
**Test conditions for numerically
controlled turning machines and
turning centres —**

**Part 2:
Geometric tests for machines with a
vertical workholding spindle**

*Conditions d'essai des tours à commande numérique et des centres de
tournage —*

*Partie 2: Essais géométriques pour les machines à broche porte-pièce
verticale*



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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 World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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 13041-2:2008), which has been technically revised.

A list of all parts in the ISO series can be found on the ISO website.

In addition to text written in the official ISO languages (English, French and Russian), this document gives text in German, Italian, Japanese and Persian (see [Annex B](#)). This text is published under the responsibility of the member bodies for Germany (DIN), Italy (UNI), Japan (JISC) and Iran (ISIRI) and is given for information only. Only the text given in the official languages can be considered as ISO text.

Introduction

A turning centre is a machine tool in which the principal movement is the rotation of the workpiece against the stationary cutting tool(s). It is a numerically controlled machine tool capable of performing multiple machining operations, including milling, turning, boring, drilling and tapping, as well as automatic tool changing from a magazine or similar storage unit in accordance with a machining program.

The objective of ISO 13041 (all parts) is to provide information as wide and comprehensive as possible on geometric, positional, contouring, thermal and machining tests which can be carried out for comparison, acceptance, maintenance or any other purpose.

ISO 13041 (all parts) specifies, with reference to ISO 230-1 and ISO 230-7, tests for turning centres and numerically controlled turning machines with/without tailstocks standing alone or integrated in flexible manufacturing systems. ISO 13041 also establishes the tolerances or maximum acceptable values for the test results corresponding to general-purpose and normal-accuracy turning centres and numerically controlled turning machines.

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Test conditions for numerically controlled turning machines and turning centres —

Part 2: Geometric tests for machines with a vertical workholding spindle

1 Scope

This document specifies, with reference to ISO 230-1 and ISO 230-7, the geometric tests for general-purpose, numerically controlled (NC) turning machines and turning centres with vertical workholding spindles, as well as the corresponding applicable tolerances.

This document explains different concepts or configurations and common features of NC turning machines and turning centres with vertical workholding spindles. It also provides a terminology and designation of controlled axes (see [Figures 1, 2, 3, and 4](#)).

This document deals only with the verification of the accuracy of the machine. It does not apply to the operational testing of the machine (e.g. vibration, abnormal noise, stick slip motion of components) nor to machine characteristics (e.g. speeds, feeds). Tests not concerning the pure geometric accuracy of the machine are dealt with in other parts of ISO 13041.

2 Normative references

The following documents are referred to in 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 230-7:2015, *Test code for machine tools — Part 7: Geometric accuracy of axes of rotation*

ISO 841:2001, *Industrial automation systems and integration — Numerical control of machines — Coordinate system and motion nomenclature*

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 <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

turning machine

machine tool in which the principal movement is the rotation of the workpiece against the stationary cutting tool(s)

3.2
numerical control
NC

computerized numerical
CNC

automatic control of a process performed by a device that makes use of numerical data introduced while the operation is in progress

[SOURCE: ISO 2806:1994, 2.1.1 and 2.1.2, modified]

3.3
numerically controlled turning machine
NC turning machine

turning machine (3.1) that operates under *numerical control* or *computerized numerical control* (3.2)

3.4
numerically controlled vertical spindle-turning machine

numerically controlled turning machine (3.3) where the workpiece is mounted on a vertical workholding spindle against the stationary cutting tool(s) and where cutting energy is brought by the workpiece and not by the tool

Note 1 to entry: This machine is controlled by numerical control (NC) providing automatic function.

Note 2 to entry: For vertical spindle-turning machines with inverted workholding spindle, i.e. with workholding device at the lower end of the spindle, see ISO 13041-3.

3.5
vertical spindle-turning centre

numerically controlled vertical spindle-turning machine (3.4) equipped with toolholding spindles and the capacity to orientate the workholding spindle around its axis

Note 1 to entry: Such a machine can perform several operations such as milling, tapping, drilling, and others by power driven tools nested in live spindles.

Note 2 to entry: This machine may include additional features such as automatic tool changing from a magazine or Y-axis motion.

Note 3 to entry: For vertical spindle-turning machines with inverted workholding spindle, i.e. with workholding device at the lower end of the spindle, see ISO 13041-3.

4 Preliminary remarks

4.1 Measurement units

In this document, all linear dimensions, deviations, and corresponding tolerances are expressed in millimetres, angular dimensions are expressed in degrees, and angular deviations and the corresponding tolerance are expressed in ratios; but in some cases, micro-radians or arc seconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind.

$$0,010/1\ 000 = 10 \times 10^{-6} = 10 \mu\text{rad} \approx 2''$$

4.2 Reference to ISO 230-1 and ISO 230-7

To apply this document, reference shall be made to ISO 230-1, especially for installation of the machine before testing, warming up of the spindle and moving components, description of measuring methods and recommended instrument uncertainty of testing equipment.

In the “Observation” block of the tests described in [Clause 5](#), the instructions are preceded by a reference to the corresponding clause in ISO 230-1:2012 or in ISO 230-7:2015 in cases where the test concerned is in compliance with their specifications. Tolerances are given for each test (see G1 to G20, R1 and R2).

4.3 Machine levelling

Prior to conducting tests on a machine, the machine should be levelled according to the recommendations of the supplier/manufacturer (see ISO 230-1:2012, 6.1.2).

4.4 Test sequence

The sequence in which tests are presented in this document in no way defines the practical order of testing. In order to make the mounting of instruments or gauging easier, tests may be performed in any order.

4.5 Test to be performed

When testing a machine, it is not always necessary or possible to carry out all the tests described in this document. When the tests are required for acceptance purposes, it is up to the user to choose, in agreement with the supplier/manufacturer, those tests relating to the components and/or the properties of the machine which are of interest. These tests are to be clearly stated when ordering a machine. Mere reference to this document for the acceptance tests, without specifying the tests to be carried out, and without agreement on the relevant expenses, cannot be considered as binding for any contracting party (see also ISO 230-1:2012, Annex A).

4.6 Measuring instruments

Measuring instruments indicated in the tests described in the following sections are examples only. Other instruments capable of measuring the same quantities and having the same, or a smaller, measurement uncertainty may be used. Reference shall be made to ISO 230-1:2012, Clause 5, that indicates the relationship between measurement uncertainties and the tolerances.

When a “dial gauge” is referred to, it can mean not only dial test indicators (DTI) but any type of linear displacement sensor such as analogue or digital dial gauges, linear variable differential transformer (LVDTs), linear scale displacement gauges, or non-contact sensors, when applicable to the test concerned (see ISO 230-1:2012, Clause 4).

Similarly, when a “straightedge” is referred to, it can mean any type of straightness reference artefact, such as a granite or ceramic or steel or cast iron straightedge, one arm of a square, one generating line on a cylinder square, any straight path on a reference cube, or a special, dedicated artefact manufactured to fit in the T-slots or other references.

In the same way, when a “square” is mentioned, it can mean any type of squareness reference artefact, such as a granite or ceramic or steel or cast iron square, a cylinder square, a reference cube, or, again, a special, dedicated artefact.

4.7 Diagrams

In this document, for reasons of simplicity, the diagrams associated with geometric tests generally illustrate only one type of machine.

4.8 Software compensation

When built-in software facilities are available for compensating certain geometric deviations, their use during these tests for acceptance purposes shall be based on an agreement between the user and the manufacturer/supplier, with due consideration of the machine tool intended use. When software compensation is used, this shall be stated in the test report. It shall be noted that when software compensation is used, axes shall not be locked for test purposes (see ISO/TR 16907).

4.9 Gravity influence for two railhead machines

For machine tools provided with two slides on the cross rail [see [Figures 2](#) a) and b) and [Figure 4](#)], the railhead not under test shall be in a defined park position according to the manufacturer's recommendation. If both railheads are used, the deviations may change due to gravity influences.

4.10 Tolerances

In this document, all tolerance values (see in ISO 230-1:2012, 4.1) are guidelines. When they are used for acceptance purposes, other values can be agreed upon between the user and the manufacturer/supplier. The required/agreed tolerance values are to be clearly stated when ordering the machine.

