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Test code for machine tools —

Part 10:

**Determination of the measuring
performance of probing systems of
numerically controlled machine tools**

**AMENDMENT 1: Measuring performance
with scanning probes**

Code d'essai des machines-outils —

*Partie 10: Détermination des performances de mesure des systèmes de
palpage des machines-outils à commande numérique*

AMENDEMENT 1: Performances de mesure avec palpeurs de scanning



Reference number
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The committee responsible for this document is ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

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Test code for machine tools —

Part 10:

Determination of the measuring performance of probing systems of numerically controlled machine tools

AMENDMENT 1: Measuring performance with scanning probes

Page 3, 3.2.1.2

Delete the Note, "Proportional probes used in continuous scanning mode are not included in the scope of this part of ISO 230."

Page 38

Add [Annex B](#) (see overleaf) before the bibliography.

Page 38, Bibliography

Add the following entry.

- [14] ISO 10360-4, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 4: CMMs used in scanning measuring mode*

Annex B (informative)

Measuring performance with scanning probes

B.1 Scope

This annex provides test procedures to evaluate the scanning performance of contacting probing systems, integrated with a numerically controlled machine tool, and used in a pre-defined path scanning mode (see B 2.9).

These tests are supplementary to the discrete point tests that are specified in Clauses 6 and 7. Contacting probing systems that do not support discrete point measurement are not covered by this annex.

Clauses 1 to 5 are applicable to this annex.

The test procedures are not intended to distinguish between the various causes of errors. They are intended to demonstrate the combined influence of the environment, machine tool, probing system and probing software on the measuring performance.

The tests in this annex are applicable to both acceptance testing and re-verification testing, and should be run periodically, after a crash of the probe or machine, or if any of the following probing conditions are changed:

- feed speed during measurement;
- stylus system (in particular stylus system length);
- feed speed during qualification;
- probing system orientation during measurement (e.g. vertical or horizontal orientation of probe);
- probe;
- nominal deflection;
- measurement range.

B.2 Terms and definitions

For the purpose of this annex, the following terms and definitions apply.

B.2.1

rest position

position of the centre of the probe's stylus tip when it is stationary and not deflected by contact with a surface

Note 1 to entry: The rest position is a nominal position that is established during qualification. The actual rest position at any time typically varies slightly from this value.

B.2.2

maximum scanning deflection

maximum deflection that can be applied to the centre of the probe's stylus tip during a scanning measurement specified by the manufacturer

Note 1 to entry: The maximum scanning deflection can vary with direction of deflection (x,y,z).

B.2.3

probe over-travel limit

maximum deflection at the centre of the probe stylus tip from the rest position that can be applied without causing damage to the probe stylus assembly

B.2.4

minimum scanning deflection

minimum deflection of the centre of the stylus tip from its rest position that is allowed during a scanning measurement

Note 1 to entry: Deflection is programmed to be large enough to ensure that the stylus tip maintains contact with the surface throughout the measurement.

B.2.5

scanning measurement range

maximum allowed distance between the nominal scan line and the actual scan line, as specified by the manufacturer/supplier

Note 1 to entry: This distance may be expressed separately for the different axes of the probe, e.g. $\pm 0,3$ mm in X and Y, $\pm 0,2$ mm in Z.

Note 2 to entry: The scanning measurement range is less than the difference between the maximum scanning deflection and the minimum scanning deflection for a number of reasons, some examples being:

- deviation from the pre-defined tool-path caused by machine tool path following errors;
- approximations during tool-path generation (e.g. approximating a curve by straight line segments);
- additional probe deflection caused by movement along the surface (e.g. friction, local surface normal deviations, surface finish).

B.2.6

stylus tip normal acceleration

acceleration at the centre of the stylus tip relative to the surface being measured, normal to the target surface

Note 1 to entry: Stylus tip normal acceleration is sometimes considered to limit the scanning feed speed for features that have sharp scanning path variations, and would therefore demand high rates of acceleration from the machine tool axes. Scanning performance is affected mostly by acceleration normal to the surface being measured, as machine position errors in the direction of the target scan line do not usually lead to significant measurement errors.

B.2.7

indicated tip centre point

indicated position of the centre of the stylus tip during a measurement

Note 1 to entry: This is also known as an “indicated measured point” (see ISO 10360-1, definition 2.12).

B.2.8

scanning sphere centre position reproducibility

maximum variation of the sphere centre positions obtained through multiple measurements compared to the sphere centre position obtained by the first measurement

B.2.9

pre-defined path scanning

method of scanning in which the motion of the probing system between two defined end points is directed by a target scan line

[SOURCE: ISO 10360-1, definition 7.5]

Note 1 to entry: In this method of scanning, feedback from the probing system is not used to direct the motion of the probing system.

B.3 General considerations

Some sources of measurement error in continuous scanning systems on machine tools are different from those on a CMM. The main differences are as follows.

