
Test code for machine tools —
Part 10:
Determination of the measuring
performance of probing systems of
numerically controlled machine tools

iTeh STANDARD PREVIEW

Code d'essai des machines-outils —
Partie 10: Détermination des performances de mesure des systèmes de
palpage des machines-outils à commande numérique

ISO 230-10:2016

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](http://Foreword - Supplementary information (standards.iteh.ai))

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

This second edition cancels and replaces the first edition (ISO 230-10:2011), of which it constitutes a minor revision. It also incorporates the amendment ISO 230-10:2011/Amd 1:2014. In [Table B.1](#) an entry with the value of "R x 0,050" has been replaced with "R x 0,500".

ISO 230 consists of the following parts, under the general title *Test code for machine tools*:

- *Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions*
- *Part 2: Determination of accuracy and repeatability of positioning numerically controlled axes*
- *Part 3: Determination of thermal effects*
- *Part 4: Circular tests for numerically controlled machine tools*
- *Part 5: Determination of the noise emission*
- *Part 6: Determination of positioning accuracy on body and face diagonals (Diagonal displacement tests)*
- *Part 7: Geometric accuracy of axes of rotation*
- *Part 8: Vibrations* [Technical Report]
- *Part 9: Estimation of measurement uncertainty for machine tool tests according to series ISO 230, basic equations* [Technical Report]
- *Part 10: Determination of the measuring performance of probing systems of numerically controlled machine tools*

The following part is under preparation:

- *Part 11: Measuring instruments and their application to machine tool geometry tests* [Technical Report]

Introduction

The purpose of ISO 230 (all parts) is to standardize methods of testing the accuracy of machine tools, excluding portable power tools.

This part of ISO 230 concerns test procedures to evaluate the measuring performance of contacting probing systems (used in a discrete-point probing mode) integrated with a numerically controlled machine tool. The test procedures are not intended to distinguish between the various causes of errors. They intend to demonstrate the combined influence of the environment, machine tool, probing system and probing software on the measuring performance.

The results of these tests do not reflect on the performance of the machine tool in a metal cutting mode. When the tests are required for acceptance purposes, it is up to the user to choose, in agreement with the manufacturer/supplier, those tests relating to the properties of the components of the machine probing system, which are of interest.

The results of these tests do not reflect on the performance of the machine tool used as a coordinate measuring machine (CMM). Such performance involves traceability issues and it is intended that they be evaluated according to ISO 10360-2 and ISO 10360-5.

An alphabetical list and short description of the symbols used in this part of ISO 230 is given in [Annex A](#).

Test procedures to measure performance with scanning probes are given in [Annex B](#).

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Test code for machine tools —

Part 10:

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

1 Scope

This part of ISO 230 specifies test procedures to evaluate the measuring performance of contacting probing systems (used in a discrete-point probing mode) integrated with a numerically controlled machine tool.

It does not include other types of probing systems, such as those used in scanning mode or non-contacting probing systems. The evaluation of the performance of the machine tool, used as a coordinate measuring machine (CMM), is outside the scope of this part of ISO 230. Such performance evaluation involves traceability issues, is strongly influenced by machine tool geometric accuracy and can, in addition to the machine tool probing system tests specified in this part of ISO 230, be evaluated according to ISO 10360-2 and ISO 10360-5.

Numerically controlled machine tools can apply contacting probing systems in machining process applications, such as

- identification that the correct workpiece has been loaded before machining,
- location and/or alignment of the workpiece,
- measurement of the workpiece after machining, but while still on the machine,
- measurement of the position and orientation of the machine tool rotary axes,
- measurement and setting of the cutting tool (radius, length and offset of the tool), and
- detection of tool breakage.

NOTE 1 This part of ISO 230 focuses on machining centres, but it is intended that other types of machines, for instance turning and grinding centres, be included in a future revision of this part of ISO 230.