When the tolerance for a geometric test is established for a measuring length different from that given in this document (see ISO 230-1:2012, 4.1), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

4.11 Machine classifications

The machines considered in this document are divided into the following basic configurations:

- Type A: single-column machines ([Figure 1](#)); related nomenclature is given in [Table 1](#) and [Figure 3](#).
- Type B: double-column machines ([Figure 2](#)); related nomenclature is given in [Table 2](#) and [Figure 4](#).

Type B machine configurations are further classified into the following types:

- fixed columns — portal type;
- moving columns — gantry type.

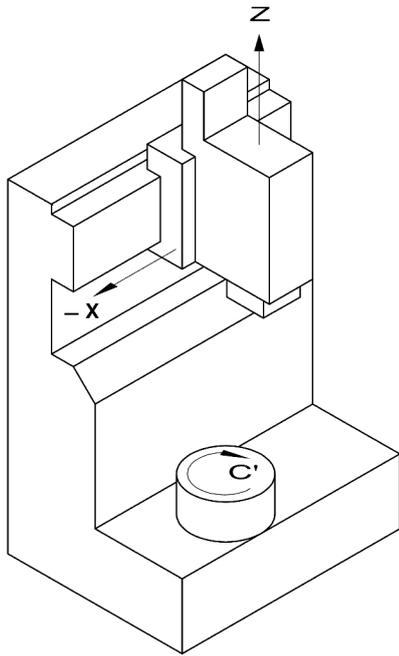
4.12 Linear motions

For simplicity, all the machine examples shown in [Figures 1](#) and [2](#) use the axis designation of a letter and a number (e.g. X, X1, X2,...) as defined in ISO 841:2001, 6.1. In all examples, the use of the letters U, V, or W could be substituted.

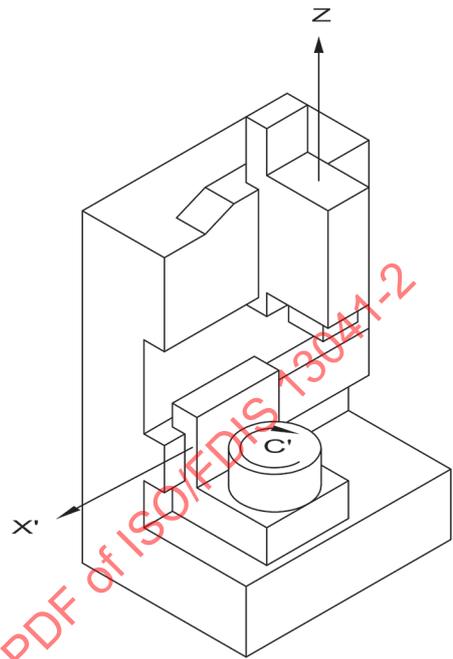
4.13 Turrets or toolholding components (element)

Depending on the machine configuration, cutting tools (stationary or power driven) can be clamped in a tool holder or in a turret located on the railhead ram and/or the side head ram and/or the turret. An automatic tool change device can also be used. However, this document does not provide any test methods for automatic tool change operations.

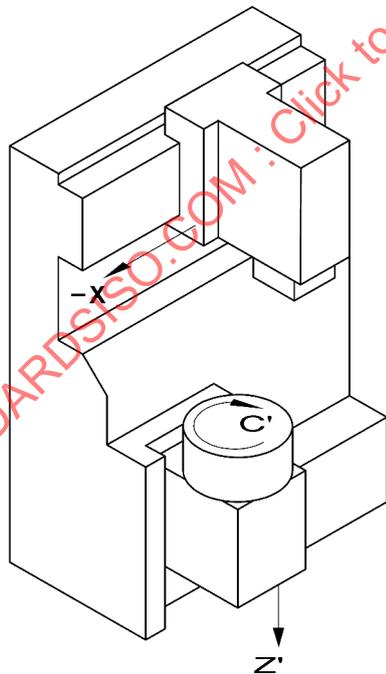
4.14 Machine configurations and designation of axes



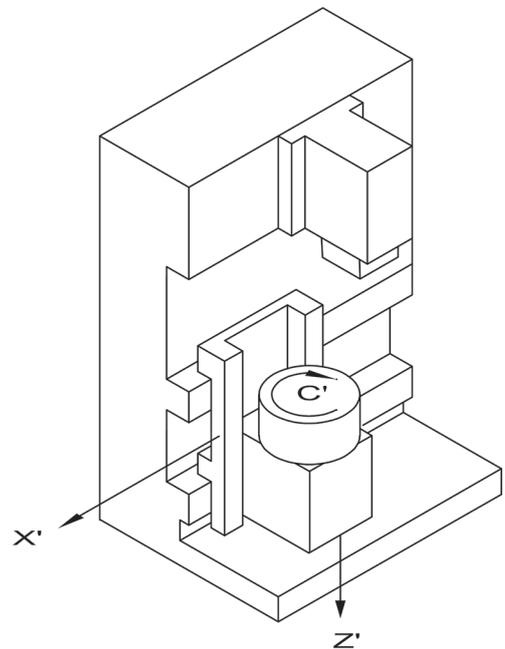
a) Compound head type
[t Z X b C' w]



b) Shared motion
(moving workholding spindle) type
[t Z b X' C' w]

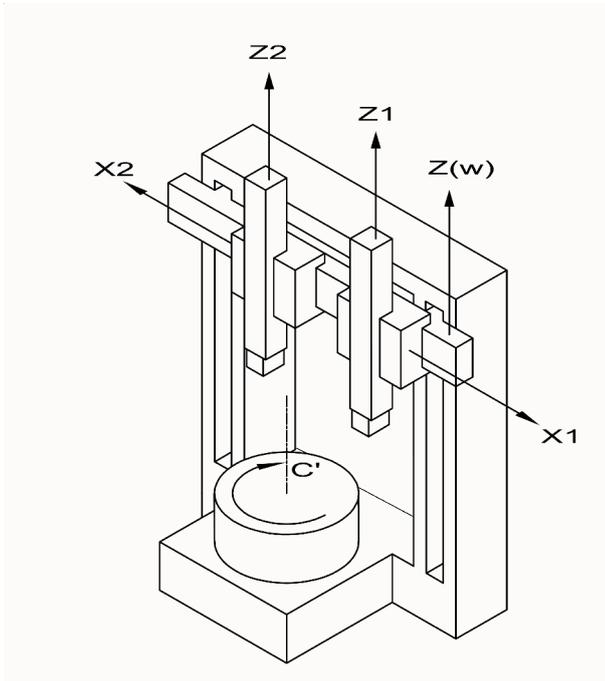


c) Shared motion
(moving head/saddle) type
[t X b Z' C' w]

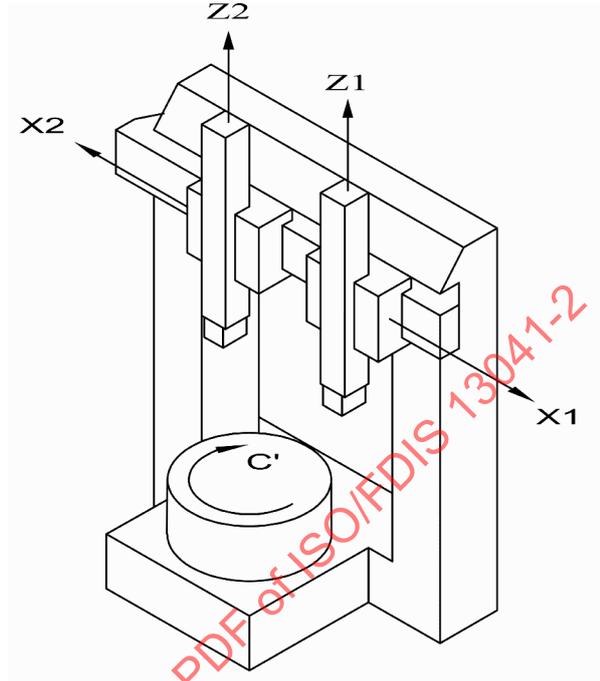


d) Compound workholding
spindle type
[t b X' Z' C' w]