- A machine tool typically does not control probe deflection while scanning. This means that the positional uncertainty of the workpiece is more likely to affect measurement uncertainty on a machine tool.
- Machine tools are optimized for cutting, not measurement. Machine position reporting errors during qualification and subsequent measurements typically create differences between the measurement accuracy of inside and outside features, for example bores and bosses.

The following tests should be performed using the feed speed and the measurement range specified for the probing system or agreed between manufacturer/supplier and user.

The tests in this annex are sensitive to stylus configuration; especially stylus length and stylus tip diameter. For acceptance testing, the stylus configuration should be agreed between manufacturer/supplier and user. For verification testing, the tests should be run whenever a new stylus configuration is used.

For probing systems that control probe deflection using real-time feedback to adjust the measurement path, the less comprehensive but shorter test specified in ISO 10360-4^[14] may be appropriate. For this

type of system, if agreed between manufacturer/supplier and user, the scanning 3D performance test (see B.5) could be replaced by the test specified in ISO 10360-4^[14]. If this is done it is nevertheless recommended that the scanning 2D performance test (see B.6) is still performed.

NOTE The scanning 3D performance test contains the measurements required for ISO 10360-4.^[14] If required, the measurement data from the scanning 3D performance test can also be analysed to produce ISO 10360-4^[14] results.

The 3D scanning performance test is performed on an external surface, whereas the 2D scanning performance test is performed on an internal surface. The two tests have been designed to be complementary to each other as scanning systems on machine tools can have significantly different uncertainties when scanning internal and external surfaces. It is recommended that both tests be performed.

The probe should be tool changed and, where applicable, the tool change indexer moved by at least one index position after qualification and between each test.

B.4 Filtering parameters

The filtering algorithms and parameters used during these tests affect the results and should be agreed between manufacturer/supplier and user. They should be stated in the test report.

B.5 Scanning 3D performance test; $E_{SC,3D,POS}$, $E_{SC,3D,DIA}$, $E_{SC,3D,FORM}$, $T_{SC,3D}$, ($Error_{SCanning,3D,POSition}$, $Error_{SCanning,3D,DIAMeter}$, $Error_{SCanning,3D,FORM}$ and $Time_{SCanning,3D}$)

B.5.1 General

This test determines the ability of the probing system to measure a test sphere when the measurement tool-path is not exactly aligned with the test sphere. This test applies to probing systems that can measure a sphere in continuous scanning mode, and simulates the deviation of workpiece position during in-process measurement.

The probe is operated over its full 3D measurement range in this test. This test does not include the effects of temperature variation on positional uncertainty. The user of a contact scanning system is advised to consider the effect of temperature variations on the measurement range requirements.

This test is designed to be run on three-axis machines, including machines that can only interpolate in XY, YZ and ZX planes. The test is specified assuming that the Z-axis of the probe is aligned with the Z-axis of the machine tool so that it is widely applicable.

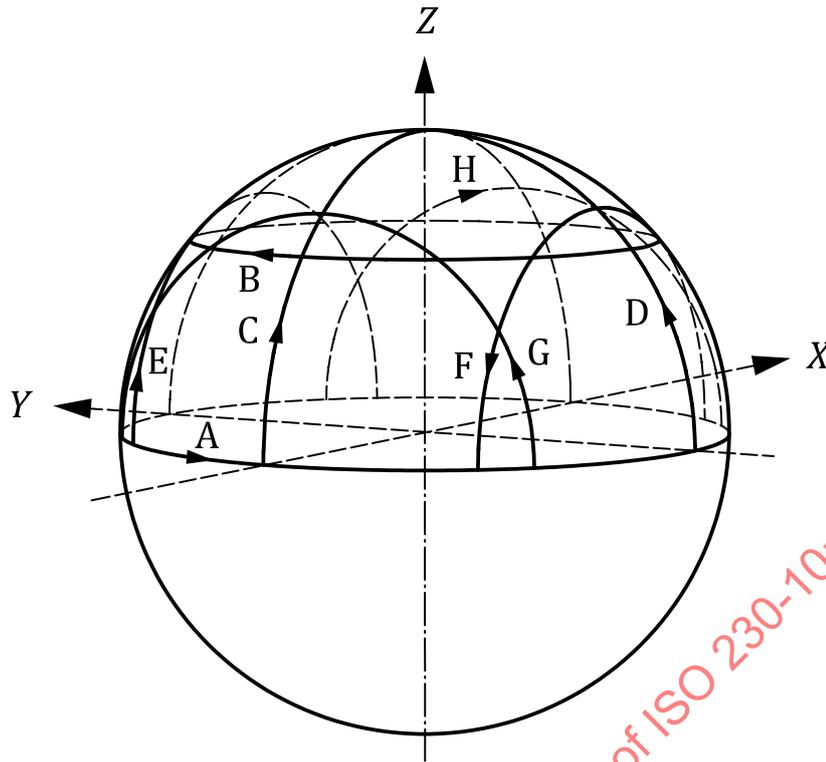
The time for the test is recorded to give an indication of system speed, and because it may affect accuracy.

B.5.2 Sphere measurement sequence

Refer to Figure B.1.

