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**Test conditions for machining  
centres —**

Part 1:  
**Geometric tests for machines with  
horizontal spindle (horizontal Z-axis)**

*Conditions d'essai pour centres d'usinage —*

*Partie 1: Essais géométriques des machines à broche horizontale (axe  
Z horizontal)*

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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](http://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](http://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*, SC 2, *Test conditions for metal cutting machine tools*.

This second edition cancels and replaces the first edition (ISO 10791-1:1998), which has been technically revised.

ISO 10791 consists of the following parts, under the general title *Test conditions for machining centres*:

- *Part 1: Geometric tests for machines with horizontal spindle (horizontal Z-axis)*
- *Part 2: Geometric tests for machines with vertical spindle or universal heads with vertical primary rotary axis (vertical Z-axis)*
- *Part 3: Geometric tests for machines with integral indexable or continuous universal heads (vertical Z-axis)*
- *Part 4: Accuracy and repeatability of positioning of linear and rotary axes*
- *Part 5: Accuracy and repeatability of positioning of work-holding pallets*
- *Part 6: Accuracy of speeds and interpolations*
- *Part 7: Accuracy of finished test pieces*
- *Part 8: Evaluation of contouring performance in the three coordinate planes*
- *Part 9: Evaluation of the operating times of tool change and pallet change*
- *Part 10: Evaluation of the thermal distortions*

## Introduction

A machining centre is a numerically controlled machine tool capable of performing multiple machining operations, including milling, boring, drilling, and tapping, as well as automatic tool changing from a magazine or similar storage unit in accordance with a machining program.

The object of ISO 10791 (all parts) is to supply information as wide and comprehensive as possible on tests which can be carried out for comparison, acceptance, maintenance, or any other purpose deemed necessary by user or manufacturer/supplier. ISO 10791 specifies, with reference to the relevant parts of ISO 230, several families of tests for machining centres with horizontal spindle, standing alone or integrated in flexible manufacturing systems.

This part of ISO 10791 also establishes the tolerances for the test results corresponding to general purpose and normal accuracy machining centres.

This part of ISO 10791 is also applicable, totally or partially, to other numerically controlled machines, when their configuration, components, and movements are compatible with the tests described herein.

Accessory spindle heads, forming the object of [Annexes A](#) through [C](#) in the first edition of this part of ISO 10791, are now covered by the more general ISO 17543-1, as they are not only used on machining centres.

In this edition of ISO 10791-1, the test of the table flatness (formerly G15) has been deleted for several reasons, among which are the following:

- the table surface is not normally used as a reference for the location of the workpiece;
- sometimes, the machine is supplied with some fixtures already mounted on the table;
- sometimes, the machine is provided with a receiver where several pallets can be mounted;
- for tests made during the working life of the machine, the surface might no longer be suitable for accurate measurements, mostly on large machines.

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# Test conditions for machining centres —

## Part 1:

# Geometric tests for machines with horizontal spindle (horizontal Z-axis)

## 1 Scope

This part of ISO 10791 specifies, with reference to ISO 230-1, the geometric tests for machining centres (or other numerically controlled machines, where applicable) with horizontal spindle (i.e. horizontal Z-axis).

This part of ISO 10791 applies to machining centres having three numerically controlled linear axes (X-axis up to 5 000 mm length, Y-axis up to 3 200 mm length, and Z-axis up to 2 000 mm length), but refers also to supplementary movements, such as those of rotary tilting, and swivelling tables. Movements other than those mentioned are considered as special features and the relevant tests are not included in this part of ISO 10791.

This part of ISO 10791 takes into consideration in [Annexes A](#) through [D](#) four possible types of tables, fixed and rotary, as hereunder described:

- [Annex A](#): horizontal non-rotating tables;
- [Annex B](#): tables rotating around a vertical B'-axis;
- [Annex C](#): tables rotating around a vertical B'-axis and tilting around a horizontal A'-axis;
- [Annex D](#): tables rotating around a horizontal A'-axis and swivelling around a vertical B'-axis.

This part of ISO 10791 does not consider accessory spindle heads, which are covered by ISO 17543-1:—<sup>1)</sup>.

This part of ISO 10791 deals only with the verification of geometric accuracy of the machine and does not apply to the testing of the machine operation, which should generally be checked separately. Tests not concerning the pure geometric accuracy of the machine are dealt with in other parts of ISO 10791, as listed in the Foreword.

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

ISO 230-7:—<sup>1)</sup>, *Test code for machine tools — Part 7: Geometric accuracy of axes of rotation*

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

ISO 10791-6:2014, *Test conditions for machining centres — Part 6: Accuracy of speeds and interpolations*

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1) To be published.

### 3 Preliminary remarks

#### 3.1 Measurement units

In this part of ISO 10791, all linear dimensions, deviations, and corresponding tolerances are expressed in millimetres; angular dimensions are expressed in degrees, and angular deviations and the corresponding tolerances are expressed in ratios as the primary method, but in some cases, microradians or arcseconds can be used for clarification purposes. The following expression should be used for conversion of the units of angular deviations or tolerances:

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

#### 3.2 Reference to ISO 230-1

To apply this part of ISO 10791, reference shall be made to ISO 230-1, especially for the installation of the machine before testing, warming up of the spindle and other moving components, description of measuring methods, and recommended uncertainty of testing equipment.

In the "Observations" block of the tests described in [Clause 4](#) and the annexes, the instructions are preceded by a reference to the corresponding clause in ISO 230-1 in cases where the test concerned is in compliance with the specifications of that International Standard.

#### 3.3 Reference to ISO 10791-6

In ISO 10791-6:2014, Annex A, B, and C, kinematic tests are described for testing circular interpolation motion by simultaneous three-axis control (AK1, AK2, BK1, BK2, CK1, CK2). These are based on using displacement sensor(s) with a sphere-ended test mandrel or using a ball bar.

These kinematic tests can be used for determining the position and orientation of rotary axes with respect to the linear axes.

Kinematic test BK2 c) [CK2 c)] in ISO 10791-6:2014 can be used as an alternative for the following tests if all relevant geometric error compensation functions are identical: BG8, BG9, CG8, CG10, DG9, and DG11.

#### 3.4 Testing sequence

The sequence in which the tests are presented in this part of ISO 10791 in no way defines the practical order of testing. In order to make the mounting of instruments or gauging easier, tests can be performed in any order.

#### 3.5 Tests to be performed

When testing a machine, it is not always necessary, nor possible, to carry out all the tests described in this part of ISO 10791. 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 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 part of ISO 10791 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.

### 3.6 Tolerances

In this part of ISO 10791, all tolerance values (see 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 establishing the tolerance for a measuring length different from that given in this part of ISO 10791 the tolerance can be determined by means of the law of proportionality (see ISO 230-1:2012, 4.1.2). It shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

### 3.7 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 can be used. Reference shall be made to ISO 230-1:2012, Clause 5, which 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.

When “3D probe” is referred to, it means three displacement sensors, housed in a nest, used to measure the changes in the position of the centre of a precision sphere; when the nest and the sphere are moved together along a programmed tool path.

### 3.8 Diagrams

For reasons of simplicity, diagrams in this part of ISO 10791 illustrate only one type of machine.

### 3.9 Pallets

For machines working with several pallets, the tests concerning the intrinsic geometric features or their behaviour related to the axes of the machine (tests in [Annexes A](#) through [D](#)) are to be performed on only one representative pallet clamped in position, unless otherwise specified by an agreement between the user and the manufacturer/supplier. For checking other pallets, see ISO 10791-5.

### 3.10 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 the 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.

### 3.11 Machine configurations

[Figure 1](#) and [Table 1](#) show 12 possible configurations of machining centres, with different architectures and different components moving along the linear axes. These configurations are identified by means

of numbers from 01 to 12 for referring [Figure 1](#) and [Table 1](#) to each other. For the axes orientation and nomenclature, reference should be made to ISO 841.

### 3.12 Designation

A designation is also supplied in [Table 1](#) in order to define the architecture of a machining centre, being a short code; this designation is given by

- the number of this part of ISO 10791,
- the letter H for “horizontal”, and
- a list of the structural and moving components from the workpiece (w) to the tool (t).

[Table 1](#) shows examples of designations referred to the machine configurations shown in [Figure 1](#), where

- the kinematic chain of moving axes is described in square brackets,
- the axis not under NC positioning is represented in brackets [e.g. (C)], and
- “w”, “t”, and “b”, respectively, represent the work holding table, the tool, and the bed.

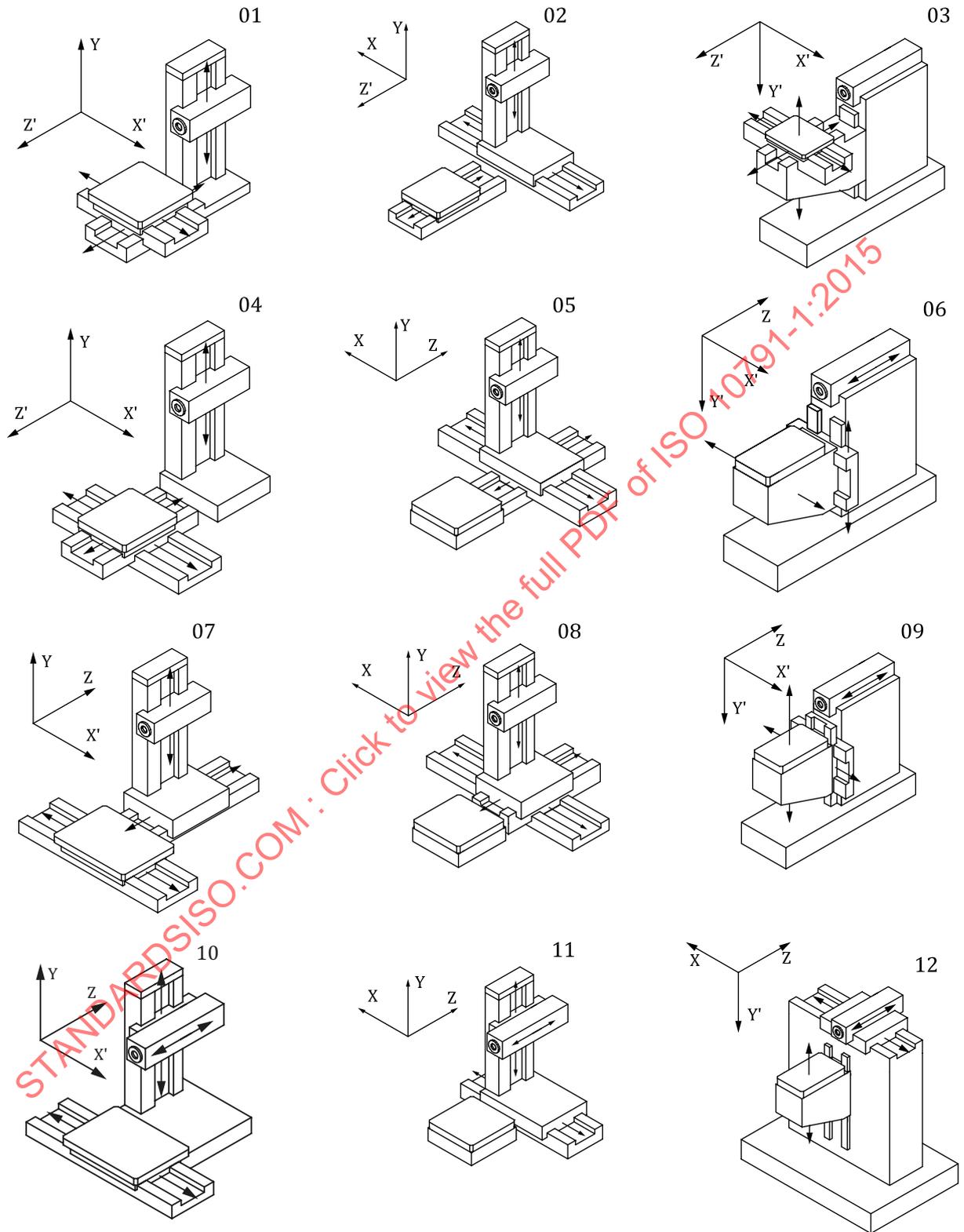
The sequence can be either from the work holding table to the tool or from the tool to the work holding table.