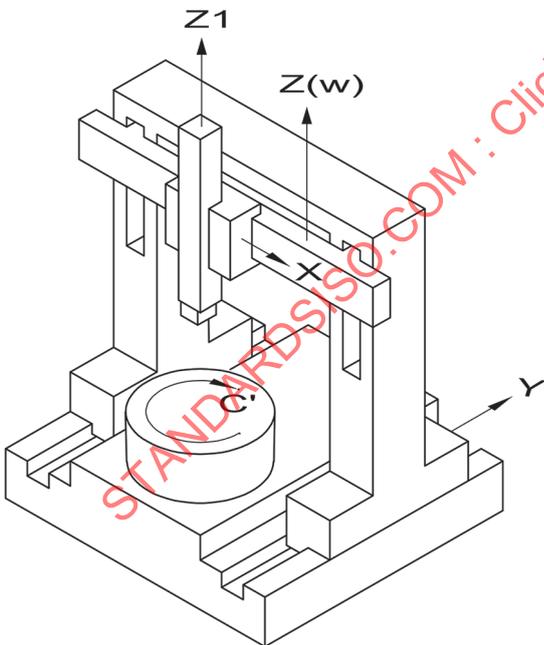
Figure 1 — Examples of machine configurations: Single-column machines (Type A)



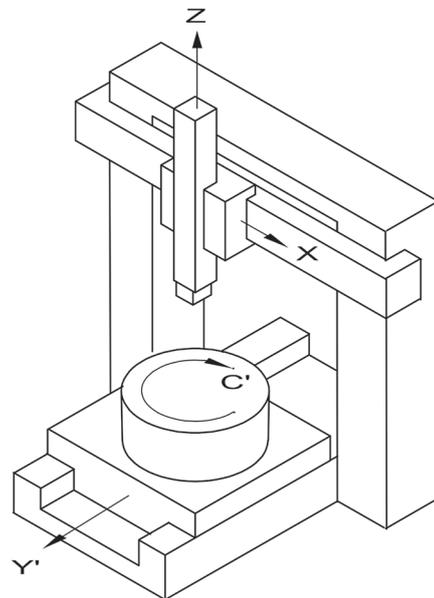
a) Fixed column, moving cross-rail
 $[t_1 Z1 X1 Z b C' w]$
 $[t_2 Z2 X2 Z b C' w]$



b) Fixed column, fixed cross-rail
 $[t_1 Z1 X1 b C' w]$
 $[t_2 Z2 X2 b C' w]$

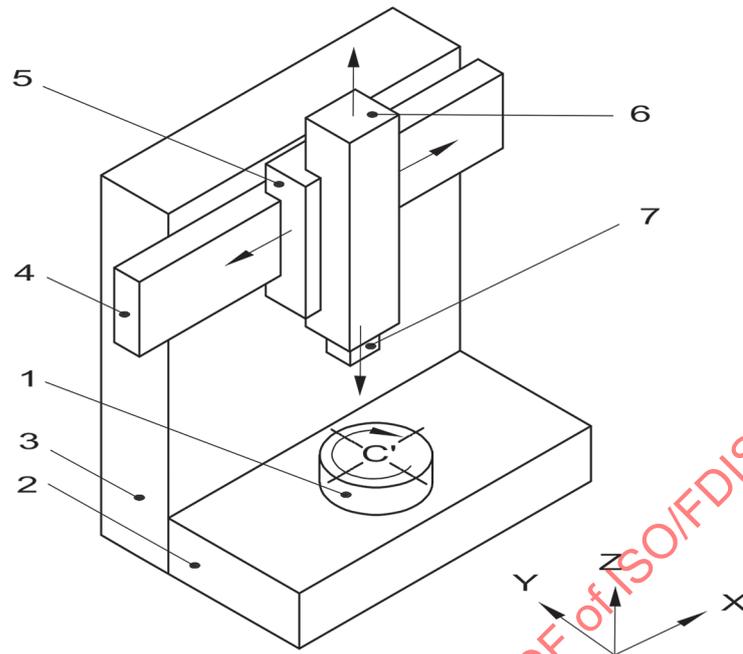


c) Moving column (gantry type), moving cross-rail
 $[t Z1 X Z Y b C' w]$



d) Fixed column (portal type), moving workholding spindle (Y-axis)
 $[t Z X b Y' C' w]$

Figure 2 — Examples of machine configurations: Double-column machines (Type B)



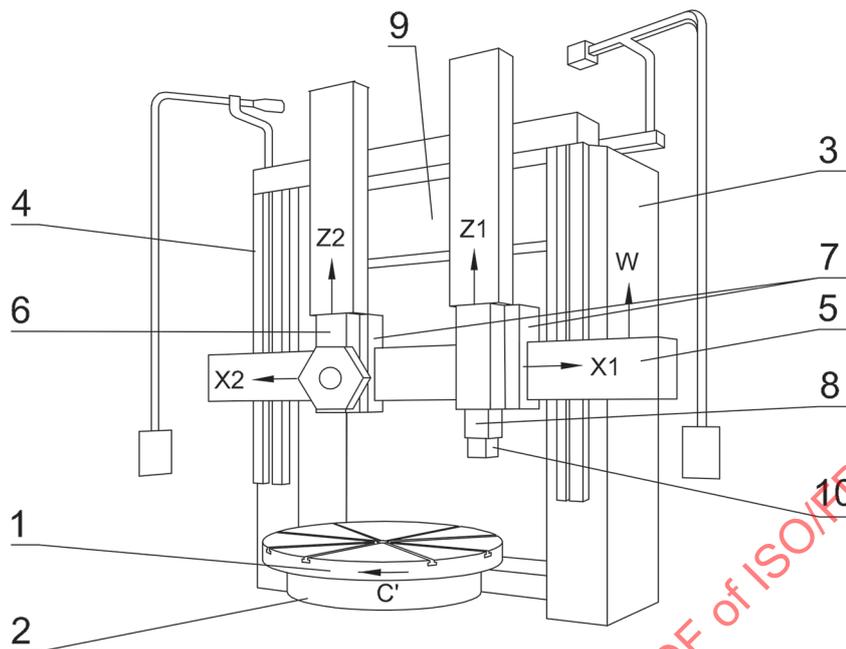
NOTE See [Table 1](#) for the key.

Figure 3 — Single-column machines [t Z X b C' w]

Table 1 — Terminology corresponding to [Figure 3](#)

Item number	Designation	Description of item	
		English	French
1	C'	Workholding spindle (turntable)	Plateau tournant
2		Base	Base
3		Column	Montant
4		Cross-rail	Traverse porte-chariot
5	X	Railhead (saddle)	Coulant du chariot de traverse (traînard)
6	Z	Tool holder slide	Chariot de tourelle
7		Tool holder	Porte-outils

NOTE For languages other than official ISO languages, see [Table B.1](#).



NOTE See [Table 2](#) for the key.

Figure 4 — Double-column machines [t₁ Z1 X1 Z b C'w]/[t₂ Z2 X2 Z b C' w]

Table 2 — Terminology corresponding to [Figure 4](#)

Item number	Designation	Description of item	
		English	French
1	C'	Workholding spindle (turntable)	Brouche (plateau) tournant
2		Base	Base
3		Right-hand column	Montant droit
4		Left-hand column	Montant gauche
5	Z(W)	Cross-rail	Traverse
6	Z1	Railhead ram	Coulisseau du chariot de traverse
7	X1, X2	Railhead (saddle)	Chariot de traverse (traînard)
8	Z2	Railhead ram	Coulisseau du chariot de traverse
9		Bridge	Entretoise
10		Tool holder	Porte-outils

NOTE For languages other than official ISO languages, see [Table B.2](#).