- a) The coordinate system origin is at the centre of the sphere, and is aligned with the X-, Y- and Z-axes of the probe. The pole of the sphere is at $X = 0$, $Y = 0$, $Z = r$ (radius of sphere).
- b) The arrows on the diagram indicate the directions of travel along the target scan lines.

The direction and feed speed of the approach moves to the target scan lines should be in accordance with the manufacturer/supplier's recommendations.



Key

- A target scan line A (CCW) is on the equator in the XY plane
- B target scan line B (CW) is parallel to the XY plane, 8 mm above the equator (diameter of sphere is 25 mm)
- C, D target scan lines C (CCW) and D (CW) are in the ZX and ZY planes respectively, and go through the pole
- E, F target scan lines E (CCW) and F (CW) are parallel to the ZX plane, at Y = +8 mm and Y = -8 mm, respectively
- G, H target scan lines G (CW) and H (CCW) are parallel to the ZY plane, at X = -8 mm and X = +8 mm respectively

Figure B.1 — Target scan lines and required direction of travel for the scanning 3D performance test

B.5.3 Test set up and procedure

- a) Position a test sphere of approximately 25 mm diameter, calibrated for size and form, in a workpiece representative position within the machine tool measuring volume.
- b) The user is free to choose the location of the mounting of the test sphere within the specified measuring volume. However, it is recommended that the test sphere not be placed at the location used for the probing system qualification.
- c) The stylus tip and the reference/test sphere(s) should be cleaned before the probing system qualification so as to leave no residual contamination that could affect the measuring or test result.
- d) Ensure that the probing system has been qualified according to the manufacturer/supplier's instructions.
- e) Measure the centre coordinates of the test sphere by probing it with five or more discrete points. Establish a WCS datum point at the measured centre of the test sphere.
- f) Use the sphere measurement sequence specified in B.5.2 to scan the sphere. The sphere should be scanned 10 times setting the nominal position of the sphere according to the values in Table B.1.

- g) Record the time for the test $T_{SC,3D}$ as the time taken to perform the test from the start of the first scan sequence of the first measurement (at the intermediate point) to the end of the last scan sequence of the last measurement (at the intermediate point).

NOTE The test sphere itself is not moved during this test; the scanning path for the sphere measurement is generated assuming that the test sphere is located at the specified nominal positions.

Table B.1 — X-, Y-, and Z-axis offsets for the scanning 3D performance test

| Measurement number | Nominal centre position with respect to the reference position mm | | |
|--------------------|--|-------------------|------------------|
| | X | Y | Z |
| 1 | 0 | 0 | 0 |
| 2 | 0 | R_{XY} | 0 |
| 3 | R_{XY} | 0 | 0 |
| 4 | $-R_{XY}$ | 0 | 0 |
| 5 | 0 | $-R_{XY}$ | 0 |
| 6 | 0 | 0 | R_{ZPOS} |
| 7 | 0 | 0 | $-R_{ZNEG}$ |
| 8 | $R \times 0,683$ | $R \times 0,183$ | $R \times 0,707$ |
| 9 | $R \times -0,500$ | $R \times 0,050$ | $R \times 0,707$ |
| 10 | $R \times -0,183$ | $R \times -0,683$ | $R \times 0,707$ |

R_{XY} is the XY-plane scanning measurement range as specified by the manufacturer/supplier.
 R_{ZPOS} , and R_{ZNEG} are the Z axis measurement range (positive and negative material condition respectively) as specified by the manufacturer/supplier.
 R is the smallest of R_{XY} , R_{ZPOS} , and R_{ZNEG} .

B.5.4 Analysis of results

Filtering algorithms and parameters may be used for the analysis of the scanning 3D performance test as agreed between manufacturer/supplier and user. If filtering is applied, the parameters and algorithms used should be stated with the test results (see B.4).

For each sphere measurement, proceed as follows.

- a) Compute the centre location and diameter of the Gaussian (least squares) sphere (associated feature) using all of the tip centre points of all eight scans. Record these values as centre coordinates $X_{SC,3D}$, $Y_{SC,3D}$, $Z_{SC,3D}$, and the diameter $D_{SC,3D}$ of the sphere.
- b) For each of the measured scan points, calculate the radial distance, r , to the centre coordinates of the sphere [according to item a)].
- c) Compute the scanning probing error, $F_{SC,3D}$ as the range of the calculated radial distances, r .

Using the above data, proceed as follows.

- 1) Calculate the scanning 3D position reproducibility, $E_{SC,3D,POS}$ as the maximum distance of any of the sphere centre locations $X_{SC,3D}$, $Y_{SC,3D}$, $Z_{SC,3D}$ recorded in measurement 2 to 10 from the sphere centre location recorded in measurement 1.
- 2) Calculate the scanning 3D diameter error $E_{SC,3D,DIA}$ as the maximum deviation of any of the 10 $D_{SC,3D}$ measurements from the sum of the stylus tip diameter and the calibrated test sphere diameter. If the scanning system can report the qualified diameter of the stylus tip, then this value should be used, otherwise the nominal diameter of the stylus tip should be used.