INTERNATIONAL STANDARD

ISO 230-10

Third edition

Test code for machine tools —

Part 10: Determination of the measuring performance of probing systems of numerically controlled machine tools

Code d'essai des machines-outils —

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

PROOF/ÉPREUVE

Reference number
ISO 230-10:2021(E)

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Published in Switzerland

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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 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 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

This third edition cancels and replaces the second edition (ISO 230-10:2016), which has been technically revised.

The main changes compared to the previous edition are as follows:

— The document scope has been revised to include specification in 7.2, 7.3 and 8.2;

— a definition for laser light barrier principle is added in 3.2.12;

— Figures 1, 4, 6 and 7 have been revised;

— Symbols of variables in Formulae (3) and (4) have been changed to be consistent with symbols in 8.2.8.4.1;

— a new subclause 7.3 on "Determination of the performance of bore gauge systems" has been added.

— a new subclause 8.2 on "Non-contacting laser light barrier tool measuring systems" has been added.

A list of all parts in the ISO 230 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

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

This document specifies test procedures to evaluate the measuring performance of contacting and non-contacting probing systems integrated with CNC machine tools. 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 the tests that are of interest, in agreement with the manufacturer/supplier.

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 based on methods of ISO 10360-2 and ISO 10360-5.

Test procedures to measure performance with touch trigger probes are given in 7.1 and 8.1, scanning probes in 7.2, bore gauge systems in 7.3. and with non-contacting tool measuring systems applying laser light barrier principle in 8.2.

Numerically controlled machine tools can apply 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,

— dimensional measurement of the workpiece after machining, but while still on the machine tool,

— 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.

Test code for machine tools —

Part 10:
Determination of the measuring performance of probing systems of numerically controlled machine tools

1 Scope

This document specifies test procedures to evaluate the measuring performance of probing systems integrated with a numerically controlled machine tool. Test procedures for touch trigger probing systems and scanning probing systems operating in discrete-point measurement mode are specified in 7.1. Test procedures are specified for scanning probing systems in 7.2, for bore gauge systems in 7.3, for contacting tool measuring systems in 8.1, and for non-contacting tool measuring systems using the laser light barrier principle in 8.2.

The evaluation of the performance of the machine tool, used as a coordinate measuring machine (CMM), is outside the scope of this document. 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 document, be evaluated according to ISO 10360-2 and ISO 10360-5.

Descriptions of test procedures in this document are referred to machining centres. However, tests apply in principle to most NC machine tools.

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 230-1:2012, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions*

ISO 230-3:2020, *Test code for machine tools — Part 3: Determination of thermal effects*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

NOTE In measuring mode, machine tools are used like CMMs. Therefore, definitions for probing systems performance tests for CMMs apply also to machine tools. However, since not all machine tool users are familiar with the use of CMMs, this document 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, reference to "machine tool" instead of "machine coordinate system".]

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

3.2 Terms relating to the probing system

3.2.1
probe
device that senses a surface and generates the signal(s) during probing

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 can be available as either "contacting" or "non-contacting" systems.

[SOURCE: ISO 10360-1:2000, 3.1 — modified, Note 1 to entry and Note 2 to entry have been added.]

3.2.1.1
contacting probe
probe (3.2.1) that needs material contact with a surface being measured (detected) in order to function

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/supplier 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.

Note 3 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) operation in the + Z direction.

Note 4 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 1, 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.

3.2.1.2
non-contacting probe
probe (3.2.1) that needs no material contact with a surface being measured in order to function

EXAMPLE Optical and laser systems, inductive and capacitive systems.

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Note 1 to entry: In this document, only laser light barrier systems as a non-contacting probing system is included.

3.2.1.3
switching probe
touch trigger probe
probe (3.2.1) that gives a binary signal as a result of detection of a surface

3.2.1.4
laser light barrier principle
principle utilising a laser light transmitter and an opto-electronic receiver to detect light interruption for performing non-contacting measurement tasks

3.2.2
probing
to probe
measurement action that results in the determination of values (e.g., coordinate values, length values, false/true values)

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

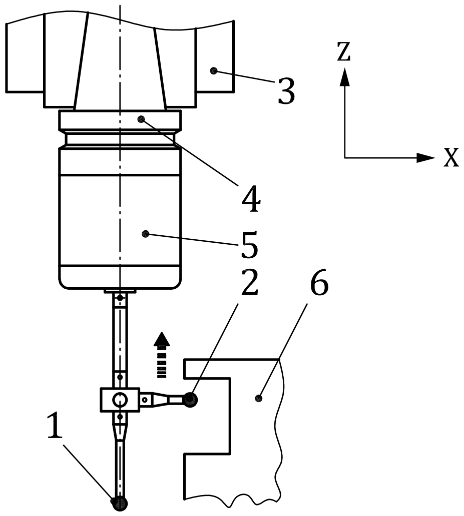
Note 2 to entry: Probing associated with tool breakage detection results in the determination of a false/true state.

