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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

Reference number
ISO/FDIS 230-10:2015(E)

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

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 amendments 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.

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

ISO/TR 230-9, *Test code for machine tools — Part 9: Estimation of measurement uncertainty for machine tool tests according to series ISO 230, basic equations*

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.]

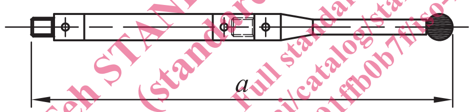
3.2.7
stylus system
system composed of a stylus and stylus extension(s) (if any)

[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.

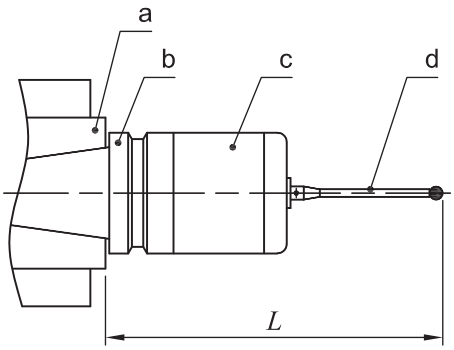
3.2.10
probing-tool length
distance from the most protruding point of the stylus tip to the machine tool spindle reference surface or gauge line that connects to the probing tool

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

a spindle

b tool holder

c probe

d 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

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

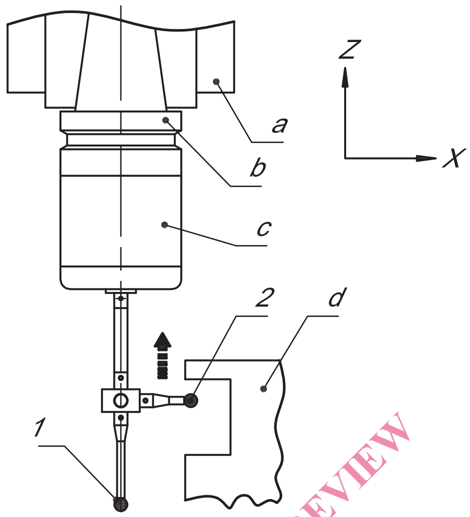
Note 1 to entry: 1D measurement capability is associated with the probing system performance, not only with the contacting probe capabilities.

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 −X 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

a spindle

b tool holder

c probe

d workpiece

1 stylus tip 1

2 stylus tip 2

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 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. ± 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