NOTE 2 This part of ISO 230 does not include non-contacting type of probes (e.g. optical probes), but it is intended that they be included in a future revision of this part of ISO 230.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 230-1, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions*

ISO 230-2, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning of numerically controlled axes*

ISO 230-3:2007, *Test code for machine tools — Part 3: Determination of thermal effects*

ISO 10360-5:2010, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 5: CMMs using single and multiple stylus contacting probing systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE In measuring mode, machine tools are used like CMMs. Therefore, definitions for probing systems performance tests for CMMs apply also for machine tools. However, since not all machine tool users are familiar with the use of CMMs, this part of ISO 230 provides definitions specifically with machine tools in mind, making sure that they do not create any conflicts with CMM definitions.

3.1 General terms

3.1.1

machine coordinate system

MCS

coordinate system fixed with respect to physical or calculated axes of a machine tool

[SOURCE: ISO 10360-1:2000, 2.5 — modified.]

3.1.2

workpiece coordinate system

WCS

coordinate system fixed with respect to a workpiece

[SOURCE: ISO 10360-1:2000, 2.4]

3.1.3

measuring volume

three-dimensional space encompassing all linear coordinates that are accessible for measurement on the machine tool

[SOURCE: ISO 10360-1:2000, 2.3 — modified.]

3.2 Terms relating to the probing system

3.2.1

probe

device that senses a feature and generates the signal(s) during probing

[SOURCE: ISO 10360-1:2000, 3.1 — modified.]

Note 1 to entry: There are several types of probes used on machine tools and they use different technologies to achieve the same aim.

Note 2 to entry: Probes can either be “switching” types or “proportional” types. These are all available as either “contacting” or “non-contacting” systems. Non-contacting systems are not part of the scope of this part of ISO 230.

3.2.1.1

switching probe

probe that gives a binary signal as a result of contact with a surface being measured (detected)

3.2.1.2

proportional probe

probe that gives a signal (analogue or digital) proportional to a displacement of the stylus tip

3.2.1.3 contacting probe

probe that needs material contact with a surface being measured (detected) in order to function

[SOURCE: ISO 10360-1:2000, 3.2 — modified.]

EXAMPLE Electrical circuit breakage, strain gauge.

Note 1 to entry: The contacting feed speed applied to obtain the material contact can influence the performance of such probes. Proper contacting feed speed is specified in the manufacturer's/supplier's instructions.

Note 2 to entry: For best performance, the contacting feed speed applied during measurement is the same as the feed speed applied during probe qualification.

3.2.1.4 non-contacting probe

probe that needs no material contact with a surface being measured in order to function

[SOURCE: ISO 10360-1:2000, 3.3 — modified.]

EXAMPLE Optical and laser systems, inductive and capacitive systems.

Note 1 to entry: Non-contacting probes are not included in the scope of this part of ISO 230.

3.2.2 probing system

system consisting of a *probe* (3.2.1), signal transmission system (e.g. optical, radio, wire), signal conditioning hardware, the probing hardware and software and, where present, probe extensions, probe changing system, stylus and stylus extensions, when used in conjunction with a suitable numerically controlled machine tool

[SOURCE: ISO 10360-1:2000, 2.6 — modified.]

Note 1 to entry: Tests specified in this part of ISO 230 are referred to probing systems consisting of contacting probes equipped with a single stylus system that is parallel to the machine tool spindle axis average line, as depicted in [Figure 2](#). For applications using stylus systems equipped with multiple styli (see [Figure 3](#)), and for application where measurement is performed by using multiple orientations of the spindle axis average line with respect to the WCS, additional tests are specified in ISO 10360-5.

3.2.3 probing system qualification

establishment of the parameters of a probing system (based on manufacturer's/supplier's instructions) necessary for subsequent measurements

Note 1 to entry: *Effective stylus tip diameter* (3.2.5) and location of the stylus tip centre with respect to the MCS are typical parameters established by probing system qualification.

Note 2 to entry: Suppliers' technical literature sometimes refers to probing system qualification with the expression "probing system calibration"; this expression is not appropriate.

