits and fits*.

ISO 10360 consists of the following parts, under the general title *Coordinate metrology*:

— *Part 2: Performance assessment of coordinate measuring machines*

— *Part 3: Performance test for CMMs with a rotary axis as the fourth axis*

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

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Introduction

The primary assessment of the performance of a coordinate measuring machine (CMM) is, where practicable, a length-measuring task. The reasons for this approach are:

— to make the test conform, as closely as possible, to a frequently-performed measurement procedure;

— to provide well-defined traceability to the unit length, the metre.

The test of the probing system is intended to assess probing errors, including those not revealed by the acceptance test, associated with the contacting type of CMM probing system operating in the discrete-point measuring mode.

Because it is not possible to completely isolate the probing errors from other sources of machine error, some measurement errors, of both static and dynamic origin, inherent in the other parts of the CMM measuring system will also be measured by this test.

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Coordinate metrology —

Part 2:
Performance assessment of coordinate measuring machines

1 Scope

This part of ISO 10360 specifies:

a) the acceptance test, which verifies that the performance of a coordinate measuring machine (CMM) and the CMM probing system is as stated by the manufacturer;

b) the reverification test, which enables the user to reverify CMM performance and the CMM probing system periodically;

c) the interim check (see annex A), which enables the user to make checks on a CMM and the CMM probing system between regular reverification tests;

in relation to the three-dimensional error of length measurement of a CMM capable of measuring Cartesian, cylindrical or spherical coordinates of points in space. A limited number of tests is carried out, but their locations may be anywhere within the working volume of the CMM. Three nonredundant axes (excluding the axes associated with the probe system) shall be tested.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10360. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10360 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3650:1978, *Gauge blocks.*

VIM, *International Vocabulary of Basic and General Terms in Metrology.*

3 Definitions

For the purposes of this part of ISO 10360, the following definitions apply.

3.1 coordinate measuring machine (CMM): Measuring device, the base of which is fixed in place during use, designed to take measurements from at least three linear or angular displacements generated by the machine. At least one of the three displacements shall be linear measurement.

3.2 error of indication of a CMM: Indication of a CMM minus the (conventional) true value of the measurand.

NOTE 1 Error of indication includes the error of the material standard of length.

3.3 uncertainty of dimensional measurement: Estimate characterizing the range of values within which the true value of a measurand lies.

3.4 material standard: Material measure reproducing a known value of a dimensional quantity (length, diameter, etc.) which is traceable to national standards, and is used for the verification test of a CMM.

3.5 material standard of length: Material standard containing two or more nominally parallel planes, the distance between these planes being specified.

NOTE 2 Examples of material standards of length are gauge blocks according to ISO 3650 and step gauges.

3.6 error of indication of a CMM for length measurement, E: By convention, the error with which the length of the material standard can be determined with a CMM, the measurement being taken through two opposite points on two nominally parallel planes, normal to one of the planes, when the points are approached from opposite directions.

The error of indication of a CMM for length measurement, E, expressed in micrometres, is stated in one of three forms:

$E = A + L/K \leqslant B$, or

$E = A + L/K$, or

$E = B$

where

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

K is a dimensionless constant supplied by the CMM manufacturer;

L is the measured length, in millimetres;

B is the maximum value of E, in micrometres, as stated by the CMM manufacturer.

The expressions apply for any position or orientation of the material standard within the CMM.

Measurements shall be made utilising the three axes of the machine to which the manufacturer has stated that the quoted value of E applies.

3.7 error of indication of a CMM for periodic reverification, V: Error of indication chosen by the user for the periodic reverification test, according to the user's requirements and use of the machine.

3.8 probing error, R: By convention, the error within which the range of radii of a material standard can be determined with a CMM, the measurements being taken using a sphere as substrate.

R is a positive constant error whose value is supplied by the CMM manufacturer.

The value of R applies for any location of the material standard within the working volume of the CMM and for any probing direction.

3.9 probing error for periodic reverification, S: Probing error chosen by the user for the periodic reverification test, according to the user's requirements and use of the machine.

3.10 radial distance, r: Distance between the centre of the Gaussian (least-squares) sphere (substitution element) and the probed point.

4 Acceptance test and periodic reverification of the CMM

4.1 Operating conditions

Before beginning the tests given in 4.2 and 4.3, the CMM shall be operated using the procedures as specified in the manufacturer's instruction manual, for example:

a) machine start-up;

b) probe qualification;

c) probe configuration.

The necessary information should be provided by the manufacturer.

For the tests given in 4.2 and 4.3, the environmental and operating conditions recommended by the manufacturer shall apply.

4.2 Acceptance test

4.2.1 Principle

To establish whether the CMM is capable of measuring within the manufacturer's stated value of E, values of the error of length measurement, ΔL, are determined.

4.2.2 Apparatus

4.2.2.1 Coordinate measuring machine to be tested (see 3.1).

4.2.2.2 Material standard of length, either a step gauge or a series of gauge blocks conforming to ISO 3650 being strongly recommended.

It is recommended that

— the longest length of the material standard is at least 66 % of the longest space diagonal;

— the shortest length of the material standard is less than 30 mm.

If a manufacturer's material standard is used, then no additional uncertainty shall be added to the value of E. If a user's material standard is used, and if the uncertainty of the user's material standard, F, is greater than 20 % of the value of E, then E shall be redefined as the sum of E and F.