**Table 1 — Designations of configurations shown in [Figure 1](#)**

01	ISO 10791-1 H [w X' Z' b Y (C) t]
02	ISO 10791-1 H [w Z' b X Y (C) t]
03	ISO 10791-1 H [w X' Z' Y' b (C) t]
04	ISO 10791-1 H [w Z' X' b Y (C) t]
05	ISO 10791-1 H [w b Z X Y (C) t]
06	ISO 10791-1 H [w X' Y' b Z (C) t]
07	ISO 10791-1 H [w X' b Z Y (C) t]
08	ISO 10791-1 H [w b X Z Y (C) t]
09	ISO 10791-1 H [w Y' X' b Z (C) t]
10	ISO 10791-1 H [w X' b Y Z (C) t]
11	ISO 10791-1 H [w b X Y Z (C) t]
12	ISO 10791-1 H [w Y' b X Z (C) t]

### 3.13 Axes not under test

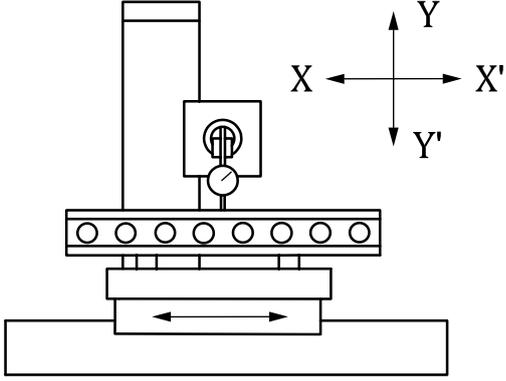
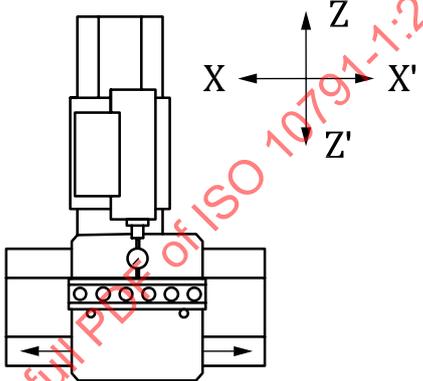
During the execution of some geometric tests on one axis of motion, the position of the other axes, not under test, can affect the results. Therefore, the positions of these axes, as well as the offsets on the tool side and on the workpiece side, are to be recorded in the test report.

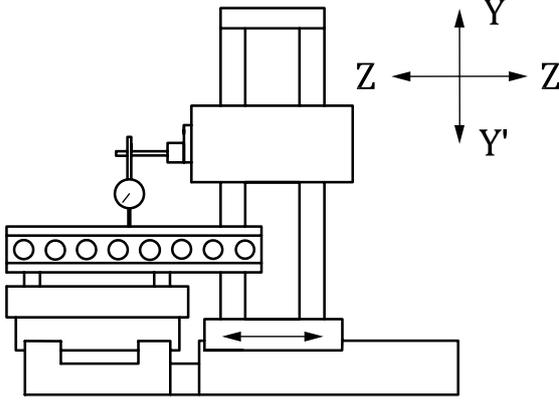
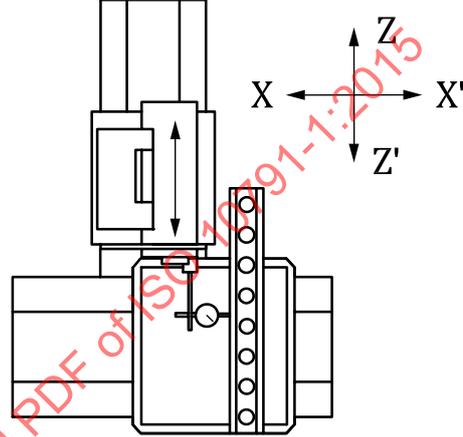


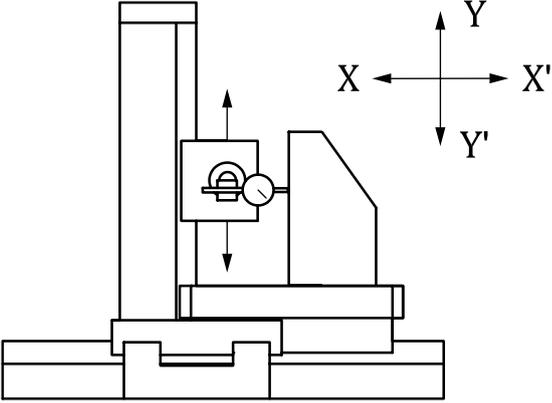
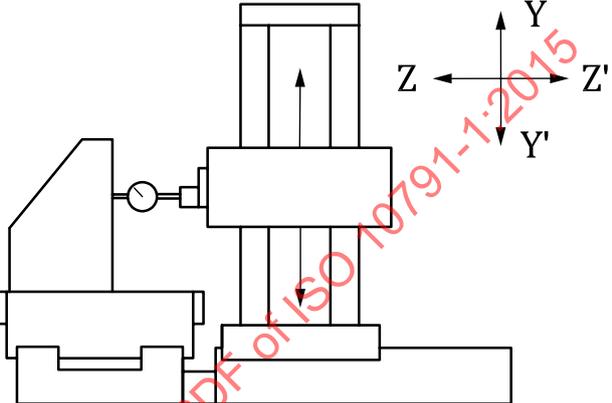
**Figure 1 — Possible configurations of linear axes**  
 (Rotary and swivelling axes of the table are shown in [Annexes B](#) through [D](#))

4 Geometric tests

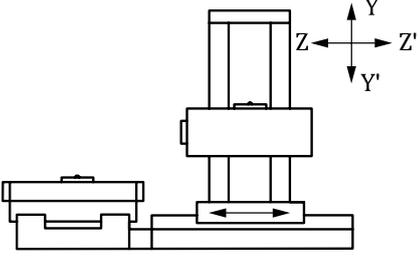
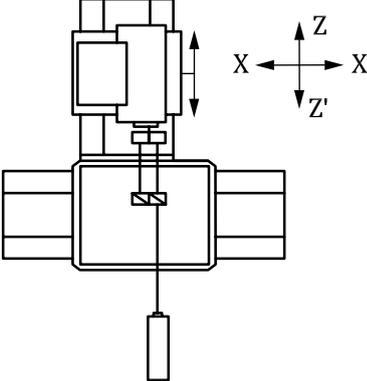
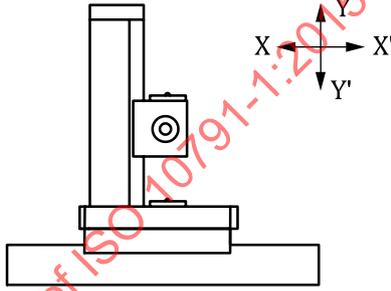
4.1 Straightness errors of linear motions

<b>Object</b>		<b>G1</b>			
Checking of straightness of the X-axis motion: a) in the vertical XY plane ( $E_{YX}$ ) b) in the horizontal ZX plane ( $E_{ZX}$ )					
<b>Diagram</b>					
a) 		b) 			
<b>Tolerance</b>					
		$X \leq 500$ a) and b)	0,010		
		$500 < X \leq 800$ a) and b)	0,015		
		$800 < X \leq 1\,250$ a) and b)	0,020		
		$1\,250 < X \leq 2\,000$ a) and b)	0,025		
		$2\,000 < X \leq 3\,200$ a)	0,050	b)	0,032
		$3\,200 < X \leq 5\,000$ a)	0,065	b)	0,040
Local tolerance 0,007 for a measuring length of 300					
<b>Measured deviation</b>					
For X = .....					
a)		b)			
Maximum local deviation:					
a)		b)			
<b>Measuring instruments</b>					
a) straightedge and dial gauge or optical methods					
b) straightedge and dial gauge or microscope and taut wire or optical methods					
<b>Observations and references to ISO 230-1:2012, 8.2 and 8.2.2</b>					
For all machine configurations, the straightedge or the taut wire or the straightness reflector shall be placed on the table. If the spindle can be locked, the dial gauge or the microscope or the interferometer can be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine. The measuring line should pass as close as possible to the centre of the table. The height of the reference straight line above the table shall be stated in the test report. Methods based on measurements of angles (ISO 230-1:2012, 12.1.3) shall not be applied as these methods are restricted to measurements of functional surfaces.					

<b>Object</b>	<b>G2</b>								
<p>Checking of straightness of the Z-axis motion:</p> <p>a) in the vertical YZ plane (<math>E_{YZ}</math>)</p> <p>b) in the horizontal ZX plane (<math>E_{XZ}</math>)</p>									
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>									
<p><b>Tolerance</b></p> <table border="0" style="width: 100%;"> <tr> <td style="text-align: right;"><math>Z \leq 500</math> a) and b)</td> <td style="text-align: right;">0,010</td> </tr> <tr> <td style="text-align: right;"><math>500 &lt; Z \leq 800</math> a) and b)</td> <td style="text-align: right;">0,015</td> </tr> <tr> <td style="text-align: right;"><math>800 &lt; Z \leq 1\,250</math> a) and b)</td> <td style="text-align: right;">0,020</td> </tr> <tr> <td style="text-align: right;"><math>1\,250 &lt; Z \leq 2\,000</math> a) and b)</td> <td style="text-align: right;">0,025</td> </tr> </table> <p>Local tolerance 0,007 for a measuring length of 300</p>		$Z \leq 500$ a) and b)	0,010	$500 < Z \leq 800$ a) and b)	0,015	$800 < Z \leq 1\,250$ a) and b)	0,020	$1\,250 < Z \leq 2\,000$ a) and b)	0,025
$Z \leq 500$ a) and b)	0,010								
$500 < Z \leq 800$ a) and b)	0,015								
$800 < Z \leq 1\,250$ a) and b)	0,020								
$1\,250 < Z \leq 2\,000$ a) and b)	0,025								
<p><b>Measured deviation</b></p> <p>For <math>Z = \dots\dots\dots</math></p> <p>a) <span style="margin-left: 200px;">b)</span></p> <p>Maximum local deviation:</p> <p>a) <span style="margin-left: 200px;">b)</span></p>									
<p><b>Measuring instruments</b></p> <p>a) straightedge and dial gauge or optical methods</p> <p>b) straightedge and dial gauge or microscope and taut wire or optical methods</p>									
<p><b>Observations and references to ISO 230-1:2012, 8.2 and 8.2.2</b></p> <p>For all machine configurations, the straightedge or the taut wire, or the straightness reflector shall be placed on the table. If the spindle can be locked, the dial gauge or the microscope or the interferometer can be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine.</p> <p>The measuring line should pass as close as possible to the centre of the table. The height of the reference straight line above the table shall be stated in the test report.</p> <p>Methods based on measurements of angles (ISO 230-1:2012, 12.1.3) shall not be applied as these methods are restricted to measurements of functional surfaces.</p>									

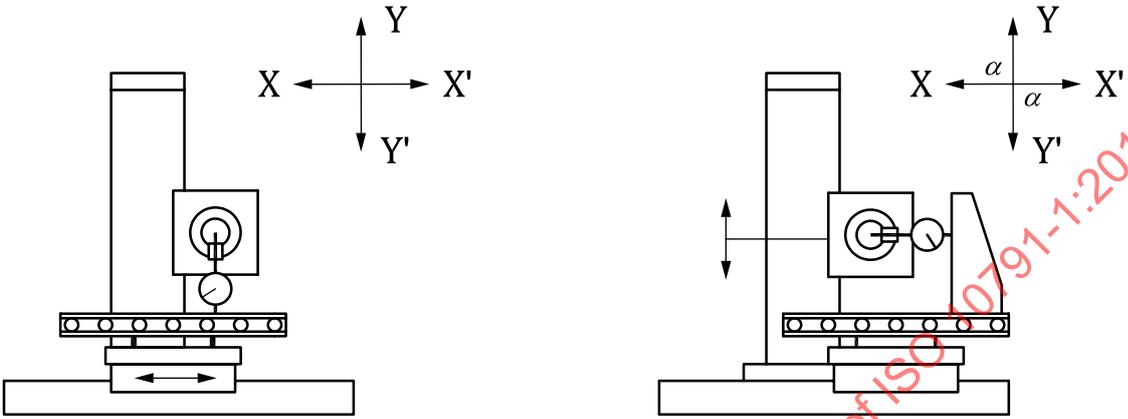
<b>Object</b>	<b>G3</b>										
Checking of straightness of the Y-axis motion: a) in the XY plane ( $E_{XY}$ ) b) in the YZ plane ( $E_{ZY}$ )											
<b>Diagram</b> a)  b) 											
<b>Tolerance</b> For a) and b) <table style="margin-left: 200px; border: none;"> <tr> <td style="padding-right: 20px;"><math>Y \leq 500</math></td> <td>0,010</td> </tr> <tr> <td><math>500 &lt; Y \leq 800</math></td> <td>0,015</td> </tr> <tr> <td><math>800 &lt; Y \leq 1\,250</math></td> <td>0,020</td> </tr> <tr> <td><math>1\,250 &lt; Y \leq 2\,000</math></td> <td>0,025</td> </tr> <tr> <td><math>2\,000 &lt; Y \leq 3\,200</math></td> <td>0,032</td> </tr> </table> Local tolerance 0,007 for a measuring length of 300		$Y \leq 500$	0,010	$500 < Y \leq 800$	0,015	$800 < Y \leq 1\,250$	0,020	$1\,250 < Y \leq 2\,000$	0,025	$2\,000 < Y \leq 3\,200$	0,032
$Y \leq 500$	0,010										
$500 < Y \leq 800$	0,015										
$800 < Y \leq 1\,250$	0,020										
$1\,250 < Y \leq 2\,000$	0,025										
$2\,000 < Y \leq 3\,200$	0,032										
<b>Measured deviation</b> For Y = ..... a) <span style="margin-left: 200px;">b)</span> Maximum local deviation: a) <span style="margin-left: 200px;">b)</span>											
<b>Measuring instruments</b> For a) and b): square and dial gauge or microscope and taut wire or optical methods											
<b>Observations and references to ISO 230-1:2012, 8.2 and 8.2.2</b> For all machine configurations, the square or the taut wire or the straightness reflector shall be placed in the centre of the table. If the spindle can be locked, the dial gauge or the microscope or the interferometer can be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine. The reference straight line applied shall be stated in the test report. Methods based on measurements of angles (ISO 230-1:2012, 12.1.3) shall not be applied as these methods are restricted to measurements of functional surfaces.											