3.2.4 pre-travel

distance between the point of first material contact of the probe stylus tip with the surface being measured (detected) and the point where the probe signal is generated

Note 1 to entry: Pre-travel is affected by probe construction, probing direction, probing speed, switching force, stylus system length and compliance, time delay between probing signal and machine tool position transducer read-out, etc.

Note 2 to entry: Pre-travel variation (commonly referred to as "lobing"), under specified probing conditions, is a very important probing system characteristic.

Note 3 to entry: Some probe qualification techniques can significantly reduce the effects of probing system pre-travel variation.

3.2.5

effective stylus tip diameter
effective stylus tip size

stylus tip dimension used by some probing software to compensate for measured feature size, etc.

Note 1 to entry: The effective stylus tip diameter (size) is associated with probing system performance and is determined by appropriate probing system qualification, rather than by simply measuring the stylus tip size.

3.2.6

stylus tip

physical element that establishes the contact with the object to measure

[SOURCE: ISO 10360-1:2000, 4.2 — modified.]

3.2.7

stylus system

system composed of a stylus and stylus extension(s) (if any)

[SOURCE: ISO 10360-1:2000, 4.4 — modified.]

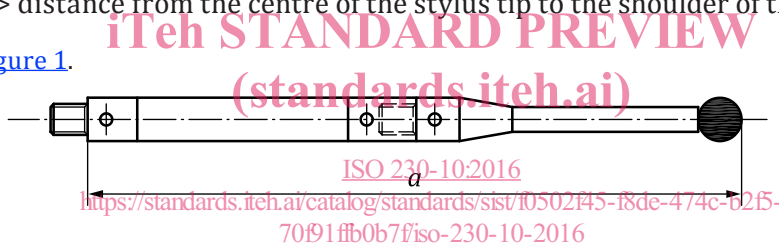
Note 1 to entry: Stylus extensions can reduce stylus system stiffness and can adversely influence probing system performance. Therefore, performance tests are carried out using the particular stylus extension(s) of interest.

3.2.8

stylus system length

<spherical stylus tip> distance from the centre of the stylus tip to the shoulder of the stylus system

Note 1 to entry: See [Figure 1](#).



Key

a stylus system length

Figure 1 — Stylus system length

3.2.9

probing tool

device consisting of a probe and its stylus system, attached to a tool holder

Note 1 to entry: See [Figure 2](#).

3.2.10

probing-tool length

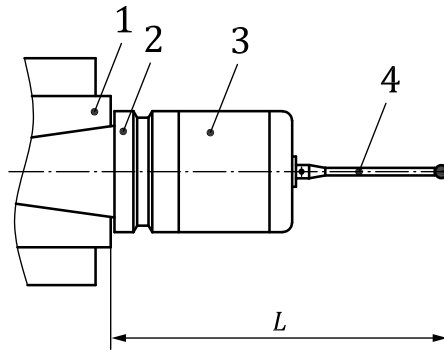
distance from the most protruding point of the stylus tip to the machine tool spindle reference surface or gauge line that connects to the probing tool

Note 1 to entry: See [Figure 2](#).

Note 2 to entry: Some probing systems establish the probing-tool length as the distance from the centre of the stylus tip surface to the machine tool spindle reference surface that connects to the probing tool.

Note 3 to entry: For solid-shank-type tool holders, the spindle reference surface is at the spindle cone gauge line. For other tool holders (hollow shank), the spindle reference surface is the spindle face.

Note 4 to entry: The procedure for establishing the length of the probing tool is specified in manufacturer's/supplier's instructions.

**Key**

- 1 spindle
- 2 tool holder
- 3 probe
- 4 stylus
- L probing-tool length

Figure 2 — Probing-tool length**3.2.11****stylus tip offset**

effective distance from the centre of the stylus tip to the axis average line of the spindle, in which the probing tool is mounted

3.3 Terms relating to probing

ISO 230-10:2016

3.3.1**probing
probe**

measurement action that results in the determination of values (e.g. coordinate values, length values, false/true values)

[SOURCE: ISO 10360-1:2000, 2.7 — modified.]