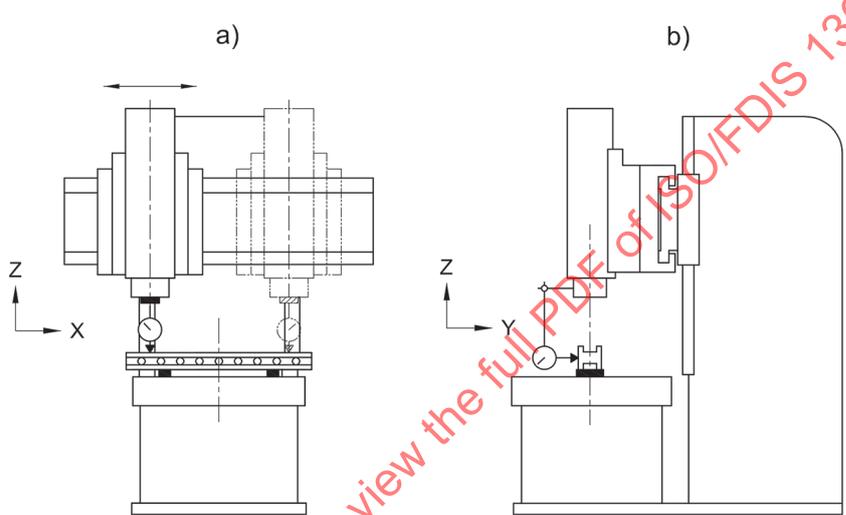
5 Geometric tests

5.1 Workholding spindle or table

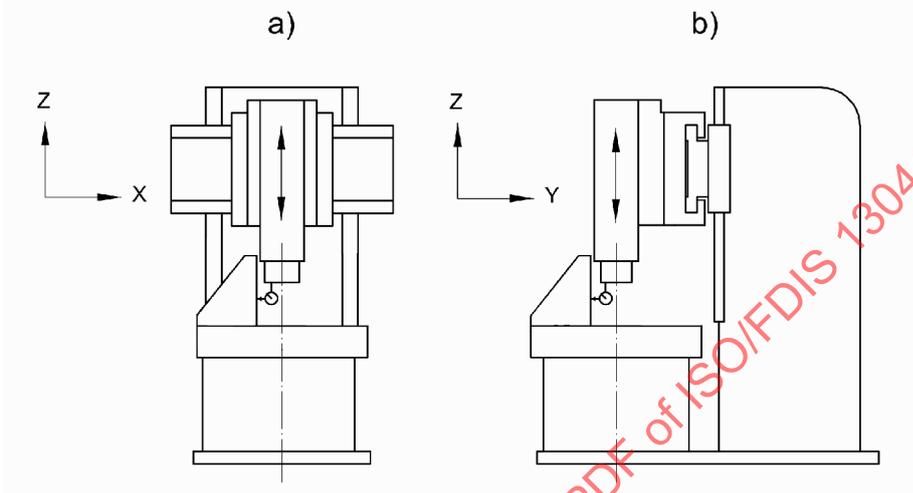
Object		G1
Checking of the face run-out of workholding table or spindle a) face run-out of the workholding table surface; b) face run-out of the spindle face.		
Diagram		
Tolerance		Measured deviation
a) For diameters up to 1 000 mm:	0,010	a)
For every further increase of up to 1 000 mm diameter:	+0,010	
b) For all diameters:	0,010	b)
Measuring instruments		
a) and b) Linear displacement sensor		
Observations and references to ISO 230-1:2012, 9.1		
a) The dial gauge shall be placed on a component of the machine tool carrying the tool and shall be placed as near as possible to the workholding table periphery and approximately 180° from the position occupied by the tool when the workholding table was machined <i>in situ</i> (see also Test R1). Cross-rail and railhead locked in position, where possible.		
b) The dial gauge measurements shall be taken on the maximum diameter of the spindle face.		

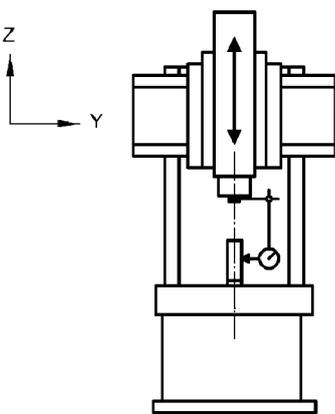
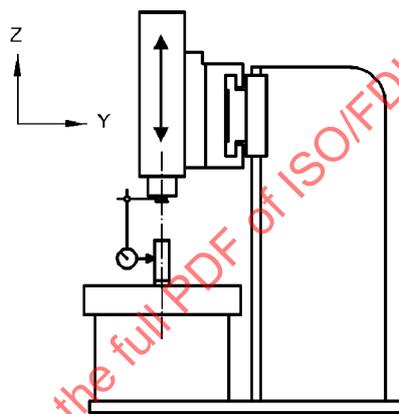
Object		G2
Checking of run-out of a) the workholding table bore; b) the external cylindrical surface of the workholding table (in the case of a workholding table not having a central bore); c) centring diameter of the workholding spindle.		
Diagram		
Tolerance		Measured deviation
a) For workholding spindle diameter up to 1 000 mm:	0,010	a)
For workholding spindle diameter greater than 1 000 mm:	max 0,020	
b) For diameter up to 1 000 mm:	0,010	b)
For every further increase of up to 1 000 mm diameter:	+0,010	
c) For all centering diameter sizes:	0,010	c)
Measuring instruments		
Linear displacement sensor		
Observations and references to ISO 230-1:2012, 12.5		
a) and b) The dial gauge shall be placed approximately 180° from the position occupied by the tool when the workholding table was machined. Cross-rail, railhead and slide locked in position, where possible. The dial gauge should be placed on the tool holder close to the tool position.		
c) See ISO 230-1:2012, 12.5.2. When the surface is conical, the stylus of the dial gauge shall be normal to the contacting surface.		

5.2 Linear axes X and Z

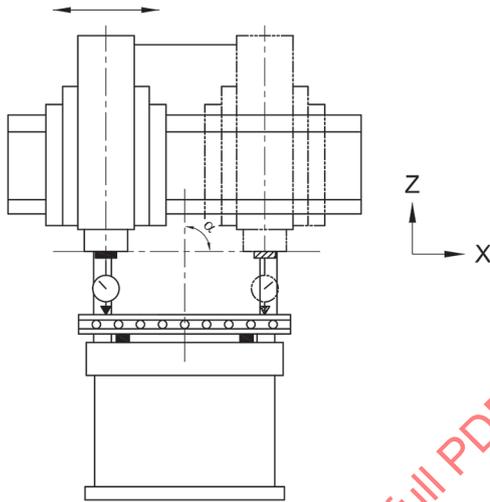
<p>Object</p> <p>Checking of the straightness of the railhead (X-axis) motion on the cross-rail</p> <p>a) in the vertical ZX plane (E_{ZX});</p> <p>b) in the horizontal XY plane (E_{YX}).</p> <p>NOTE Test setup shown in b) is for turning centres only.</p>	G3
<p>Diagram</p> 	
<p>Tolerance</p> <p>For a) and b)</p> <p>0,020 for measuring length of 1 000 mm</p> <p>Add 0,010 for each additional length of 500 mm</p> <p>Local tolerance: 0,010 for any measuring length of 500 mm</p>	<p>Measured deviation</p> <p>a)</p> <p>b)</p>
<p>Measuring instruments</p> <p>a) Straightness reference artefact, adjustable blocks and linear displacement sensor or optical equipment</p> <p>b) Straightness reference artefact, adjustable blocks and linear displacement sensor or optical equipment or taut wire and microscope</p>	
<p>Observations and references to ISO 230-1:2012, 8.2</p> <p>If the column or workholding spindle (table) is movable in the Y-axis direction, it shall be positioned such that the measuring line should be close to the workholding spindle axis of rotation.</p> <p>Position the railhead ram in the middle position of its travel. The straightedge shall be placed on the workholding spindle or table perpendicular to the C-axis, or the lack of squareness shall be considered in the measurement.</p> <p>The dial gauge, the interferometer, the target or the microscope shall be mounted on the railhead near the position of a tool.</p> <p>Alternatively, when the straightedge is not aligned mechanically, the results can be evaluated according to ISO 230-1:2012, 3.4.8.</p>	

<p>Object</p> <p>Checking of the angular deviations of the railhead motion on the cross-rail (X-axis)</p> <p>a) in the ZX plane E_{BX} (pitch);</p> <p>b) in the YZ plane E_{AX} (roll);</p> <p>c) in the XY plane E_{CX} (yaw).</p>		<p>G4</p>
<p>Diagram</p>		
<p>Key</p> <p>1 measuring level 3 autocollimator</p> <p>2 reference level 4 mirror</p>		
<p>Tolerance</p> <p>For a), b), and c).</p> <p>For measuring length up to 1 600 mm: 0,040/1 000 (40 μrad)</p> <p>For measuring length over 1 600 mm: 0,060/1 000 (60 μrad)</p>		<p>Measured deviation</p> <p>a)</p> <p>b)</p> <p>c)</p>
<p>Measuring instruments</p> <p>a) Precision level, or optical angular deviation measuring instrument</p> <p>b) Precision level</p> <p>c) Optical angular deviation measuring instrument</p>		
<p>Observations and references to ISO 230-1:2012, 3.4.16, 8.4</p> <p>The measuring level or instrument shall be placed on the tool holder.</p> <p>a) (E_{BX}: pitch) level, or optical instrument oriented in the ZX plane (set vertically);</p> <p>b) (E_{AX}: roll) level oriented in the YZ plane;</p> <p>c) (E_{CX}: yaw) optical instrument oriented in the XY plane (set horizontally);</p> <p>When railhead motion causes an angular deviation of both railhead and workholding spindle or table, differential measurements of the two angular deviations shall be made and this shall be stated.</p> <p>The reference level shall be placed on the workholding spindle or table.</p> <p>Measurements shall be carried out at a minimum of five positions equally spaced along the path of travel in both directions of the movement.</p>		