The manufacturer's material standard shall have a calibration uncertainty no greater than 20 % of E.

4.2.3 Test procedure

4.2.3.1 Measure the material standard of length in any seven different configurations (combinations of position and orientation), chosen at the discretion of the user, making only bidirectional measurements either externally or internally.

4.2.3.2 For each of the seven configurations, take and record measurements of five test lengths, each measured three times. (The total number of length measurements is thus 105.) Measure one point only at each end of the test length for each length measurement.

NOTE 3 Supplementary measurements are normally required for alignment purposes. It is recommended that the alignment method used be consistent with the procedures used during calibration.

4.2.4 Calculation of results

For each of the 105 measurements, calculate the error of length measurement, ΔL, as the absolute value of the difference between the indicated value and the true value of the relevant test length.

The indicated value of a particular measurement (of a particular test length in a particular configuration) may be corrected to account for systematic errors if the CMM has accessory devices to correct systematic instrument errors, or software for this purpose. Manual correction of the result obtained from the computer output to take account of temperature or other corrections shall not be allowed when the environmental conditions recommended by the manufacturer apply.

The true value of the test length is taken as the calibrated length between the measuring faces of the material standard. This value should be temperature-corrected only if this facility is normally available in the software of the CMM under test.

4.2.5 Interpretation of results

The performance of the CMM is verified if none of the 105 values of error of length measurement (converted to micrometres) obtained as in 4.2.4 is greater than the manufacturer's stated value of E.

A maximum of five of the 35 test length measurements may have one of the three replicate values of the error of length measurement greater than E. Each such test length shall have the measurement that is out of tolerance repeated ten times at the relevant configuration.

If all the values of the error of length measurement from the repeat measurements are within E, then the performance of the CMM is verified.

4.3 Periodic reverification

Carry out the test procedure and calculation of results as specified in 4.2.

The performance of the CMM is reverified if the conditions in 4.2.5 are satisfied when V is substituted for E.

5 Acceptance test and reverification of the CMM probing system

5.1 Principle

The principle of the acceptance method is used to establish whether the CMM is capable of measuring within the manufacturer's stated value of R by determining the range of values of the radial distance r on a reference sphere.

5.2 Apparatus

5.2.1 Coordinate measuring machine probing system to be tested (see 3.1).

The user is free to choose the configuration of the stylus components of the probe, within the limits specified by the manufacturer.

5.2.2 Certified reference sphere, having

— diameter between 10 mm and 50 mm inclusive;

NOTE 4 Spheres up to 30 mm in diameter are commonly used.

— errors of certified form no greater than $R/5$.

The sphere supplied with the CMM for probe-qualifying purposes shall not be used for this test.

The sphere should be mounted rigidly to avoid errors due to bending.

5.3 Test procedure

5.3.1 Select the probe configuration, either one of the seven configurations used for length measurement (see 4.2.3.1) or a different configuration.

NOTE 5 It is recommended that the orientation of the stylus is not parallel to any CMM axis.

5.3.2 Set up and qualify the probe in accordance with the manufacturer's procedures.

5.3.3 Take and record a pattern of 25 points in random order on the reference sphere. The distribution of points should be as nearly uniform as practical over a hemisphere. The orientation of the hemisphere chosen is at the discretion of the user.

5.4 Calculation of results

Using all 25 measurements, compute the centre of the Gaussian (least-squares) sphere (substitution element). For each of the 25 measurements, calculate the radius, r.

5.5 Interpretation of results

The performance of the probing system is verified if the range $r_{max} - r_{min}$ of the 25 radial distances obtained in accordance with 5.4 is no greater than the manufacturer's stated value of R.

If the range exceeds the manufacturer's stated value of R, the probing system should be thoroughly checked and the test should be repeated once, starting from requalification of the probe. If the range of values of r from the repeat measurements is within the value of R, then the performance of the probe is verified.

5.6 Periodic reverification

Carry out the test procedure and calculation of results as specified in clause 5.

The performance of the CMM probing system is reverified if the conditions in 5.5 are satisfied.

Annex A
(informative)

Interim checking

A.1 Interim machine checking of the CMM

It is strongly recommended that the CMM be checked regularly between periodic reverification. The interval between checks should be determined from the environmental conditions and the measurement performance required.

The CMM should be checked immediately after any significant event which could affect the CMM performance.

It is recommended that the characteristic dimensions of material standards, other than material standards of length, be measured. The measurements should be made directly after the performance verification test; the position(s) and orientation(s) of these reference objects should be noted and subsequently duplicated.

Dependent upon the measurement tasks for which the CMM is being used, it is recommended that the most relevant of the following commonly-used reference objects should be chosen:

— a purpose-made testpiece which has features representing typical geometric elements, is dimensionally stable, mechanically robust, and which has a surface finish that does not significantly affect the uncertainty of measurement;

— a ball-ended bar;

— a bar that can be kinematically located between a fixed reference sphere and the sphere of the CMM probe-stylus;

— a circular reference object, e.g. a ring gauge;

— a ball-plate;

— a hole-plate.

A.2 Interim probe checking

Carry out the test procedure and calculation of results in accordance with clause 5.

It is strongly recommended that the change in probing error associated with different probe configurations used in practice, for example multiple styli and stylus extensions, is checked regularly between periodic reverifications.

The apparatus, test procedure and calculation method specified in 5.2 to 5.4 should be used for the interim probe checking.