Note 1 to entry: Probing associated with the measurement of cutting tools does not necessarily result in the determination of coordinate values.

Note 2 to entry: Probing associated with tool breakage detection results in the determination of a false/true state.

3.3.1.1**1D probing**

measurement allowing for probing motion parallel to one machine coordinate system axis or to one workpiece coordinate system axis at one time only

Note 1 to entry: 1D measurement capability is associated with the probing system performance, not only with the contacting probe capabilities.

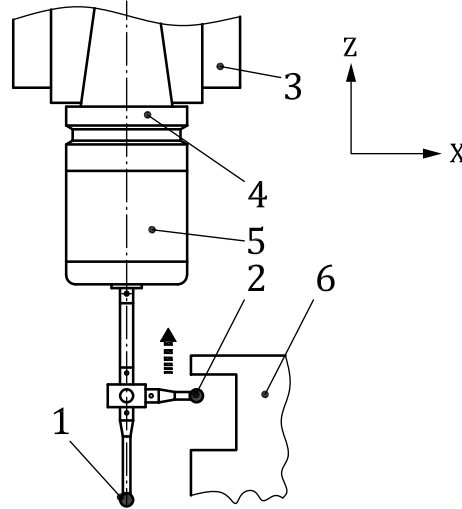
3.3.1.2**2D probing**

measurement allowing for probing motion along a vector in a plane

Note 1 to entry: Typical contacting probes that operate in the $-X$, $+X$, $-Y$, $+Y$ and $-Z$ directions, and in any combination of such directions, are sometimes referred to as 2,5D probes. These contacting probes do not allow for (or allow for very limited) traction in the $+Z$ direction.

Note 2 to entry: Measurement in the +Z direction capability can be obtained by the use of stylus systems equipped with multiple styli, as depicted in Figure 3, where stylus tip 2 (moving in the +Z direction) contacts the workpiece surface and causes the probe to generate the signal as a consequence of the deflection in the -Z direction.

Note 3 to entry: Independent qualification for stylus tip 1 and for stylus tip 2, and additional tests, are specified in ISO 10360-5.



Key

- 1 stylus tip 1
- 2 stylus tip 2
- 3 spindle
- 4 tool holder
- 5 probe
- 6 workpiece

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Figure 3 — Probing-tool equipped with 2 styli

3.3.1.3

3D probing

measurement allowing for probing motion along any vector in space

3.3.2

probing repeatability

degree of closeness of coordinate values provided by the probing system when it is repeatedly applied to the same measurand under the same test conditions

Note 1 to entry: This definition specifically refers to the scope of this part of ISO 230 and the probing systems under test; it is not extended to the general definition associated with the metrological characteristics defined in other International Standards.

Note 2 to entry: Probing repeatability can be expressed quantitatively in terms of the dispersion characteristics of the measured values or by the range of measured values.

Note 3 to entry: Probing repeatability relates to the complete probing system. It is not comparable with “probe repeatability” as defined in the probe suppliers’ handbooks.

3.3.3 probing error

P_{FTU}

error within which the range of the radii of a reference artefact can be determined by a machine tool using one stylus system

Note 1 to entry: The symbol, P_{FTU} , is taken from ISO 10360-5:2010, 3.6 and 3.9. The character P indicates that the error is related primarily to the probing system performance, the character F indicates that it is a form error, the character T refers to a contacting (tactile) probing system and the character U indicates the use of a single (unique) stylus.

Note 2 to entry: A typical reference artefact for 2D probing is a ring calibrated for form. A typical reference artefact for 3D probing is a sphere calibrated for form.

Note 3 to entry: 2D probing error is addressed in 6.5 and 3D probing error is addressed in 6.6.

3.4 Terms relating to scanning probes (See Annex B)

3.4.1 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.