[SOURCE: ISO 10360-1:2000, 2.7 — modified, definition has been partly modified by explaining "values", Note 1 to entry and Note 2 to entry have been added.]

3.2.2.1
1D probing
measurement allowing only for probing motion parallel to one machine coordinate system axis or to one workpiece coordinate system axis

3.2.2.2
2D probing
measurement allowing for probing motion along a vector in a plane

Note 1 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

Figure 1 — Probing-tool equipped with 2 styli

3.2.2.3
3D probing
measurement allowing for probing motion along any vector in space

3.2.3
probing system
system consisting of a *probe* (3.2.1), *contacting probe* (3.2.1.1) or *non-contacting probe* (3.2.1.2), 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

Note 1 to entry: Some of the tests specified in this document 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 1), 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.

[SOURCE: ISO 10360-1:2000, 2.6 — modified, Note 1 to entry has been added.]

3.2.4
probing system qualification
establishment of the parameters of a probing system (based on manufacturer/supplier instructions) necessary for subsequent measurements

Note 1 to entry: *Effective stylus tip diameter* (3.2.6) and location of the stylus tip centre with respect to spindle axis average line 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.

[SOURCE: ISO 10360-1:2000, 3.7 — modified, Note 1 to entry and Note 2 to entry have been added.]

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3.2.5
pre-travel
distance between the point of first material contact of the probe stylus tip with the surface being 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.

3.2.6
effective stylus tip diameter
effective stylus tip size
stylus tip dimension used by some probing software to determine feature size from the measurement data

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.

3.2.7
stylus tip
physical element that establishes the contact with the object to measure

[SOURCE: ISO 10360-1:2000, 4.2 — modified, "workpiece" replaced with "object to measure".]

3.2.8
stylus system
system composed of a stylus and stylus extension(s) (if any)

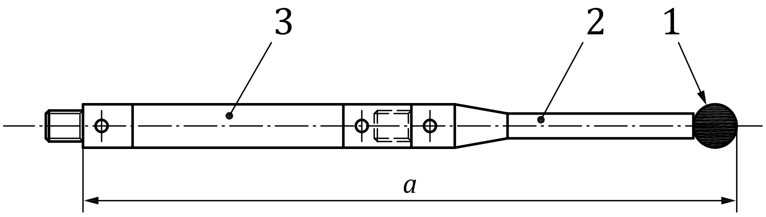
[SOURCE: ISO 10360-1:2000, 4.4 — modified, Note 1 to entry has been added.]

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.

3.2.9
stylus system length
<spherical stylus tip> distance from the centre of the stylus tip to the feature interfacing with the probe of the *stylus system* (3.2.8)

Note 1 to entry: See Figure 2.

Note 2 to entry: Some *probing systems* (3.2.3) establish the stylus system length as the distance from the centre of the stylus tip and others from the most protruding point of the stylus tip.



Key

1 stylus tip (3.2.7)

2 stylus

3 stylus extension (3.2.9)

a stylus system length

Figure 2 — Stylus system length

3.2.10
probing-tool
device consisting of a probe and its *stylus system* (3.2.8), attached to a tool holder

Note 1 to entry: See Figure 2.

3.2.11
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* (3.2.10)

Note 1 to entry: See Figure 3.

Note 2 to entry: Some probing systems establish the probing-tool length as the distance from the centre of the stylus tip to the machine tool spindle reference surface that connects to the probing-tool and others from the most protruding point of the stylus tip 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: Typically, the probing system is handled by the machine controller as a tool, therefore, the overall length is considered.

Note 5 to entry: The procedure for establishing the length of the probing-tool is specified in manufacturer/supplier instructions.

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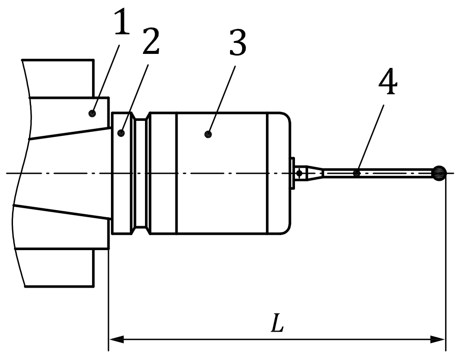

Key

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

Figure 3 — Probing-tool length

3.2.12
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

Note 1 to entry: Test for stylus tip offset see 7.1.3.