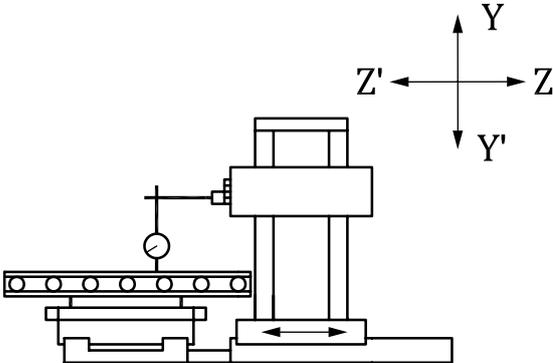
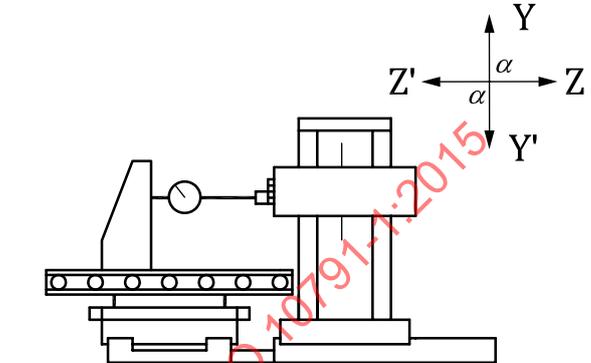


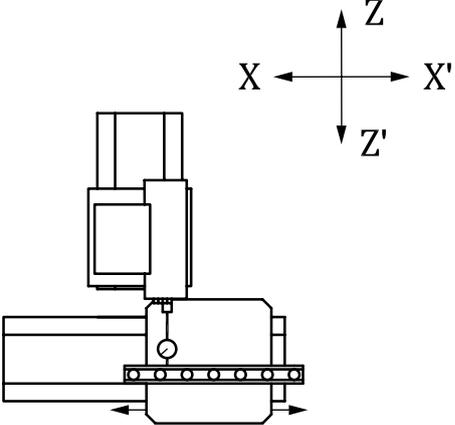
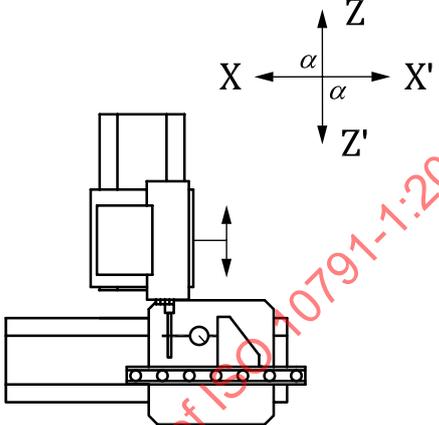
<b>Object</b>	<b>G5</b>									
<p>Checking of angular errors of the Z-axis motion:</p> <p>a) in the vertical YZ plane perpendicular to the spindle axis (pitch <math>E_{AZ}</math>)</p> <p>b) in the horizontal ZX plane (yaw <math>E_{BZ}</math>)</p> <p>c) in the vertical XY plane parallel to the spindle axis (roll <math>E_{CZ}</math>)</p>										
<p><b>Diagram</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>a)</p>  </div> <div style="text-align: center;"> <p>b)</p>  </div> <div style="text-align: center;"> <p>c)</p>  </div> </div>										
<p><b>Tolerance</b></p> <p>For a), b), and c) <math>Z \leq 2\ 000</math> 0,060/1 000 or 12''</p> <p>Local tolerance: 0,016/1 000 (or 16 <math>\mu</math>rad or 3,2'') for a measuring length of 300</p>										
<p><b>Measured deviation</b></p> <p>Z = .....</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; text-align: center;">a)</td> <td style="width: 33%; text-align: center;">b)</td> <td style="width: 33%; text-align: center;">c)</td> </tr> <tr> <td colspan="3">Maximum local deviation:</td> </tr> <tr> <td style="text-align: center;">a)</td> <td style="text-align: center;">b)</td> <td style="text-align: center;">c)</td> </tr> </table>		a)	b)	c)	Maximum local deviation:			a)	b)	c)
a)	b)	c)								
Maximum local deviation:										
a)	b)	c)								
<p><b>Measuring instruments</b></p> <p>a) (pitch <math>E_{AZ}</math>) precision level or optical angular deviation measuring instruments</p> <p>b) (yaw <math>E_{BZ}</math>) optical angular deviation measuring instruments</p> <p>c) (roll <math>E_{CZ}</math>) precision level</p>										
<p><b>Observations and references to ISO 230-1:2012, 8.4 and 8.4.2</b></p> <p>The instrument shall be placed on the movable component:</p> <p>a) (pitch <math>E_{AZ}</math>) longitudinally</p> <p>b) (yaw <math>E_{BZ}</math>) horizontally</p> <p>c) (roll <math>E_{CZ}</math>) transversely</p> <p>Measurements shall be taken at least at five positions equally spaced along the travel, in both directions of movement at every position. The difference between the maximum and the minimum reading is the error to be reported.</p> <p>When Z-axis motion causes an angular movement of both spindle head and workholding table, differential measurements of the two angular movements shall be made and this shall be stated. In this case, when using precision levels for measurement, the reference level shall be located on the non-moving component (spindle head or workholding table) of the machine.</p>										

<b>Object</b>	<b>G6</b>									
<p>Checking of angular errors of the Y-axis motion:</p> <p>a) in the vertical YZ plane parallel to the spindle axis (<math>E_{AY}</math>)</p> <p>b) in the vertical XY plane perpendicular to the spindle axis (<math>E_{CY}</math>)</p> <p>c) in the horizontal ZX plane (roll <math>E_{BY}</math>)</p>										
<p><b>Diagram</b></p>										
<p><b>Tolerance</b></p> <p>For a), b), and c)</p> <table style="margin-left: 40px;"> <tr> <td><math>Y \leq 500</math></td> <td>0,040/1 000 or 8 "</td> </tr> <tr> <td><math>500 &lt; Y \leq 1 250</math></td> <td>0,050/1 000 or 10 "</td> </tr> <tr> <td><math>1 250 &lt; Y \leq 3 200</math></td> <td>0,060/1 000 or 12 "</td> </tr> </table> <p>Local tolerance: 0,016/1 000 (or 16 <math>\mu</math>rad or 3,2 ") for a measuring length of 300</p>		$Y \leq 500$	0,040/1 000 or 8 "	$500 < Y \leq 1 250$	0,050/1 000 or 10 "	$1 250 < Y \leq 3 200$	0,060/1 000 or 12 "			
$Y \leq 500$	0,040/1 000 or 8 "									
$500 < Y \leq 1 250$	0,050/1 000 or 10 "									
$1 250 < Y \leq 3 200$	0,060/1 000 or 12 "									
<p><b>Measured deviation</b></p> <p>Y = .....</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; text-align: center;">a)</td> <td style="width: 33%; text-align: center;">b)</td> <td style="width: 33%; text-align: center;">c)</td> </tr> <tr> <td colspan="3">Maximum local deviation:</td> </tr> <tr> <td style="text-align: center;">a)</td> <td style="text-align: center;">b)</td> <td style="text-align: center;">c)</td> </tr> </table>		a)	b)	c)	Maximum local deviation:			a)	b)	c)
a)	b)	c)								
Maximum local deviation:										
a)	b)	c)								
<p><b>Measuring instruments</b></p> <p>a) and b): Precision level or optical angular deviation measuring instruments</p> <p>c) (roll <math>E_{BY}</math>): Cylindrical square, precision level and dial gauge, or precision cube and dial gauges, or sweeping alignment laser</p>										
<p><b>Observations and references to ISO 230-1:2012, 8.4 and 8.4.2</b></p> <p>Measurements shall be taken at least at five positions equally spaced along the travel, in both directions of movement at every position. The difference between the maximum and the minimum reading is the error to be reported.</p> <p>For a) (<math>E_{AY}</math>) and b) (<math>E_{CY}</math>), when Y-axis motion causes an angular movement of both spindle head and workholding table, differential measurements of the two angular movements shall be made and this shall be stated. In this case, when using precision levels for measurement, the reference level shall be located on the non-moving component (spindle head or workholding table) of the machine.</p> <p>For c) (roll <math>E_{BY}</math>), when a sweeping alignment laser is not used, place a cylindrical square (or a precision cube) on the table, approximately parallel to the Y-axis, and set the stylus of a dial gauge mounted on a special arm against the square. Note the readings and mark the corresponding heights on the square. Move the X-axis and move the dial gauge to the other side of the spindle head so that the stylus can touch the square again along the same line. The possible roll deviation of the X-axis motion shall be measured and taken into account (if a precision cube is used, no X-axis motion is required). The dial gauge shall be zeroed again and the new measurements shall be taken at the same heights of the previous ones, then noted. For each measurement height, calculate the difference <math>\Delta</math> of the two readings. The algebraic maximum and minimum of these differences shall be selected and the result of</p> $\frac{\Delta_{\max} - \Delta_{\min}}{d}$ <p>is the error to be reported, "d" being the distance between the two positions of the dial gauge.</p> <p>If a sweeping alignment laser is used, the sweeping plane is to be aligned approximately parallel to the machine XY plane. The measurement procedure is the same as above, where the dial gauge is to be replaced by the laser target and no X-axis motion is required.</p>										

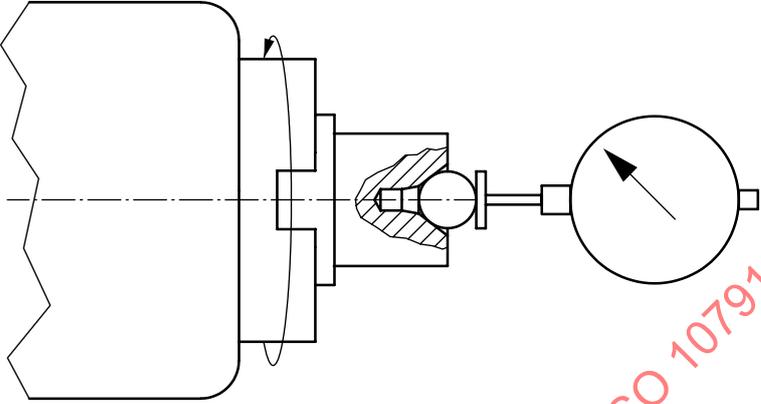
4.3 Squareness errors between linear motions

<b>Object</b>	<b>G7</b>
Checking of $E_{C(0X)Y}$ squareness error of the Y-axis motion to the X-axis motion.	
<p><b>Diagram</b></p> <p>Step 1) <span style="margin-left: 200px;">Step 2)</span></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;"><math>Y \leq 2\,000</math> 0,040/1 000 or 8 “  <math>2\,000 &lt; Y \leq 3\,200</math> 0,050/1 000 or 10 “</p>	
<p><b>Measured deviation</b></p> <p>Y = .....</p>	
<p><b>Measuring instruments</b></p> <p>Straightedge or surface plate, square, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.2</b></p> <p>In step 1), the straightedge or the surface plate shall be set parallel to the X-axis, or the lack of parallelism shall be considered in the measurement.</p> <p>In step 2), the Y-axis shall then be checked by means of a square standing on the straightedge or on the surface plate.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than <math>90^\circ</math>, shall be noted.</p>	

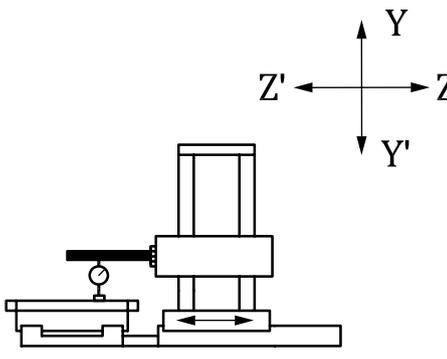
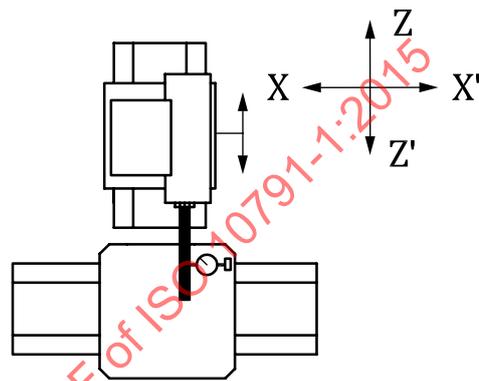
<b>Object</b>	G8
Checking of $E_{A(0Z)Y}$ squareness error of the Y-axis motion to the Z-axis motion	
<p><b>Diagram</b></p> <p>Step 1) </p> <p>Step 2) </p>	
<p><b>Tolerance</b></p> <p style="text-align: center;"><math>Y \leq 2\,000</math> 0,040/1 000 or 8 “</p> <p style="text-align: center;"><math>2\,000 &lt; Y \leq 3\,200</math> 0,050/1 000 or 10 “</p>	
<p><b>Measured deviation</b></p> <p>Y = .....</p>	
<p><b>Measuring instruments</b></p> <p>Straightedge or surface plate, square, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.2</b></p> <p>In step 1), the straightedge or the surface plate shall be set parallel to the Z-axis, or the lack of parallelism shall be considered in the measurement.</p> <p>In step 2), the Y-axis shall then be checked by means of a square standing on the straightedge or on the surface plate.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than <math>90^\circ</math>, shall be noted.</p>	