3.4.2

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).

3.4.3

probe over-travel limit

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

3.4.4

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.

3.4.5

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, including

- 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), and

— additional probe deflection caused by movement along the surface (e.g. friction, local surface normal deviations, surface finish).

3.4.6

stylus tip normal acceleration

acceleration of 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.

3.4.7

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 10360-1:2000, 2.12).

3.4.8

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

3.4.9

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 10360-1:2000, 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.

4 Preliminary remarks

4.1 Influences on the measurement performance of the probing system

Measurement performance of the probing system includes the machine tool characteristics over a limited, small volume and shall not be simply derived from the stand-alone probe specifications.

The main influences on performance of probing systems of a machine tool are the following:

- a) repeatability of machine tool;
- b) geometric accuracy of machine tool, i.e. positioning accuracy (including resolution, backlash), straightness, roll, pitch, yaw error motion, squareness between axes, etc.;
- c) contamination of surfaces being measured (detected);
- d) probing error and repeatability of probing system, including probing-tool changing and relocation;
- e) probing system qualification;
- f) temperature influences on machine tool, probing system, artefact and workpiece/tool, including drift of moving axes and spindles;
- g) feed speed and accelerations during measurement;
- h) standoff and overtravel distances;

- i) time delay and time delay variation between probing signal and read-out of machine tool position transducers;
- j) surface of workpiece/tool probed.

Workpiece probing repeatability shall be checked in accordance with the tests in 6.2; probing-tool location repeatability shall be checked in accordance with the test in 6.4; tool setting repeatability shall be checked in accordance with the tests in 7.3.

Testing for performance of workpiece probing system and geometric accuracy of the machine tool (in a limited, small volume) is given in 6.5 and 6.6.

Testing for time delay variation between probing signal and read-out of machine position transducers is given in 6.9; feature size measurement performance tests are given in 6.10.

Temperature influences are best observed using procedures given in 5.2 and in ISO 230-3.

4.2 Measurement units

In this part of ISO 230, all linear dimensions and deviations are expressed in millimetres. All angular dimensions are expressed in degrees. Angular deviations are, in principle, expressed in ratios but in some cases, microradians or arc-seconds may be used for clarification purposes. The following expression should be used for conversion of the units of angular deviations or tolerances:

$$0,010/1\ 000 = 10\ \mu\text{rad} \approx 2''$$

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4.3 Reference to ISO 230-1 (standards.iteh.ai)

To apply this part of ISO 230, reference should be made to ISO 230-1, especially for the installation of the machine before testing.

ISO 230-10:2016
<https://standards.iteh.ai/catalog/standards/sist/f0502f45-f8de-474c-b2f5-70f91ffb0b7f/iso-230-10-2016>

4.4 Recommended instrumentation and test equipment

The measuring instruments indicated in the tests described in the following clauses are examples only. Other instruments measuring the same quantities and having the same or smaller measurement uncertainty may be used. Linear displacement sensors shall have a resolution of 0,001 mm or better.

4.5 Machine conditions prior to testing

Before starting the measurements, the machine tool geometric performance shall be assessed in accordance with relevant International Standards (e.g. ISO 230-1, ISO 230-2, ISO 230-3, ISO 10791-1).

NOTE Appropriate national standards can apply.

In addition, the procedures for probe configuration and qualification shall be performed according to the conditions specified by the manufacturer/supplier.

4.6 Testing sequence

The sequence in which the tests are presented in this part of ISO 230 does not define the practical order of testing. The tests described in Clauses 5, 6 and 7 may be performed either singly or in any combination.

4.7 Tests to be performed

When testing a machine, it is neither always necessary nor possible to carry out all the tests described in this part of ISO 230. When the tests are required for acceptance purposes, it is up to the user to choose, in agreement with the manufacturer/supplier, those tests which are of interest. These tests shall be clearly stated when ordering a machine. Mere reference to this part of ISO 230 for the acceptance tests,