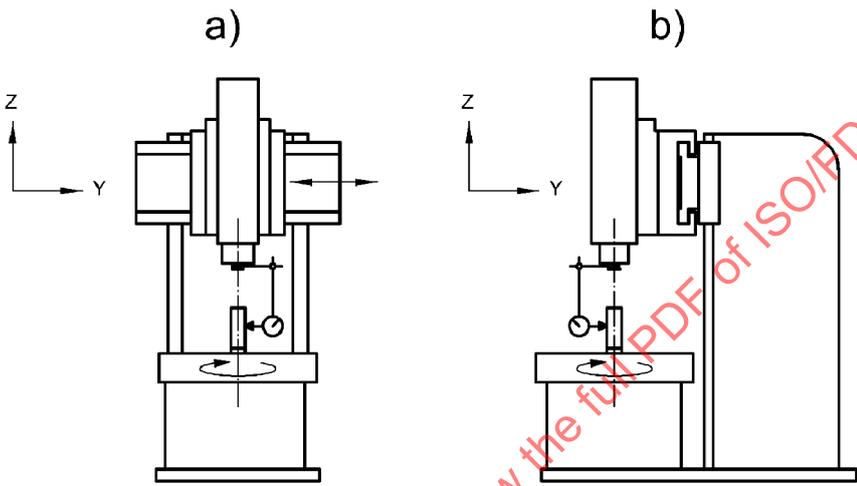
Object	G5
Checking of the straightness of motion of the toolholder-slide (ram) in the Z-axis direction a) in the XZ plane (E_{xz}); b) in the YZ plane (E_{yz}).	
Diagram 	
Tolerance For a) and b) 0,020 for a measuring length of 300 mm	Measured deviation a) b)
Measuring instruments a) and b) Square and linear displacement sensor Alternative: Sweeping alignment laser device, optical equipment, NOTE As an alternative to this test setup, see test G5 Alternative using a cylindrical square.	
Observations and references to ISO 230-1:2012, 8.2 Vertical slide over the centre of the table. Place a square in radial direction on the table, with the horizontal arm parallel to the X-axis, on one side of the vertical slide, in such a way that the table can rotate 90° to bring the square from the ZX plane to the YZ plane without interference with the vertical slide. The square does not need to be aligned with the C-axis. Take readings from the dial gauge at several positions along the Z-axis. If this test is to be combined with test G8, place the square in such a position as to allow the table to be rotated to four positions at 90° from each other. This test setup is also applicable to the tests G8, G9 and G11.	

<p>Object</p> <p>Checking of the straightness of motion of the toolholder-slide (ram) in the Z-axis direction.</p> <p>a) in the XZ plane (E_{xz}) ;</p> <p>b) in the YZ plane (E_{yz}).</p> <p>NOTE The setup shown below is an alternative to the G5 test illustrated above.</p>	<p>G5 Alternative</p>
<p>Diagram</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>a)</p>  </div> <div style="text-align: center;"> <p>b)</p>  </div> </div>	
<p>Tolerance</p> <p>For a) and b)</p> <p>0,020 for a measuring length of 300 mm</p>	<p>Measured deviation</p> <p>a)</p> <p>b)</p>
<p>Measuring instruments</p> <p>a) and b) Cylindric square and linear displacement sensor</p>	
<p>Observations and references to ISO 230-1:2012, 8.2</p> <p>Place a cylindrical square on the table centre. Centre the square on the table and carefully align it parallel to the C-axis of rotation. Take readings from the dial gauge at several positions along the Z-axis.</p> <p>This test setup is also applicable to tests G8 Alternative, G9 Alternative and G11 Alternative.</p>	

Object		G6
<p>Checking of the angular deviations of the toolholder slide (ram) motion (Z-axis) Optional, checking of rotation of the ram around Z-axis (if roll is relevant)</p> <p>a) in the YZ plane E_{AZ} (tilt around X); b) in the XZ plane E_{BZ} (tilt around Y).</p>		
Diagram		
Key		
<p>1 measuring level 2 reference level</p>		
Tolerance		Measured deviation
For measuring length up to 1 600 mm: 0,030/1 000 (30 μ rad)		a)
For measuring length over 1 600 mm: 0,060/1 000 (60 μ rad)		b)
For optional measuring of roll the tolerance is 0,040/1 000 (40 μ rad)		
Measuring instruments		
a) and b) Precision level or optical angular deviation measuring instrument		
Observations and references to ISO 230-1:2012, 3.4.16, 8.4		
Measurements shall be carried out at a minimum of five positions equally spaced along the travel in both directions of the movement.		
The reference level shall be placed on the workholding spindle or table.		

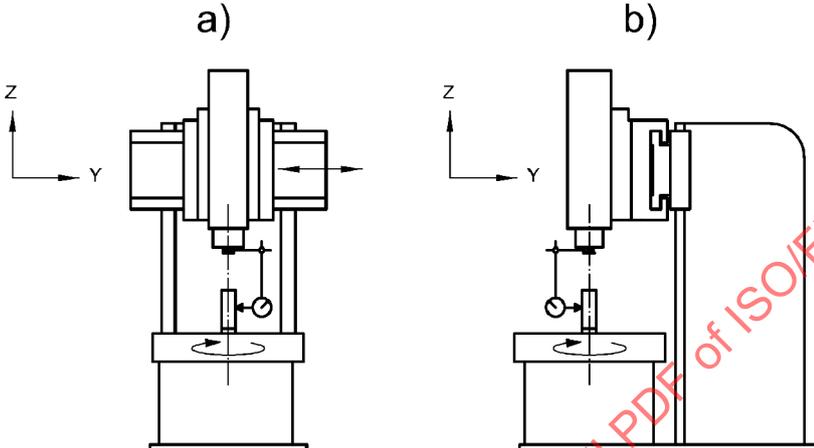
<p>Object</p> <p>Checking of the squareness between the railhead motion (X-axis) and the workholding spindle axis of rotation (C-axis) [$E_{B(0(C))X}$].</p> <p>NOTE Also applicable for a second railhead ram and tool holder on the column.</p>	<p>G7</p>
<p>Diagram</p> 	
<p>Tolerance</p> <p>0,067/1 000 (0,020/300)</p> <p>For every further increase of 300 mm measuring length: +0,010/300</p> <p>Direction of deviation: $\alpha \leq 90^\circ$</p> <p>The trajectory of X-axis shall be concave unless by special arrangement between the user and supplier/manufacturer.</p>	<p>Measured deviation</p>
<p>Measuring instruments</p> <p>Straightness reference artefact, adjustable blocks and linear displacement sensor</p>	
<p>Observations and references to ISO 230-1:2012, 10.3.3, 10.1.4.3</p> <p>A dial gauge is fixed to the turret or tool holder close to the tool position.</p> <p>The straightedge shall be placed on the workholding spindle or table perpendicular to the C-axis, or the lack of squareness shall be considered in the measurement</p> <p>or</p> <p>If the straightedge is not perfectly perpendicular to the C-axis, measurements should be taken at several positions of the X-axis motion, then rotate the spindle through 180° and take a second set of measurements at the same X locations. The squareness deviation is the range of the mean of these two sets of measurements.</p> <p>This test applies to all rail heads.</p> <p>The X-axis orientation should be identified either through its least square line or through reading in two extreme measuring points, if possible symmetrical. But some X-axes cannot move too long after the table centre. In this case, whichever option is chosen, it can apply approximately to one radius.</p>	