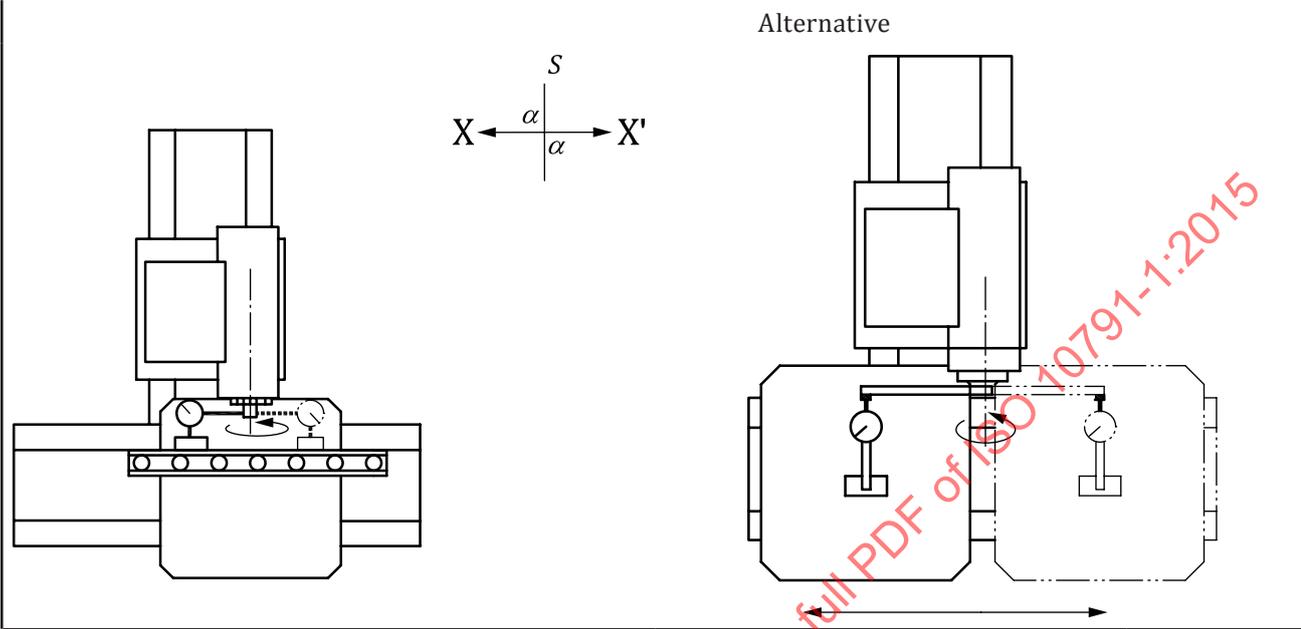
<b>Object</b>	<b>G9</b>
Checking of $E_{B(0X)Z}$ or $E_{B(0Z)X}$ squareness error of the Z-axis motion to the X-axis motion	
<b>Diagram</b>	
<p>Step 1)</p> 	<p>Step 2)</p> 
<p><b>Tolerance</b></p> <p style="text-align: center;">0,040/1 000</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Straightedge, square, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.2</b></p> <p>In step 1), the straightedge shall be set parallel to the X-axis for <math>E_{B(0X)Z}</math> or parallel to the Z-axis for <math>E_{B(0Z)X}</math>, or the lack of parallelism shall be considered in the measurement.</p> <p>In step 2), the Z (or X)-axis shall then be checked by means of a square placed on the table with one side against the straightedge.</p> <p>This test can be performed as well without the straightedge, aligning one arm of the square along one axis and checking the second axis on the other arm of the square.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>The height above the table shall be stated in the test report.</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than <math>90^\circ</math>, shall be noted.</p>	

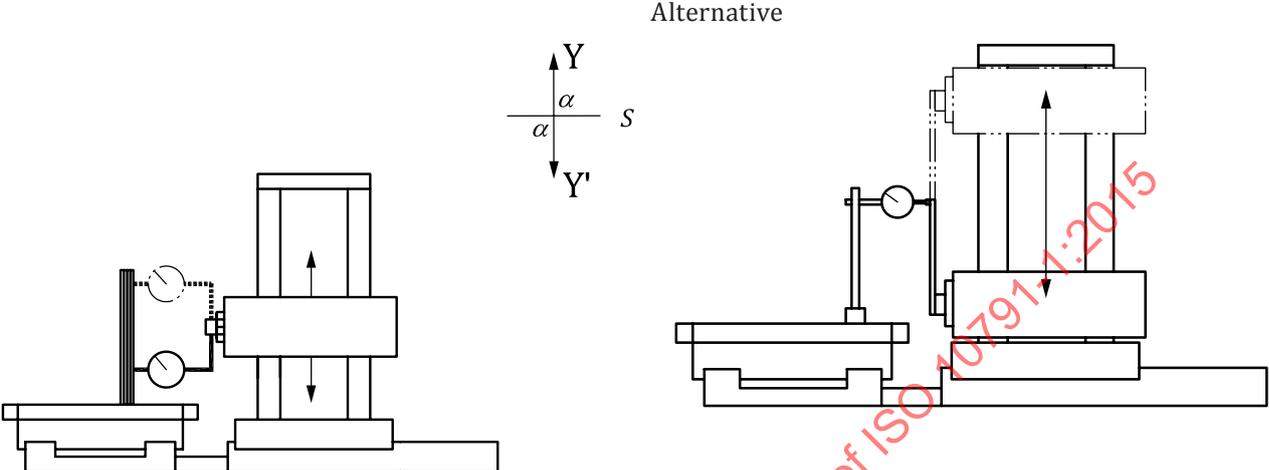
4.4 Spindle

<b>Object</b>	<b>G10</b>
Checking of axial error motion of the spindle.	
<p><b>Diagram</b></p> 	
<b>Tolerance</b>	0,005
<b>Measured deviation</b>	
<b>Measuring instruments</b> Dial gauge with flat ended stylus tip	
<p><b>Observations and references to ISO 230-1:2012, 9.1 (see also ISO 230-7)</b></p> <p>See also test ER1 in <a href="#">Annex E</a>.</p>	



<b>Object</b>	<b>G12</b>
<p>Checking of parallelism error of the spindle axis to the Z-axis motion:</p> <p>a) <math>E_{A(OZ)(C)}</math> in the vertical YZ plane</p> <p>b) <math>E_{B(OZ)(C)}</math> in the horizontal ZX plane</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p>for a) and b)</p> <p>0,050/1 000 (0,015/300)</p> <p>(or 0,050 μrad or 10")</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="float: right;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Test mandrel and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 3.6.2, 10.1.4, and 10.1.4.3</b></p> <p>Z-axis in centre of the travel.</p> <p>The signs of the parallelism errors in both planes shall be reported.</p>	

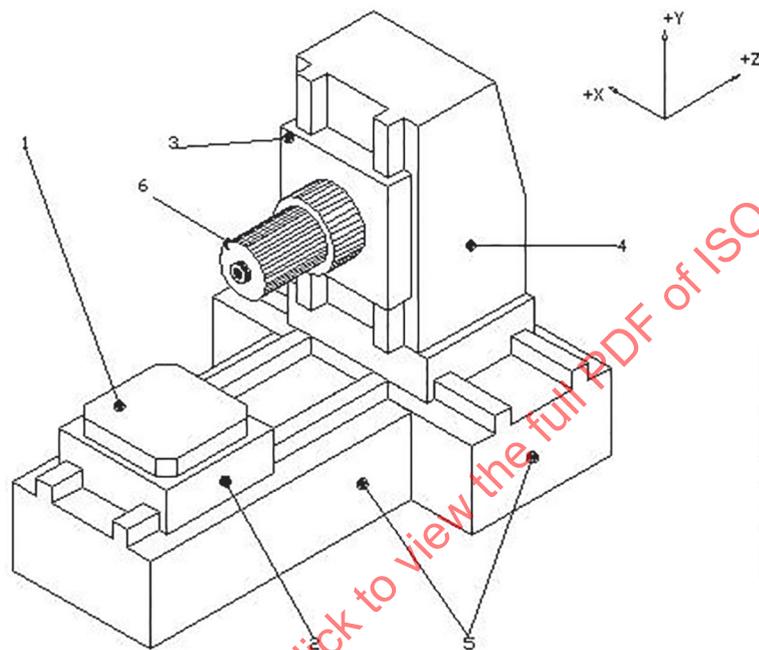
<b>Object</b>	<b>G13</b>
Checking of $E_{B(0X)(C)}$ squareness error of the spindle axis to the X-axis motion.	
<p><b>Diagram</b></p>  <p>The diagram illustrates two measurement setups. On the left, a dial gauge is mounted on a straightedge that is parallel to the X-axis. On the right, labeled 'Alternative', a dial gauge is mounted on a special arm fixed to the spindle. A central diagram shows the spindle axis S and the X-axis, with an angle <math>\alpha</math> between them.</p>	
<p><b>Tolerance</b></p> <p>0,050/1 000 (0,015/300) (or 0,050 <math>\mu</math>rad or 10")</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Straightedge, special arm, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>Z-axis to be locked, if possible (see 3.9).</p> <p>The straightedge shall be set parallel to the X-axis, or the lack of parallelism shall be considered in the measurement.</p> <p>This test can also be performed without the straightedge, by mounting the dial gauge on the table and touching with the stylus a point on a special arm fixed on the spindle, thus making the reading easier. The spindle axis shall be rotated 180° and the X-axis shall be moved in order to make the stylus touch the special arm in the same point. In this case, the measurement is influenced by the <math>E_{ZX}</math> horizontal straightness error of the X-axis.</p> <p>The squareness error obtained with this test can be cross checked with the results of tests G9 and G12 b).</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than 90°, shall be reported.</p>	

<b>Object</b>	<b>G14</b>
Checking of $E_{A(0Y)(C)}$ squareness error of the spindle axis to the Y-axis motion.	
<p><b>Diagram</b></p>  <p style="text-align: center;">Alternative</p>	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,050/1 000 (0,015/300) (or 0,050 <math>\mu</math>rad or 10")</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Square, special arm, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>Z-axis to be locked, if possible (see 3.9).</p> <p>The measurement side of the square should be set parallel to the Y-axis, or the lack of parallelism shall be considered in the measurement. The special arm shall be stiff enough so as to prevent any possible reading errors due to its opposite deflections in the two measurement positions.</p> <p>This test can also be performed without the square by placing the dial gauge support on the table and touching with the stylus a point on a special arm fixed on the spindle, thus, avoiding any possible deflection of the dial gauge arm and making the reading easier. The spindle axis shall be rotated 180° and the Y-axis shall be moved in order to make the stylus touch the special arm in the same point. In this, case the measurement is influenced by the <math>E_{ZY}</math> straightness error of the Y-axis.</p> <p>The squareness error obtained with this test can be cross checked with the results of tests G8 and G12 a).</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than 90°, shall be reported.</p>	

## Annex A (normative)

### Horizontal non-rotating tables

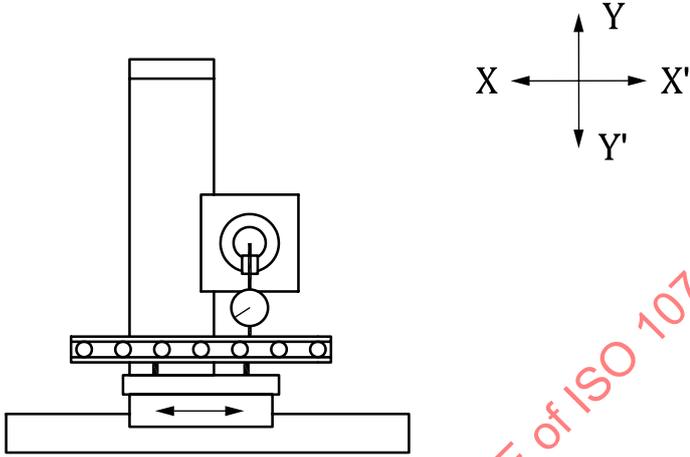
Figure A.1 hereunder shows a typical example of a machining centre with horizontal spindle and a horizontal non-rotating table.