3.3 Terms relating to probing performance

3.3.1
probing repeatability
degree of closeness of coordinate values provided by the probing system when it is repeatedly applied to the same measurand of the feature such as surface location, circle or sphere centre under the same test conditions

Note 1 to entry: This definition specifically refers to the scope of this document 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.

3.3.2
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* (3.2.8)

Note 1 to entry: In the symbol, P_{FTU}, 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, $P_{FTU,2D}$, is addressed in 7.1.5 and 3D probing error, $P_{FTU, 3D}$, is addressed in 7.1.6.

Note 4 to entry: 2D probing error $P_{FTU,2D}$ is named $P_{Form.Cir.1x36:SS:Tact}$ in ISO 10360-5:2020, and 3D probing error $P_{FTU,3D}$ is named $P_{Form.Sph.1x25:SSTact}$ in ISO 10360-5:2020.

3.4 Terms relating to scanning probes

3.4.1
scanning measurement range
maximum allowed distance between the *nominal scan line* (3.4.3) 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. ± 0,3 mm in X and Y, ± 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).

3.4.2
tip centre point
tip centre
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).

3.4.3
target scan line
nominal scan line
line along which target contact points lie

[SOURCE: ISO 10360-1:2000, 7.2]

3.4.4
pre-defined path scanning
method of scanning in which the motion of the probing system between two defined points is directed by a target scan line

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.

[SOURCE: ISO 10360-1:2000, 7.5, modified — Note has been deleted and Note 1 to entry has been added.]

3.4.5
discrete-point measurement
measurement of a single point on a surface using the analogue measurement capability of a scanning probe, where the nominal motion of the probe is normal to the surface being measured

4 Symbols

For the purposes of this document, the following symbols apply.

D	reference ring diameter or reference sphere diameter
$D_{SC,\ 2D}$	diameter of circle measurement for 2D scanning test (ring)
$D_{SC,\ 3D}$	diameter of circle measurement for 3D scanning test (sphere)

E	minimum expected measurement repeatability
$E_{CIR,D}$	size error for circle diameter measurement
$E_{CIR,TD,F}$	range of measured circle form error for time delay variation test
$E_{CIR,TD,F,MAX}$	maximum measured circle form error for time delay variation test
$E_{CIR,TD,D}$	time delay variation error for the circle diameter measurement
$E_{CIR,TD,X}$	X-axis circle centre location error for time delay variation test
$E_{CIR,TD,Y}$	Y-axis circle centre location error for time delay variation test
$E_{CML,X}$	X-axis combined machining and location error
$E_{CML,Y}$	Y-axis combined machining and location error
$E_{CML,Z}$	Z-axis combined machining and location error
$E_{COR,X}$	X-axis error for corner location
$E_{COR,Y}$	Y-axis error for corner location
$E_{COR,Z}$	Z-axis error for corner location
$E_{LIN,Y}$	WCS orientation in the reference plane identification error in the Y-axis direction
$E_{SC,2D,DIA}$	diameter error for 2D scanning test
$E_{SC,2D,FORM}$	form error for 2D scanning test
$E_{SC,2D,POS}$	positional reproducibility for 2D scanning test
$E_{SC,3D,DIA}$	diameter error for 3D scanning test
$E_{SC,3D,POS}$	positional reproducibility for 3D scanning test
$E_{SC,3D,FORM}$	form error for 3D scanning test
$E_{SPH,D}$	size error for sphere diameter measurement
$E_{SPH,TD,F}$	range of measured sphere form error for time delay variation test
$E_{SPH,TD,F,MAX}$	maximum measured sphere form error for time delay variation test
$E_{SPH,TD,D}$	error of sphere diameter measurement for time delay variation test
$E_{SPH,TD,X}$	X-axis sphere centre location error for time delay variation test
$E_{SPH,TD,Y}$	Y-axis sphere centre location error for time delay variation test
$E_{SPH,TD,Z}$	Z-axis sphere centre location error for time delay variation test
$E_{SPT,TD,X}$	X-axis error for single axis time delay variation test
$E_{SPT,TD,Y}$	Y-axis error for single axis time delay variation test
$E_{SPT,TD,Z}$	Z-axis error for single axis time delay variation test
$E_{PLA,Z}$	WCS reference plane identification error in Z-axis direction