<p>Object</p> <p>Checking of the parallelism between the Z-axis motion (railhead ram or tool holder) and the workholding spindle axis of rotation</p> <p>a) in the XZ plane [$E_{B(0(C))Z}$];</p> <p>b) in the YZ plane [$E_{A(0(C))Z}$].</p> <p>NOTE Also applicable for a second railhead ram and tool holders on the column.</p>		<p>G8</p>
<p>Diagram</p>		
<p>Tolerance</p> <p>a) 0,030/1 000 (0,010/300)</p> <p>b) 0,050/1 000 (0,015/300)</p>	<p>Measured deviation</p> <p>a)</p> <p>b)</p> <p>The sign convention of the error shall correspond to the parallelism sign between C' and Z-axis according to ISO 230-1.</p>	
<p>Measuring instruments</p> <p>a) and b) Square and linear displacement sensors</p> <p>NOTE As an alternative to this test setup, see test G8 Alternative using a cylindrical square.</p>		
<p>Observations and references to ISO 230-1:2012, 10.1.4.3 and 10.1.3</p> <p>Vertical slide over the centre of the table. Place a square in radial direction on the table, with one arm parallel to the X-axis, on one side of the vertical slide, in such a way that the table can rotate 180° to bring the square on the opposite side of the vertical slide without interference. The square does not need to be aligned with the C-axis. Take readings from dial gauge at several positions along the Z-axis. Without moving the X-axis, rotate the table by 180° so to bring the square to the opposite side of the vertical slide. Take the readings at the same heights on the square. The least square line slope provides the parallelism deviation between Z-axis and C-axis. On the other side its slope provides information on the parallelism between the square and the C-axis.</p> <p>This test setup is also applicable to the tests G5, G9 and G11.</p> <p>NOTE For machines with two railhead rams, difference of G8 tests for two railhead rams gives information about the parallelism between the railhead rams. Tolerance for this parallelism is subject to agreement between the supplier and the user.</p>		

<p>Object</p> <p>Checking of the parallelism between the Z-axis motion (railhead ram or tool holder) and the workholding spindle axis of rotation</p> <p>c) in the XZ plane [$E_{B(0(C))Z}$];</p> <p>d) in the YZ plane [$E_{A(0(C))Z}$].</p> <p>NOTE Also applicable for a second railhead ram and tool holders on the column.</p>	<p>G8 Alternative</p>
<p>Diagram</p> 	
<p>Tolerance</p> <p>a) 0,030/1 000 (0,010/300)</p> <p>b) 0,050/1 000 (0,015/300)</p>	<p>Measured deviation</p> <p>a)</p> <p>b)</p> <p>The sign convention of the error shall correspond to the parallelism sign between C' and Z-axis according to ISO 230-1.</p>
<p>Measuring instruments</p> <p>a) and b) Cylindrical square and linear displacement sensors</p>	
<p>Observations and references to ISO 230-1:2012, 10.1.4.3 and 10.1.3</p> <p>As in test G5 Alternative, place a cylindrical square on the table centre. Centre the square on the table and carefully align it parallel to the C-axis of rotation.</p> <p>If test G5 Alternative has been performed before test G8 Alternative, use the readings taken for test G5 Alternative; the difference between the two readings at the ends of the travel, divided by the travel length (or better the least square line slope of the straightness plot) provides the parallelism deviation between Z-axis and C-axis.</p> <p>This test setup is also applicable to the tests G5 Alternative, G9 Alternative and G11 Alternative.</p> <p>NOTE For machines with two railhead rams, difference of G8 tests for two railhead rams gives information about the parallelism between the railhead rams. Tolerance for this parallelism is subject to agreement between the supplier and the user.</p>	

5.3 Cross-rail movement

Object		G9
Checking of the straightness of motion of the cross-rail Z(W)-axis a) in the XZ plane (E_{XW}); b) in the YZ plane (E_{YW}).		
Diagram		
Tolerance		Measured deviation
For a) 0,050/1 000 (50 μm)		a)
For b) 0,080/1 000 (80 μm)		b)
Measuring instruments		
a) and b) Square and linear displacement sensor Alternative: Sweeping alignment laser device, optical equipment		
Observations and references to ISO 230-1:2012, 8.2		
The railhead(s) shall be placed in suitable parking position according to the manufacture's specification and the position(s) shall be reported. Vertical slide over the centre of the table. Place a dial gauge on the tool holder. Place a square in radial direction on the table, with one arm parallel to the X-axis, on one side of the vertical slide. The square does not need to be aligned with the C-axis. Readings along the Z(W)-axis shall be taken in several positions with the cross-rail clamped on the columns without moving the X-axis.		
If this test is to be combined with test G11, place the square in such a position as to allow the table to be rotated to four positions at 90° from each other.		
This test setup is also applicable to the tests G5, G8 and G11.		

<p>Object</p> <p>Checking of the straightness of motion of the cross-rail Z(W)-axis</p> <p>a) in the XZ plane (E_{XW});</p> <p>b) in the ZY plane (E_{YW}).</p>	<p>G9 Alternative</p>
<p>Diagram</p> 	
<p>Tolerance</p> <p>For a) 0,050/1 000 (50 μm)</p> <p>For b) 0,080/1 000 (80 μm)</p>	<p>Measured deviation</p> <p>a)</p> <p>b)</p>
<p>Measuring instruments</p> <p>a) and b) Straightness reference artefact, sweeping alignment laser device, cylindrical square, adjustable blocks or test mandrel and linear displacement sensor or optical equipment.</p>	
<p>Observations and references to ISO 230-1:2012, 8.2</p> <p>The railhead(s) shall be placed in suitable parking position according to the manufacture's specification and the position(s) shall be reported. Place a cylindrical square on the table centre. Centre the square on the table and carefully align it parallel to the C-axis of rotation.</p> <p>Take readings from the dial gauge at several positions along the Z(W)-axis, possibly in all positions of the cross rail, with the cross-rail clamped on the columns before each reading.</p> <p>This test setup is also applicable to the tests G5 Alternative, G8 Alternative and G11 Alternative tests.</p>	

<p>Object</p> <p>Checking of the angular deviation of the cross-rail in its Z(W)-axis motion. Optional, checking of rotation of the ram around Z-axis (if roll is relevant)</p> <p>a) in the vertical YZ plane (E_{AW} or E_{AZ}); b) in the vertical ZX plane (E_{BW} or E_{BZ}).</p>	<p>G10</p>
<p>Diagram</p>	
<p>Key</p> <p>1 measuring level (preferred position) 2 measuring level (alternative position) 3 reference level</p>	
<p>Tolerance</p> <p>For a) and b) For any measuring length 0,030/1 000: (30 μrad) For optional measuring of roll the tolerance is 0,040/1 000 (40 μrad)</p>	<p>Measured deviation</p> <p>a) b)</p>
<p>Measuring instruments</p> <p>a) and b) Precision level or optical angular deviation measuring instruments.</p>	
<p>Observations and references to ISO 230-1:2012, 8.4</p> <p>Place the measuring level at possibly mid-position of the cross-rail (tool holder) on an appropriate surface and read the indication in the quoted positions.</p> <p>The railhead shall be placed in suitable parking position according to the manufacturer's specification and shall be reported.</p> <p>When Z-axis motion causes angular deviation of both the cross-rail and the workholding spindle or table, differential measurements of the two angular measurements shall be taken and this shall be stated.</p> <p>When differential measurement is applied, the reference level shall be placed on the workholding table.</p> <p>Lock the cross-rail at each position, where possible.</p>	

Object		G11
<p>Checking of the parallelism between the cross-rail Z(W)-axis motion and the workholding spindle or table axis of rotation</p> <p>a) in the XZ plane [$E_{B(0C)W}$ or $E_{B(0C)Z}$];</p> <p>b) in the YZ plane [$E_{A(0C)W}$ or $E_{A(0C)Z}$].</p>		
Diagram		
Tolerance		Measured deviation
a) 0,050/1 000 (0,015/300)		a)
b) 0,067/1 000 (0,020/300)		b)
Measuring instruments		
a) and b) Linear displacement sensor or sweeping alignment laser device and square		
Observations and references to ISO 230-1:2012, 10.1.3 and 10.1.4.3		
<p>The railhead(s) shall be placed in suitable parking position according to the manufacture's specification and the positions shall be reported. Vertical slide over the centre of the table. Place a dial gauge on the tool holder. Place a square in radial direction on the table, with one arm parallel to the X-axis, on one side of the vertical slide, in such a way that the table can rotate 180° to bring the square on the opposite side of the vertical slide without interference. The square does not need to be aligned with the C-axis. Take readings from the dial gauge at several positions along the Z(W)-axis with the cross-rail clamped on the columns before each reading. If test G9 has been performed before test G11, use the readings taken for test G9. For both a) and b), without moving the X-axis, rotate the table by 180° to bring the square to the opposite side of the vertical slide. Take the readings from the dial gauge at the same heights on the square. Half algebraic differences of all pairs of readings at the same heights provide the straightness deviations of the Z(W)-axis (already checked by G9). The difference between the two results obtained at the ends of the travel, divided by the travel length (or better the least square line slope of the plot) provides the parallelism deviation between Z(W)-axis and C-axis. On the other side, the average values (half algebraic sum) of all pairs of readings provide an information on the straightness of the vertical square side, and its slope will provide information on the parallelism between the square and the C-axis, which has not affected the measurements.</p> <p>This test setup is also applicable to the tests G5, G8 and G9.</p>		