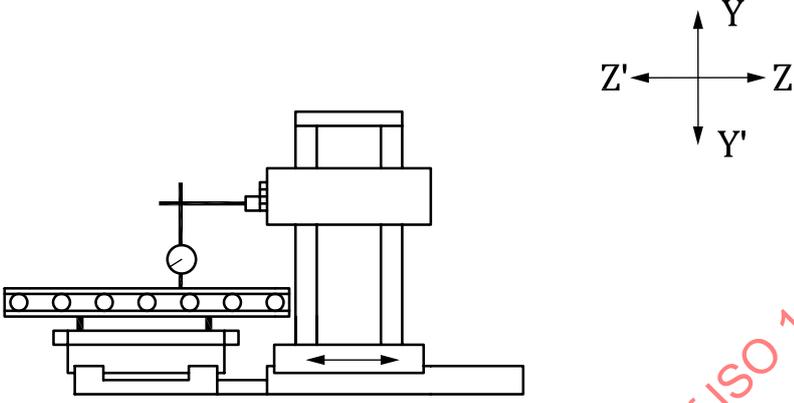


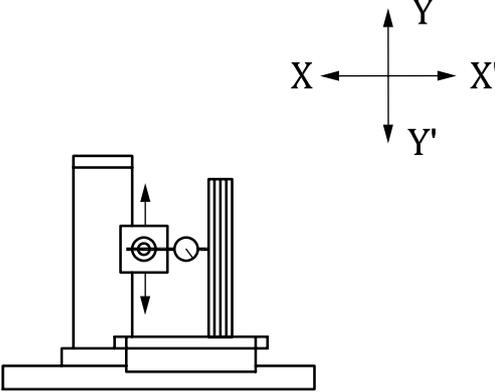
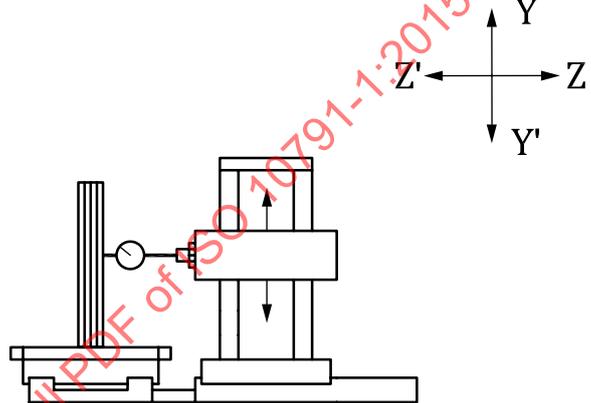
**Key**

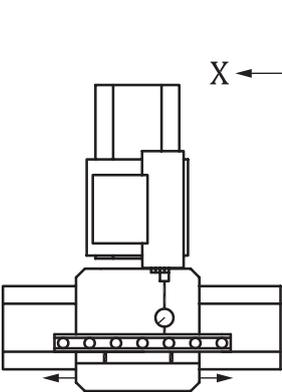
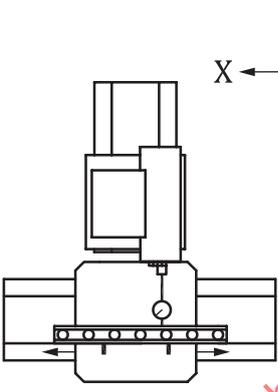
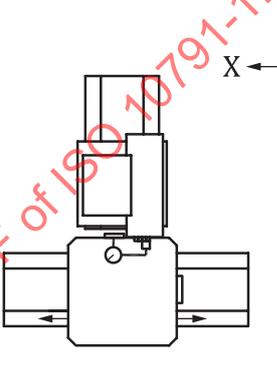
- 1 table
- 2 table saddle (Z'-axis)
- 3 spindle head (Y-axis )
- 4 column (X-axis)
- 5 bed (b)
- 6 spindle [(C)]

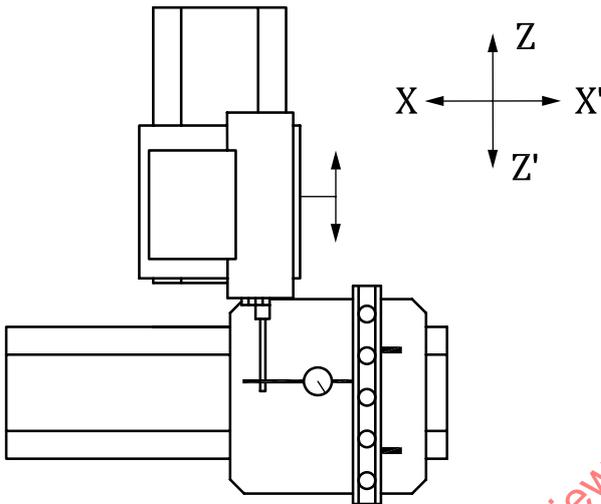
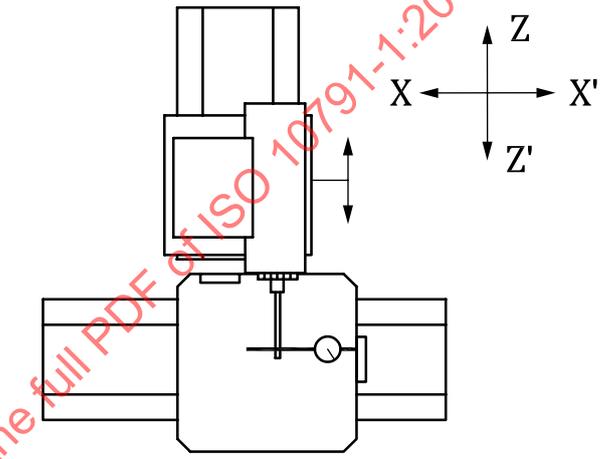
**Figure A.1** — Typical example of horizontal machining centre with a non-rotating Table Machining centre ISO 10791-1 H [w Z' b X Y (C) t] (see 3.12)

<b>Object</b>	<b>AG1</b>										
Checking of $E_{C(OX)T}$ parallelism error of the table <sup>1)</sup> surface to the X-axis motion 1) Built-in table or one representative non-rotary pallet clamped in position											
<b>Diagram</b> 											
<b>Tolerance</b> <table style="margin-left: 40px;"> <tr> <td><math>L \leq 500</math></td> <td>0,020</td> </tr> <tr> <td><math>500 &lt; L \leq 800</math></td> <td>0,025</td> </tr> <tr> <td><math>800 &lt; L \leq 1\ 250</math></td> <td>0,030</td> </tr> <tr> <td><math>1\ 250 &lt; L \leq 2\ 000</math></td> <td>0,040</td> </tr> <tr> <td><math>2\ 000 &lt; L \leq 3\ 200</math></td> <td>0,060</td> </tr> </table> Where $L$ is the table length in the X direction		$L \leq 500$	0,020	$500 < L \leq 800$	0,025	$800 < L \leq 1\ 250$	0,030	$1\ 250 < L \leq 2\ 000$	0,040	$2\ 000 < L \leq 3\ 200$	0,060
$L \leq 500$	0,020										
$500 < L \leq 800$	0,025										
$800 < L \leq 1\ 250$	0,030										
$1\ 250 < L \leq 2\ 000$	0,040										
$2\ 000 < L \leq 3\ 200$	0,060										
<b>Measured deviation</b> For $L = \dots\dots\dots$											
<b>Measuring instruments</b> Straightedge, equal height spacer blocks, and dial gauge											
<b>Observations and references to ISO 230-1:2012, 12.3.2.5</b> The stylus of the dial gauge is to be placed approximately at the working position of the tool. The measurement can be made on a straightedge laid parallel to the table surface. If the table is ground and new, or freshly re-conditioned, the dial gauge stylus can directly touch the table surface. If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine. For this test, the difference between the maximum and the minimum reading of the dial gauge is the error to be reported.											

<b>Object</b>	<b>AG2</b>								
Checking of $E_{A(0Z)T}$ parallelism error of the table <sup>1)</sup> surface to the Z-axis motion. 1) Built-in table or one representative non-rotary pallet clamped in position.									
<b>Diagram</b> 									
<b>Tolerance</b> <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;"><math>W \leq 500</math></td> <td style="text-align: center;">0,020</td> </tr> <tr> <td style="text-align: center;"><math>500 &lt; W \leq 800</math></td> <td style="text-align: center;">0,025</td> </tr> <tr> <td style="text-align: center;"><math>800 &lt; W \leq 1\ 250</math></td> <td style="text-align: center;">0,030</td> </tr> <tr> <td style="text-align: center;"><math>1\ 250 &lt; W \leq 2\ 000</math></td> <td style="text-align: center;">0,040</td> </tr> </table> Where W is the table width in the Z direction		$W \leq 500$	0,020	$500 < W \leq 800$	0,025	$800 < W \leq 1\ 250$	0,030	$1\ 250 < W \leq 2\ 000$	0,040
$W \leq 500$	0,020								
$500 < W \leq 800$	0,025								
$800 < W \leq 1\ 250$	0,030								
$1\ 250 < W \leq 2\ 000$	0,040								
<b>Measured deviation</b> For W = .....									
<b>Measuring instruments</b> Straightedge, equal height spacer blocks, and dial gauge									
<b>Observations and references to ISO 230-1:2012, 10.3, 10.3.3, and 12.3.2.5</b> Y-axis to be locked, if possible. The stylus of the dial gauge is to be placed approximately at the working position of the tool. The measurement can be made on a straightedge laid parallel to the table surface. If the table is ground and new or freshly re-conditioned, the dial gauge stylus can directly touch the table surface. If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine. For this test, the difference between the maximum and the minimum reading of the dial gauge is the error to be reported.									

<b>Object</b>	<b>AG3</b>
<p>Checking of squareness error of the table<sup>1)</sup> surface to the Y-axis motion:</p> <p>a) <math>E_{C(OY)T}</math> in the vertical XY plane perpendicular to the spindle axis</p> <p>b) <math>E_{A(OY)T}</math> in the vertical YZ plane parallel to the spindle axis</p> <p>1) Built-in table or one representative non-rotary pallet clamped in position.</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p>for a) and b)</p> <p>0,050/1 000 (= 0,015/300)</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="float: right;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Surface plate, square or cylindrical square, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.4.5</b></p> <p>a) X-axis to be locked, if possible.</p> <p>b) Z-axis to be locked, if possible.</p> <p>The surface plate shall be located on the centre of the table and a square or cylindrical square shall be placed on it. If a surface plate is not used, the squareness error can be heavily affected by any small imperfection of the table surface under the narrow base of a square or cylindrical square. In this case, this test is to be carried out only on ground and new or freshly re-conditioned tables.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>The squareness errors measured with this test can be cross checked with the results of the following tests:</p> <p>for a), tests G7 and AG1;</p> <p>for b), tests G8 and AG2.</p>	

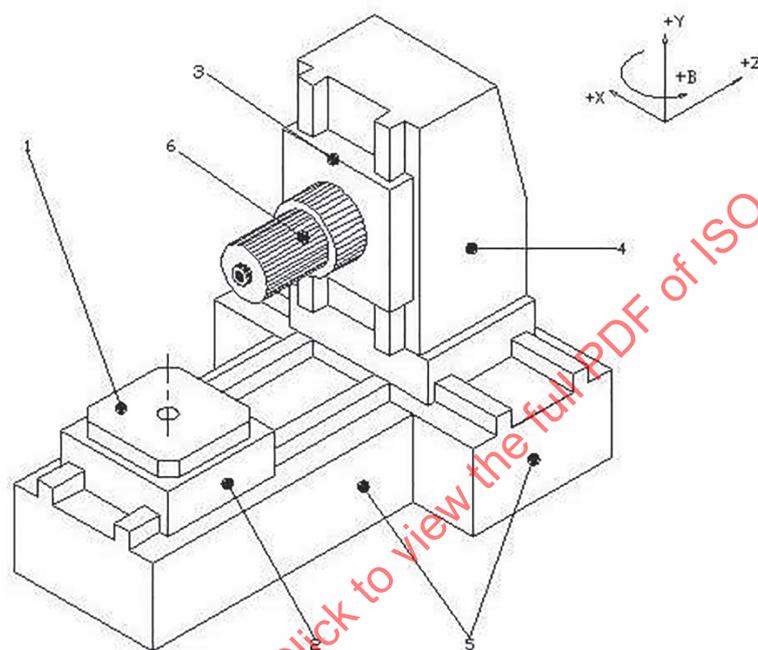
<b>Object</b>	<b>AG4</b>
<p>Checking of <math>E_{B(0X)T}</math> parallelism error of:</p> <p>a) the longitudinal median or reference T-slot, or</p> <p>b) the centre line of the alignment holes (if longitudinal), or</p> <p>c) the longitudinal edge locator</p> <p>of the table<sup>1)</sup> to the X-axis motion.</p> <p>1) Built-in table or one representative non-rotary pallet clamped in position.</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p> <p>c) </p>	
<p><b>Tolerance</b></p> <p>for a), b), and c)</p> <p>0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p>	
<p>Gauge blocks or master pins and dial gauge.</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>Z-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the centre of the table. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p>	

Object	AG5
<p>Checking of <math>E_{B(0Z)T}</math> parallelism error of</p> <p>a) the centre line of the alignment holes (if transverse), or</p> <p>b) the transverse edge locator</p> <p>of the table<sup>1)</sup> to the Z-axis motion.</p> <p>1) Built-in table or one representative non-rotary pallet clamped in position.</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p>for a) and b)</p> <p>0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge blocks or master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>X-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a cross tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the centre of the table. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p>	

## Annex B (normative)

### Tables rotating around a vertical B' axis

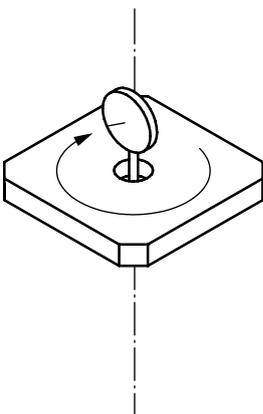
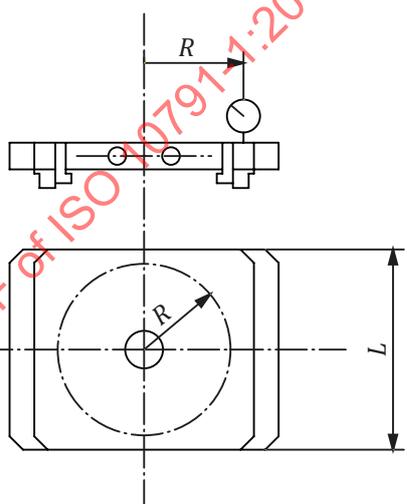
Figure B.1 hereunder shows a typical example of a machining centre with horizontal spindle and a horizontal table rotating around a vertical B' axis.

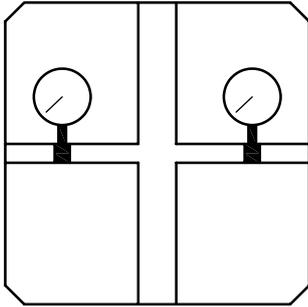
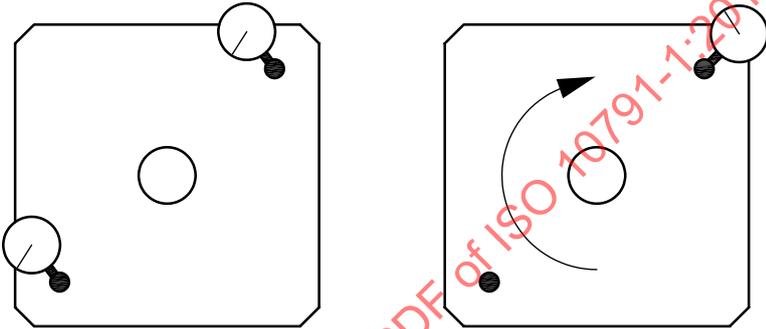


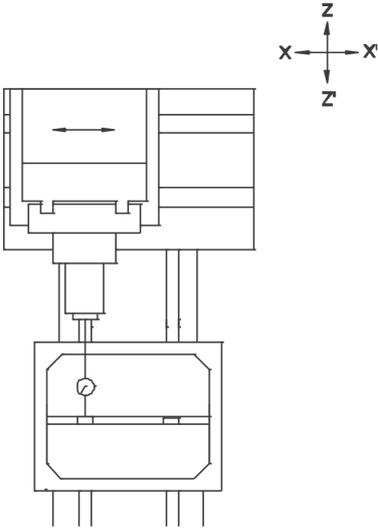
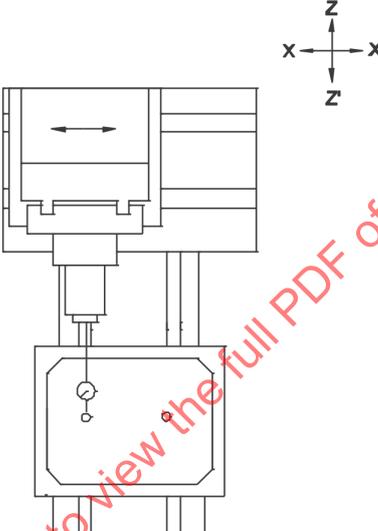
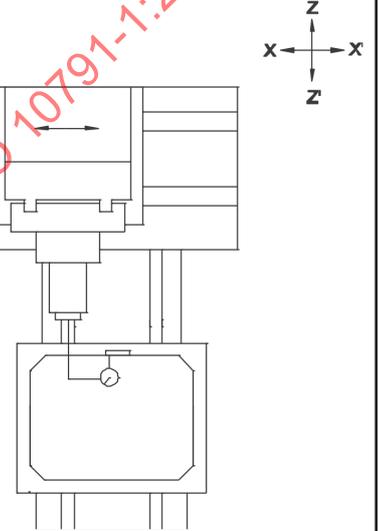
#### Key

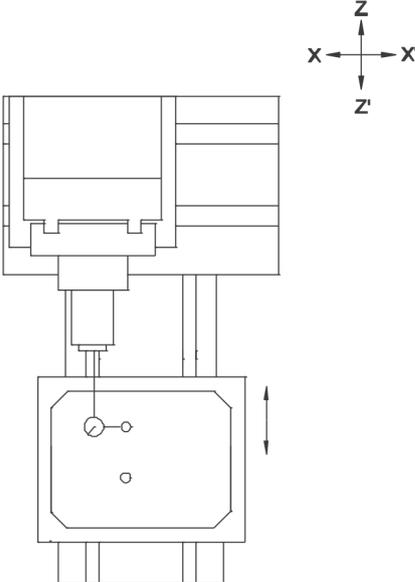
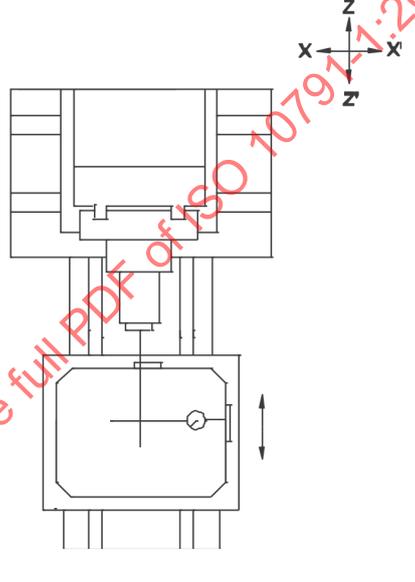
- 1 table
- 2 table saddle (Z'-axis)
- 3 spindle head (Y-axis)
- 4 column (X-axis)
- 5 bed (b)
- 6 spindle [(C)]

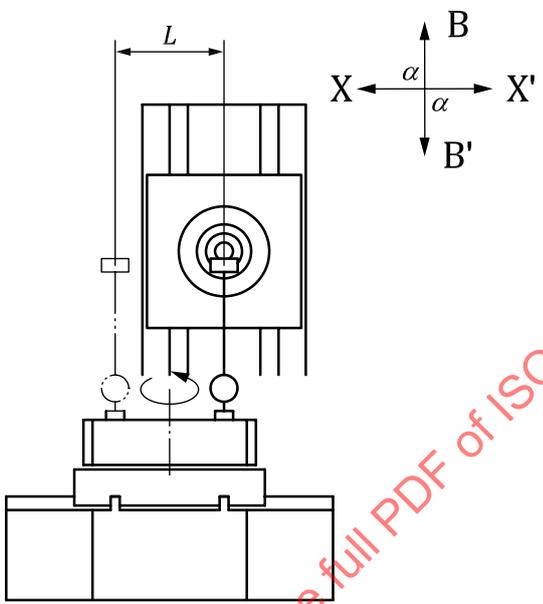
**Figure B.1** — Typical example of horizontal machining centre with a non-rotating Table Machining centre ISO 10791-1 H [w B' Z' b X Y (C) t] (see 3.12)

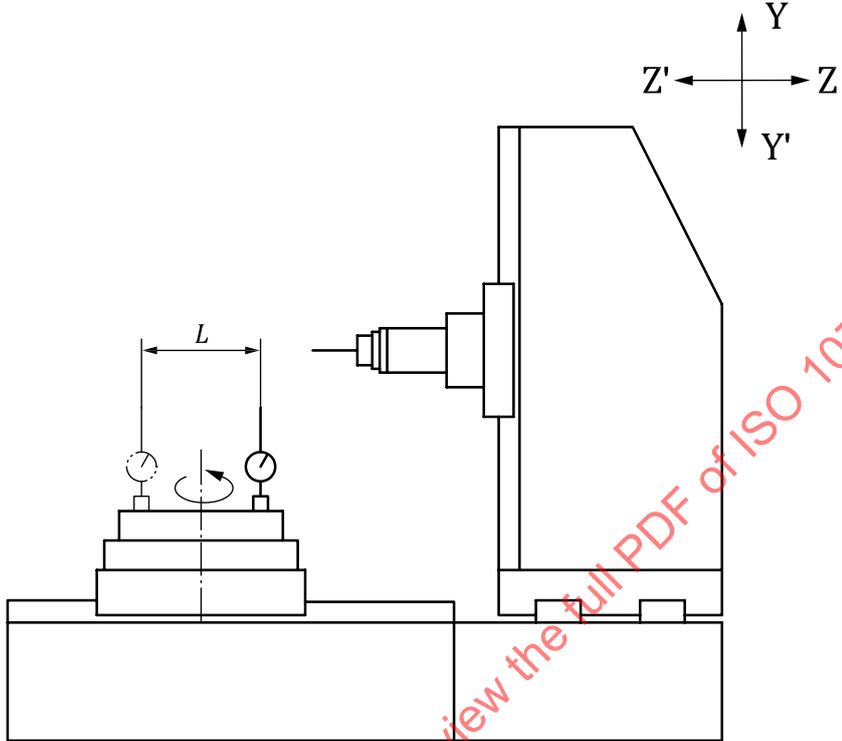
<b>Object</b>	<b>BG1</b>								
<p>Checking of:</p> <p>a) run-out of the centre hole of the table<sup>1)</sup> (when the centre hole is used for locating purposes);</p> <p>b) face error motion of the table<sup>1)</sup> surface<sup>2)</sup>.</p> <p>1) Built-in rotary table or one representative pallet clamped in position</p> <p>2) For indexing tables, check at least four positions at 90° from each other</p>									
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>									
<p><b>Tolerance</b></p> <p>a) 0,025</p> <p>b)</p> <table border="0" data-bbox="638 1243 917 1422"> <tr> <td><math>L \leq 500</math></td> <td>0,030</td> </tr> <tr> <td><math>500 &lt; L \leq 800</math></td> <td>0,040</td> </tr> <tr> <td><math>800 &lt; L \leq 1\,250</math></td> <td>0,050</td> </tr> <tr> <td><math>1\,250 &lt; L \leq 2\,000</math></td> <td>0,060</td> </tr> </table> <p>where <math>L</math> is the length of the shorter side of the table or pallet.</p>		$L \leq 500$	0,030	$500 < L \leq 800$	0,040	$800 < L \leq 1\,250$	0,050	$1\,250 < L \leq 2\,000$	0,060
$L \leq 500$	0,030								
$500 < L \leq 800$	0,040								
$800 < L \leq 1\,250$	0,050								
$1\,250 < L \leq 2\,000$	0,060								
<p><b>Measured deviation</b></p> <p>For <math>L =</math></p> <p>a) b)</p>									
<p><b>Measuring instruments</b></p> <p>a) dial gauge</p> <p>b) gauge blocks and dial gauge</p>									
<p><b>Observations and references to ISO 230-1:2012, 12.5.2 and 12.5.2.3</b></p> <p>a) If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>b) The radius <math>R</math> shall be as large as possible. Test b) can also be carried out without continuous contact between stylus and table surface, by using an intermediate gauge block and measuring in discrete positions (e.g. 8 points at 45° steps).</p> <p>See also test ER2 in <a href="#">Annex E</a>, especially if the rotary table is foreseen for turning operations.</p>									

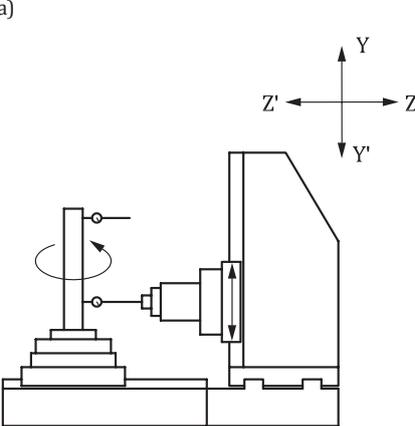
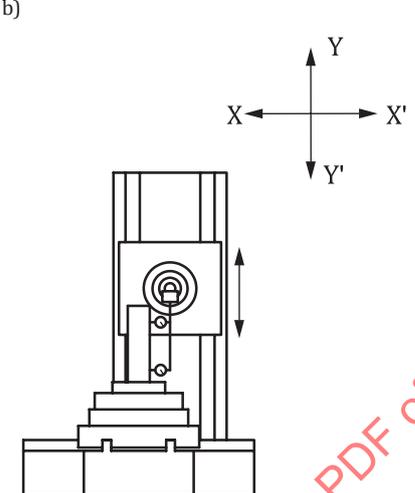
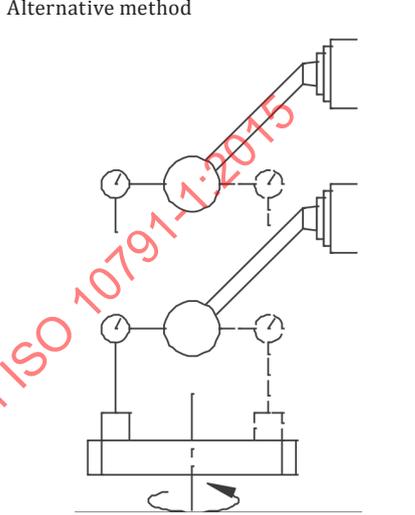
<b>Object</b>	<b>BG2</b>
<p>Checking of:</p> <p>a) intersection of the centre line of the longitudinal median T-slot, or of the cross tenon slot (when existing) or the line between the alignment holes, with the B'-axis of rotation of the table.</p> <p>b) equidistance of the alignment holes with the B'-axis of rotation of the table<sup>1)</sup>.</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p>For a) and b) 0,030</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="float: right;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>a) gauge blocks or master pins and dial gauge</p> <p>b) master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1.</b></p> <p>a) When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the axis of rotation. Adjust the B'-axis in order to have the T-slot parallel to the X-axis (or Z-axis). Parallel means that the two readings on the gauge blocks are the same. The dial gauge, placed on a fixed part of the spindle head, is then zeroed. Turn the table by 180° and again adjust the B'-axis in order to have the same readings on both gauge blocks, without resetting the dial gauge. Half of the new reading on the dial gauge is the error to be reported.</p> <p>When the alignment holes are provided, two master pins which fit in the holes and have protruding parts of the same diameter shall be used instead of the gauge blocks. The same procedure as above is then to be followed.</p> <p>b) The readings to be compared are the maximum radial readings on each master pin, which can also not precisely correspond to readings at 180° from each other, because of the deviation read in a).</p>	