<p>Object</p> <p>Checking of the parallelism between the cross-rail Z(W)-axis motion and the work-holding spindle or table axis of rotation</p> <p>a) in the XZ plane [$E_{B(0C)W}$ or $E_{B(0C)Z}$];</p> <p>b) in the YZ plane [$E_{A(0C)W}$ or $E_{A(0C)Z}$].</p>		<p>G11 Alternative</p>
<p>Diagram</p> <div style="text-align: center;"> </div>		
<p>Tolerance</p> <p>a) 0,015/300</p> <p>b) 0,020/300</p>	<p>Measured deviation</p> <p>a)</p> <p>b)</p>	
<p>Measuring instruments</p> <p>a) and b) Linear displacement sensor or sweeping alignment laser device and square</p>		
<p>Observations and references to ISO 230-1:2012, 10.1.3 and 10.1.4.3</p> <p>The railhead(s) shall be placed in suitable parking position according to the manufacture's specification and the position(s) shall be reported. As in test G9 Alternative, place a cylindrical square on the centre of the table and align it carefully parallel with the C-axis of rotation.</p> <p>Take readings from the dial gauge at several positions along the Z(W)-axis, possibly in all positions of the cross rail, with the cross-rail clamped on the columns before each reading.</p> <p>If test G9 Alternative has been performed before test G11 Alternative, use the readings taken for test G9 Alternative; the difference between the two readings at the ends of the travel, divided by the travel length (or better the least square line slope of the straightness plot) provide the parallelism deviation between W-axis and C-axis.</p> <p>This test setup is also applicable to the tests G5 Alternative, G8 Alternative and G9 Alternative.</p>		

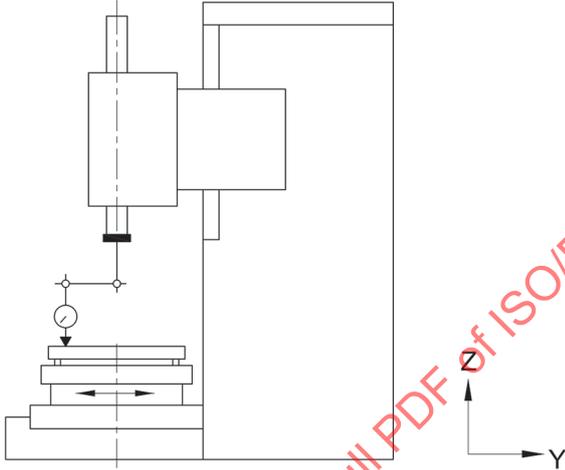
5.4 Test related to Y-axis

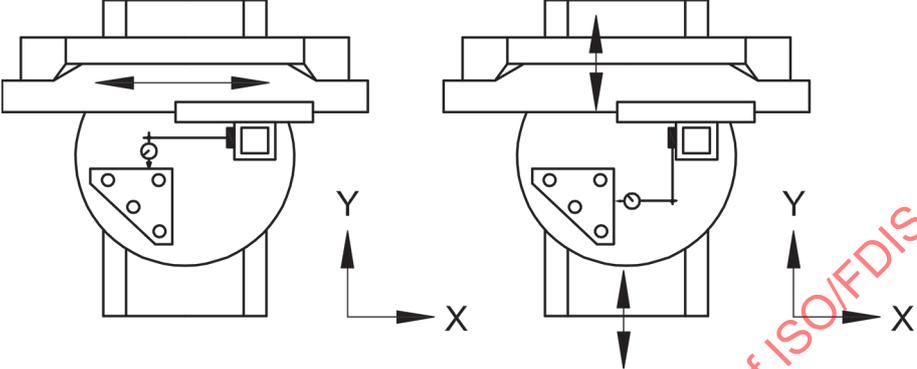
<p>Object</p> <p>Checking of the straightness of motion of moving column (gantry type) or moving workholding table (portal type) in the Y-axis direction</p> <p>a) in the vertical YZ plane (E_{ZY});</p> <p>b) in the horizontal XY plane (E_{XY}).</p>		<p>G12</p>
<p>Diagram</p>		
<p>Tolerance</p> <p>a) 0,030 for 1 000 mm</p> <p>b) 0,040 for 1 000 mm</p>		<p>Measured deviation</p> <p>a)</p> <p>b)</p>
<p>Measuring instruments</p> <p>a) Straightness reference artefact, adjustable blocks and linear displacement sensor or optical equipment</p> <p>b) Straightness reference artefact, adjustable blocks and linear displacement sensor optical equipment, sweeping alignment laser device, or microscope and taut wire</p>		
<p>Observations and references to ISO 230-1:2012, 8.2, 12.1.2.2</p> <p>For gantry type machines crossrail locked in the middle position, railhead ram in the measuring position.</p> <p>The straightedge shall be placed on the workholding table perpendicular to the C-axis, or the lack of squareness shall be considered in the measurement.</p> <p>The dial gauge, the interferometer, the target or the microscope for taut wire shall be mounted on the railhead near to the position of a tool. The measuring line should be close to the workholding table axis of rotation.</p> <p>Alternatively, when the straightedge is not aligned mechanically, the results can be evaluated according to ISO 230-1:2012, 3.4.8.</p>		

Object	G13				
<p>Checking of the angular deviations of moving portal (gantry type) or moving workholding table (portal type) in the Y direction</p> <p>a) in the YZ plane E_{AY} (pitch);</p> <p>b) in the ZX plane E_{BY} (roll);</p> <p>c) in the XY plane E_{CY} (yaw).</p>					
<p>Diagram</p> <p>Key</p> <table border="0"> <tr> <td>1 measuring level</td> <td>3 autocollimator</td> </tr> <tr> <td>2 reference level</td> <td>4 mirror</td> </tr> </table>		1 measuring level	3 autocollimator	2 reference level	4 mirror
1 measuring level	3 autocollimator				
2 reference level	4 mirror				

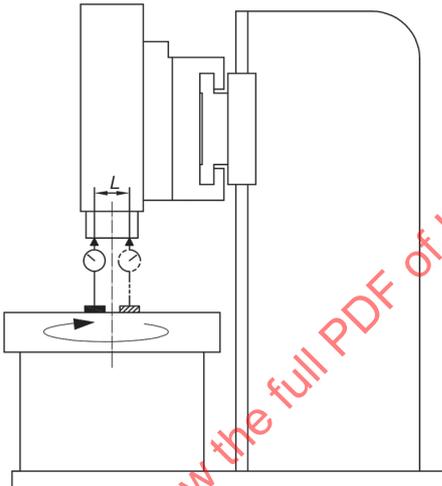
Tolerance	Measured deviation
For a), b), and c) For any measuring length 0,050/1 000: (50 μ rad)	a) b) c)
Measuring instruments a) Precision level, or optical angular deviation measuring instrument b) Precision level c) Optical angular deviation measuring instrument	
Observations and references to ISO 230-1:2012, 3.4.16, 8.4 The measuring level or instrument shall be placed on the railhead which is fixed in position: a) (E_{AY} : pitch) level, or optical instrument oriented in the YZ plane; b) (E_{BY} : roll) level oriented in the ZX plane; c) (E_{CY} : yaw) optical instrument oriented in the XY plane. When the motion of the moving element (gantry or table slide) causes angular deviations of both workholding table and column, differential measurements of the two angular deviations shall be made and this shall be stated. The reference level shall be placed on the element (table or tool holder), which is fixed in position. Measurements shall be carried out at a minimum of five positions equally spaced along the path of travel in both directions of the movement.	