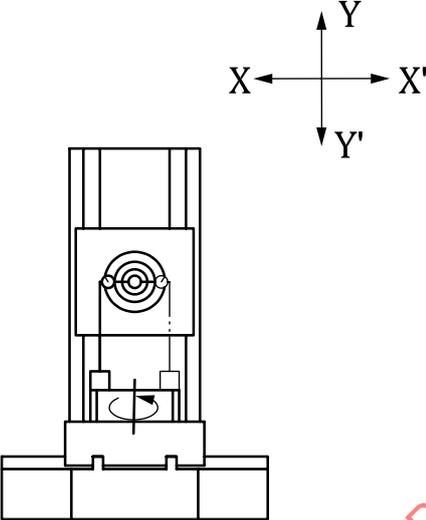
Object	BG3
<p>Checking of <math>E_{B(0X)T}</math> parallelism error of:</p> <ul style="list-style-type: none"> <li>a) the longitudinal median or reference T-slot, or</li> <li>b) the centre line of the alignment holes (if longitudinal), or</li> <li>c) the longitudinal edge locator</li> </ul> <p>of the table<sup>1)</sup>, with <math>B' = 0^\circ</math>, to the X-axis motion.</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>	
<p><b>Diagram</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>a)</p>  </div> <div style="text-align: center;"> <p>b)</p>  </div> <div style="text-align: center;"> <p>c)</p>  </div> </div>	
<p><b>Tolerance</b></p> <p style="text-align: center;">for a), b), and c)</p> <p style="text-align: center;">0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <ul style="list-style-type: none"> <li>a) gauge block and dial gauge</li> <li>b) master pins and dial gauge</li> <li>c) dial gauge</li> </ul>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>Z-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the <math>B'</math>-axis of rotation. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p><b>NOTE</b> The result of this tests includes the possible <math>E_{BB}</math> positioning deviation of the <math>B'</math>-axis at <math>0^\circ</math>.</p>	

<b>Object</b>	<b>BG4</b>
<p>Checking of <math>E_{B(0Z)T}</math> parallelism error of</p> <p>a) the centre line of the alignment holes (if transverse), or</p> <p>b) the transverse edge locator</p> <p>of the table<sup>1)</sup> with <math>B' = 0^\circ</math> to the Z-axis motion.</p> <p><sup>1)</sup> Built-in rotary table or one representative pallet clamped in position.</p>	
<p><b>Diagram</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>a)</p>  </div> <div style="text-align: center;"> <p>b)</p>  </div> </div>	
<p><b>Tolerance</b></p> <p style="text-align: center;">for a) and b)</p> <p style="text-align: center;">0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>a) master pins and dial gauge</p> <p>b) dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>X-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a cross tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the centre of the table. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p><b>NOTE</b> The result of this tests includes the possible <math>E_{BB}</math> positioning deviation of the <math>B'</math>-axis at <math>0^\circ</math>.</p>	

<b>Object</b>	<b>BG5</b>
Checking of $E_{C(OX)B}$ squareness error of the B' axis of rotation of the table <sup>1)</sup> , or receiver, to the X-axis motion 1) Built-in rotary table or any pallet clamped in position	
<b>Diagram</b> 	
<b>Tolerance</b> $0,030/1\,000 (= 0,015/500)$	
<b>Measured deviation</b>	
<b>Measuring instruments</b> Gauge block and dial gauge	
<b>Observations and references to ISO 230-1</b> Y-axis to be locked, if possible. Place a gauge block on one edge of the table, in the X direction apart from the axis of rotation; fix the dial gauge on the spindle, if it can be locked, or on the spindle head; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by 180° and move the X-axis until the stylus again touches the gauge block in the same point. The dial gauge reading, divided by the X displacement, is the error to be reported. Note the direction of the error. The sign convention of the error shall correspond to the squareness sign between B' and X-axes according to ISO 230-1:2012, 3.6.7, Note 2. This test might be influenced by the $E_{YX}$ vertical straightness error of the X-axis. The value of angle $\alpha$ , being less than, equal to or greater than 90°, shall be noted. The squareness error obtained with this test can be cross checked with the results of tests G7 and BG10 b).	

<b>Object</b>	<b>BG6</b>
Checking of $E_{A(0Z)_B}$ squareness error of the B'-axis of rotation of the table, or receiver, to the Z-axis motion	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;"><math>0,030/1\,000 (= 0,015/500)</math></p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge block and dial gauge</p>	
<p><b>Observations and references to ISO 230-1</b></p> <p>Y-axis to be locked, if possible.</p> <p>Place a gauge block on one edge of the table, in the Z direction apart from the axis of rotation; fix the dial gauge on the spindle, if it can be locked, or on the spindle head; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by 180° and move the Z-axis until the stylus again touches the gauge block. The dial gauge reading, divided by the Z displacement, is the error to be reported.</p> <p>The value of angle <math>\alpha</math>, 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 B' and Z-axes according to ISO 230-1:2012, 3.6.7, Note 2.</p> <p>This test might be influenced by the <math>E_{YZ}</math> vertical straightness error of the Z-axis.</p> <p>The squareness error obtained with this test can be cross checked with the results of tests G8 and BG10 a).</p>	

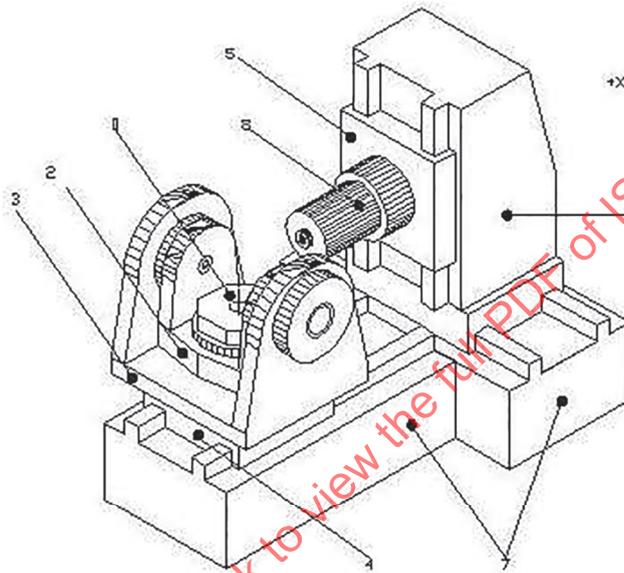
<b>Object</b>	<b>BG7</b>
<p>Checking of parallelism error of the B'-axis of rotation of the table, or receiver, to the Y-axis motion:</p> <p>a) <math>E_{A(0Y)B}</math> in the vertical YZ plane</p> <p>b) <math>E_{C(0Y)B}</math> in the vertical XY plane</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p> <p>Alternative method </p>	
<p><b>Tolerance</b></p> <p>For a) and b) 0,040/1 000 (= 0,020/500)</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="margin-left: 300px;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Cylinder square with flange base, or test sphere as an alternative, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 3.6.3, 10.1.4, 10.1.4.3, or 10.1.4.4 as alternative</b></p> <p>a) Z-axis to be locked, if possible.</p> <p>b) X-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <ol style="list-style-type: none"> <li>Fix a cylinder square with a flange base on the table, and centre it on approximately on the axis of rotation.</li> <li>Fix the dial gauge on the spindle head with the stylus oriented in the Z-axis direction for a) and X-axis direction for b).</li> <li>Touch the cylinder square by the stylus, close to the cylinder bottom, and find the maximum reading by small movements along the X-axis for a) and along Z-axis for b). Zero the dial gauge.</li> <li>Move the head apart from the table along the Y-axis, and touch again the cylinder close to its top. Note the Y travel length. Find the maximum dial gauge reading by small movements along the X-axis for a) and along Z-axis for b) and note the new dial gauge reading.</li> <li>Turn the table by 180°, and repeat steps 3) and 4).</li> <li>For both measurements a) and b), the average value (half the algebraic sum) of the two dial gauge readings on top of the cylinder, divided by the Y travel length, is the error to be reported. The sign convention of the error shall correspond to the parallelism sign between B' and Y-axis according to ISO 230-1:2012, 3.6.3 Note 2.</li> </ol> <p>Alternative method. A test sphere shall be mounted on the spindle head of the machine and the dial gauge shall be mounted on the table. The test sphere shall be centred with respect to the B'-axis average line by moving X and Z-axes, while rotating the B'-axis. The Y-axis shall then be moved to another location. The dial gauge is re-positioned to read against the test sphere at this new location. The error in the centre position shall be recorded as half the difference of the readings of the dial gauge at opposite points on the sphere. This alternative method can be used when it is possible to touch a complete horizontal circumference of the sphere.</p> <p>See also test ER2 in <a href="#">Annex E</a>, especially if the rotary table is foreseen for turning operations.</p>	

<b>Object</b>	<b>BG8</b>
Checking that the B'-axis of rotation of the table and the spindle axis lie in the same YZ plane at a predefined position (i.e. measuring the $E_{X(0(C))B}$ deviation in the X direction)	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,010</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Test mandrel and dial gauge</p>	
<p><b>Observations and references to ISO 230-1</b></p> <ol style="list-style-type: none"> <li>1) Move the X-axis by numerical control to the central position where the B'-axis of rotation of the table and the spindle axis should lie in the same YZ plane.</li> <li>2) Fix the test mandrel in the spindle, and the dial gauge on the table with the stylus parallel to the table surface in radial direction.</li> <li>3) With the dial gauge stylus oriented in the X-axis direction touch the test mandrel, close to the spindle nose, and find the maximum reading by small movements along the Y-axis. Zero the dial gauge.</li> <li>4) Move up the head along the Y direction, in order to take the test mandrel off the dial gauge. Turn both the table and the spindle by 180°, and again bring the test mandrel into contact with the dial gauge by means of Y-axis movements.</li> <li>5) Find the maximum reading by small movements along the Y-axis.</li> <li>6) Half of the new reading on the dial gauge is the error to be reported.</li> </ol> <p>NOTE 1 If this test is carried out in different positions of the Z-axis it is affected by the <math>E_{B(0Z)(C)}</math> parallelism error between the spindle axis and the Z-axis and by the <math>E_{XZ}</math> horizontal straightness error of the Z-axis.</p> <p>NOTE 2 If this test is carried out in different positions of the Y-axis it is affected by the <math>E_{C(0Y)B}</math> parallelism error between the B' axis of rotation of the table and the Y-axis and by the <math>E_{XY}</math> straightness error of the Y-axis.</p>	

## Annex C (normative)

### Tables rotating around a vertical B' axis and tilting around a horizontal A' axis

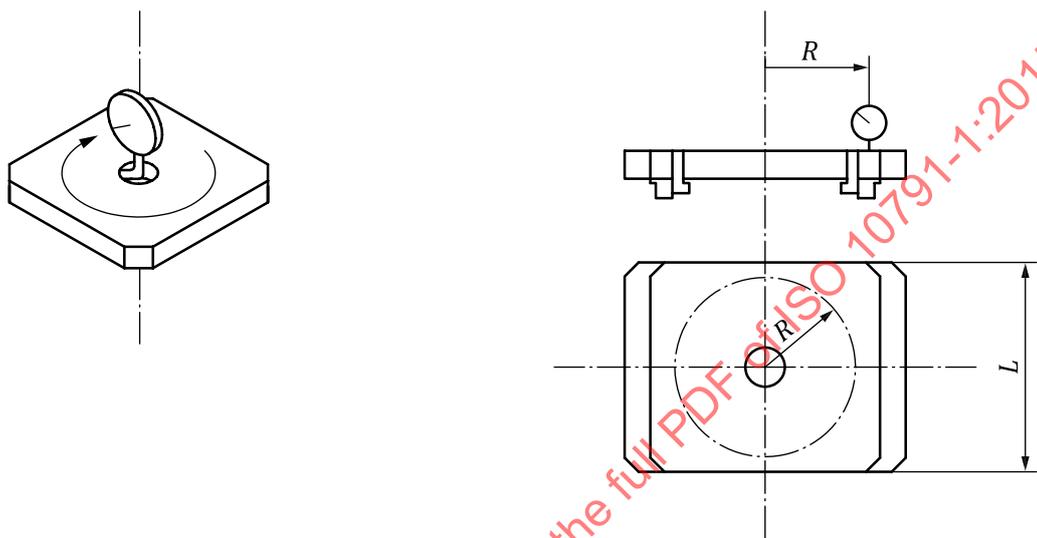
Figure C.1 hereunder shows a typical example of a machining centre with horizontal spindle and a table rotating around a B' axis and tilting around a horizontal A' axis.