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Object	G14
<p>Checking of squareness of the Y-axis motion (portal or workholding table) to the C-axis [EA(OC)Y].</p> <p>NOTE This test applies to machines according to Figure 2 c) and Figure 2 d).</p>	
<p>Diagram</p> 	
<p>Tolerance</p> <p>0,040/1 000</p>	<p>Measured deviation</p>
<p>Measuring instruments</p> <p>Gauge block and linear displacement sensor.</p>	
<p>Observations and references to ISO 230-1:2012, 12.1.2.2</p> <p>Place a gauge block on one edge of the table, in the Y direction apart from the axis of rotation; fix the dial gauge on the tool holder; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by 180° and move the Y-axis until the stylus touches the gauge block again. The dial gauge reading, divided by the Y displacement, is the error to be reported.</p> <p>The value of angle α, being less than, equal to or greater than 90°, shall be noted. The sign convention of the error shall correspond to the squareness sign between C' and Y-axis according to ISO 230-1.</p>	

<p>Object</p>	<p>G15</p>
<p>Checking of squareness of the Y-axis motion (portal or workholding table) to the X-axis motion (rail head) $E_{C(OX)Y}$.</p> <p>NOTE This test applies to machines according to Figure 2 c) and Figure 2 d).</p>	
<p>Diagram</p> 	
<p>Tolerance</p> <p>0,040/1 000</p>	<p>Measured deviation</p>
<p>Measuring instruments</p> <p>Squareness reference artefact and linear displacement sensor or optical instruments</p>	
<p>Observations and references to ISO 230-1:2012, 10.3.2</p> <p>Mount the displacement sensor on the tool holder. Place the square on the turntable (workholding spindle) and adjust it parallel to rail head movement using the displacement sensor.</p> <p>Adjust the stylus of the displacement sensor perpendicular to the other side of the square.</p> <p>For gantry type machines:</p> <p>Move the portal with the displacement sensor along the square and take the reading.</p> <p>For machines with moving turntable:</p> <p>Move the turntable with the square along the stationary displacement sensor and take the reading.</p> <p>Squareness deviation is the change of difference in the indicator readings divided by the distance travelled between the measurement locations.</p>	

5.5 Tool holders and turrets

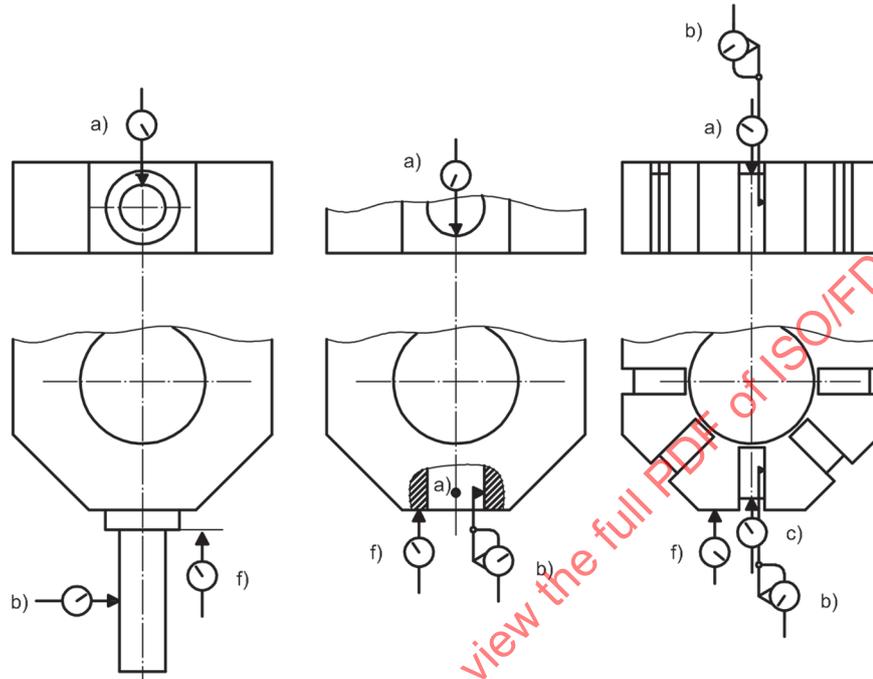
<p>Object</p> <p>Checking of the squareness between the tool-fixing faces of the tool holder and the workholding spindle axis of rotation.</p> <p>NOTE The test applies to tool-fixing faces of turrets that are square to the workholding spindle axis.</p>	<p>G16</p>
<p>Diagram</p> 	
<p>Tolerance</p> <p>0,020/L</p> <p>L is the diameter of measurement</p>	<p>Measured deviation</p>
<p>Measuring instruments</p> <p>Linear displacement sensor and reference block</p>	
<p>Observations and references to ISO 230-1:2012, 12.4.1</p> <p>A dial gauge shall be fixed on the workholding spindle and shall touch the reference block located on the face of tool holder located opposite.</p> <p>The workholding spindle shall be rotated and the dial gauge shall be moved to touch the face of the tool holder on the largest possible diameter.</p> <p>If the machine is equipped with a turret, the test shall be repeated for each of the tool-fixing faces of the turret.</p>	

Object

Checking of the accuracy of the turret indexing.

NOTE This test applies only for machines equipped with a turret.

Diagram



Tolerance

0,030

Measured deviation

Measuring instruments

Linear displacement sensor

Observations and references to ISO 230-1:2012

Position the dial gauge styli a), b) and c) so that they contact the turret reference holes or grooves. Record the turret axis position. Record the dial gauge readings. Withdraw the turret position to clear off the dial gauge, index the turret to the next orientation, and reposition the turret axis. Record the dial gauge readings.

If the turret reference face is used, the dial gauge should be used at position f).

Repeat the test three times for each turret orientation; the readings at each orientation are then averaged to minimize the effect of turret repeatability. The maximum difference of all averaged dial gauge readings is the accuracy of turret indexing.

The repeatability of the turret indexing might influence the readings.

5.6 Toolholding spindles

Object		G18
Checking of the run-out of the internal taper of the toolholding spindle(s) a) at the toolholding spindle nose; b) at a distance of 300 mm from the toolholding spindle nose.		
Diagram		
Tolerance		Measured deviation
a) 0,010		a)
b) 0,020		b)
Measuring instruments		
a) and b) Linear displacement sensor and test mandrel		
Observations and references to ISO 230-1:2012, 12.5.3		
Attach a dial gauge to the table (workholding spindle) and insert the test mandrel in the live toolholding spindle. Place the displacement sensor as close as possible to position a), rotate the toolholding spindle and record the reading. Repeat the same operation at position b). If the machine is equipped with a turret, carry out these tests for each toolholding spindle of the (see also R2 test).		

Object		G19
<p>Checking of the parallelism between the toolholding spindle axis of rotation C1 and the railhead ram motion Z</p> <p>a) in the YZ plane [$E_{A(0Z)}(C1)$];</p> <p>b) in the ZX plane [$E_{B(0Z)}(C1)$].</p>		
Diagram		
Tolerance	Measured deviation	
For a) and b) 0,067/1 000 (0,020/300)	a)	
	b)	
Measuring instruments		
a) and b) Linear displacement sensor and test mandrel		
Observations and references to ISO 230-1:2012, 10.1.3; 10.1.4		
A test mandrel is mounted on the tooling spindle.		
NOTE If necessary, workholding spindle should be clamped.		
a) Dial gauge is attached to the workholding spindle indicating against the mandrel in the Y direction. Mean orientation of the mandrel is determined by rotating the tooling spindle between the two extreme readings of the displacement sensor. Displacement sensor is set to zero at this mean orientation. Then the railhead ram is moved to the other end of the measuring stroke and the displacement sensor reading is recorded.		
b) Dial gauge is attached to the workholding spindle indicating against the mandrel in the X direction. Mean orientation of the mandrel is determined by rotating the tooling spindle between the two extreme readings of the displacement sensor. Displacement sensor is set to zero at this mean orientation. Then the railhead ram is moved to the other end of the measuring stroke and the displacement sensor reading is recorded		
or		
take readings at several positions of the Z-axis and then rotate the toolholding spindle by 180° and take the second set of readings at the same Z positions. Parallelism deviation is the change of difference in the indicator readings divided by the distance travelled between the measurement locations.		