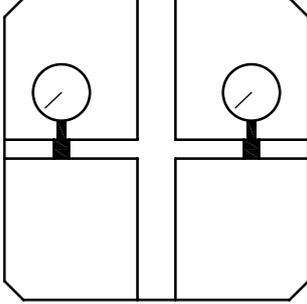
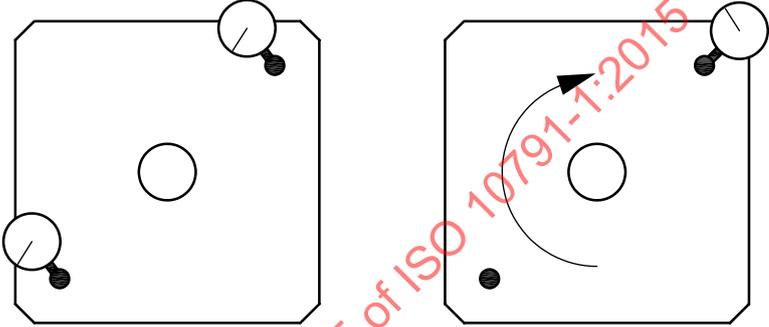


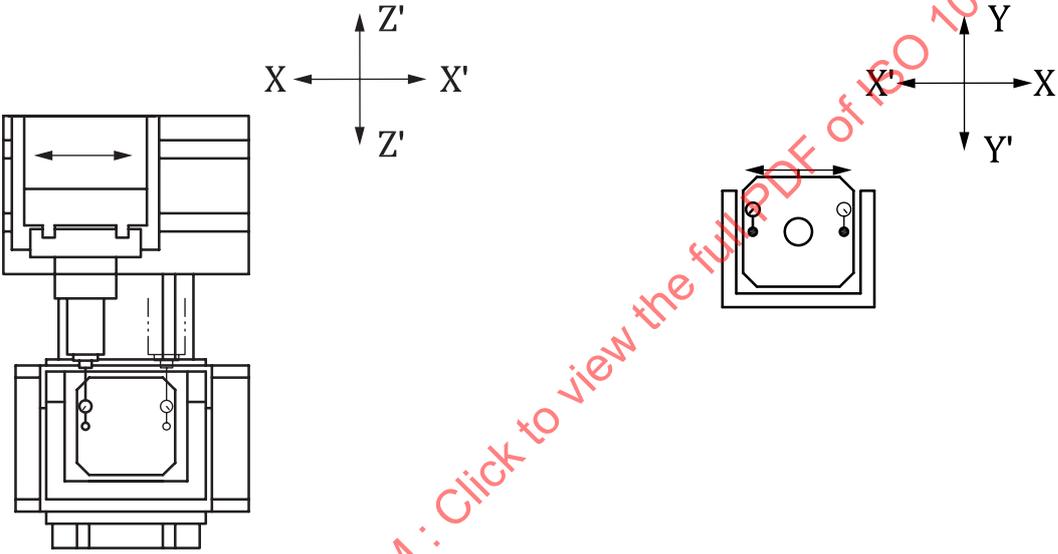
#### Key

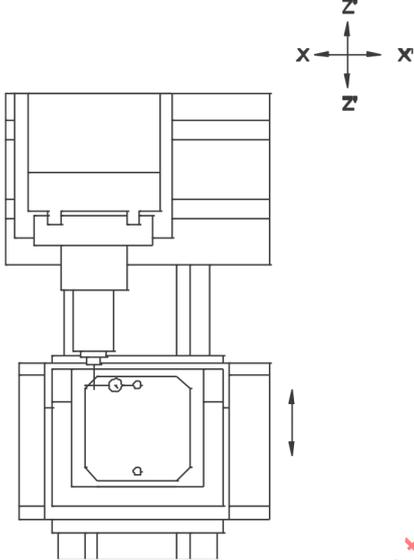
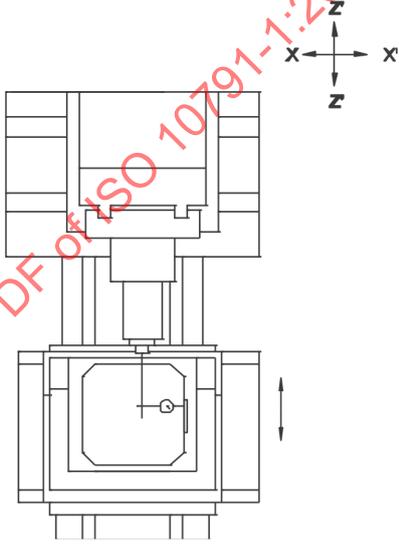
- 1 rotary table (B'-axis)
- 2 cradle (A'-axis)
- 3 trunnion
- 4 table saddle (Z'-axis)
- 5 spindle head (Y-axis)
- 6 column (X-axis)
- 7 bed (b)
- 8 spindle [(C)]

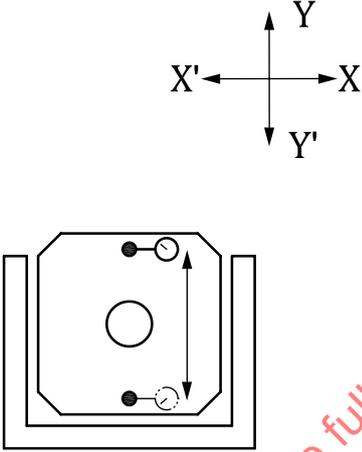
**Figure C.1 — Typical example of horizontal five-axis machining centre with a table rotating around a vertical B' axis and tilting around a horizontal A' axis**  
Machining centre ISO 10791-1 H [w B' A' Z' b X Y (C) t] (see 3.12)

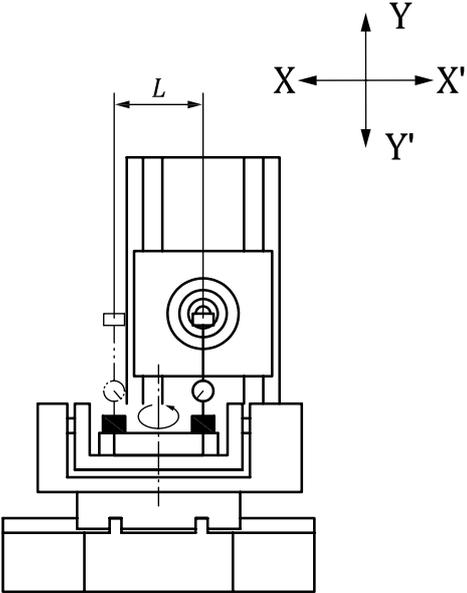
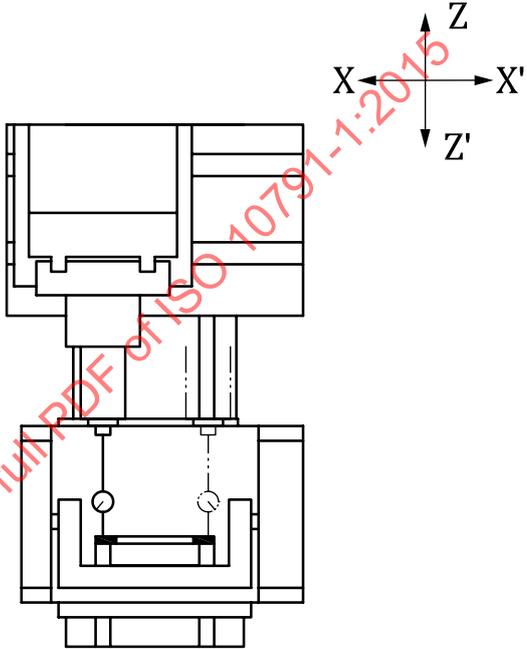
<b>Object</b>	<b>CG1</b>
<p>Checking of</p> <p>a) run-out of the centre hole of the table (when the centre hole is used for locating purposes)</p> <p>b) face error motion of the table<sup>1)</sup> surface</p> <p>1) Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p>  <p>a) b)</p>	
<p><b>Tolerance</b></p> <p>a) 0,025</p> <p>b) <math>L \leq 500</math> 0,030  <math>500 &lt; L \leq 800</math> 0,040  <math>800 &lt; L \leq 1\ 250</math> 0,050  <math>1\ 250 &lt; L \leq 2\ 000</math> 0,060</p> <p>where <math>L</math> is the length of the shorter side of the table or pallet.</p>	
<p><b>Measured deviation</b></p> <p>For <math>L = \dots\dots\dots</math></p> <p>a) b)</p>	
<p><b>Measuring instruments</b></p> <p>a) Dial gauge b) Gauge blocks and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 9.1 (see also ISO 230-7)</b></p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>b) The radius <math>R</math> shall be as large as possible. Test b) can also be carried out without continuous contact between stylus and table surface, by using an intermediate gauge block and measuring in discrete positions (e.g. 8 points at 45° steps).</p> <p>See also test FR1 in <a href="#">Annex F</a>.</p>	

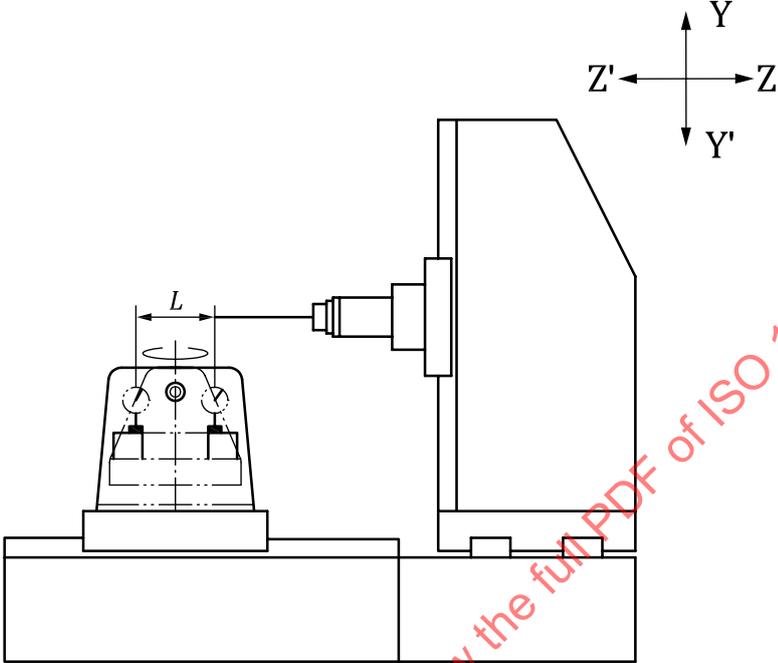
<b>Object</b>	<b>CG2</b>
<p>Checking of</p> <p>a) intersection of the centre line of the longitudinal median T-slot, or of the cross tenon slot (when existing) or the line between the alignment holes, with the B'-axis of rotation of the table.</p> <p>b) equidistance of the alignment holes with the B'-axis of rotation of the table.</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p style="text-align: center;">For a) and b) 0,030</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="float: right;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>a) Straightedge, gauge blocks or master pins, and dial gauge</p> <p>b) Master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1</b></p> <p>a) When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the axis of rotation. Adjust the B'-axis in order to have the T-slot parallel to the X-axis (or Z-axis). Parallel means that the two readings on the gauge blocks are the same. The dial gauge, placed on a fixed part of the spindle head, is then zeroed. Turn the table by 180° and again adjust the B'-axis in order to have the same readings on both gauge blocks, without resetting the dial gauge. Half of the new reading on the dial gauge is the error to be reported.</p> <p>When the alignment holes are provided, two master pins which fit in the holes and have protruding parts of the same diameter shall be used instead of the gauge blocks. The same procedure as above is then to be followed.</p> <p>b) The readings to be compared are the maximum radial readings on each master pin, which might also not precisely correspond to readings at 180° from each other, because of the deviation read in a).</p>	

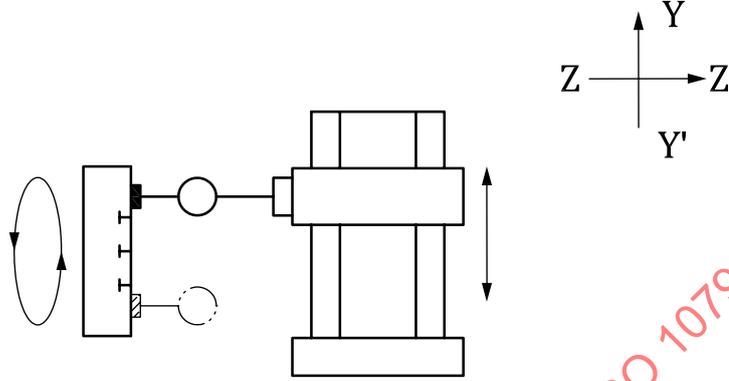
<b>Object</b>	<b>CG3</b>
<p>Checking of parallelism error of</p> <ul style="list-style-type: none"> <li>— the longitudinal median or reference T-slot, or</li> <li>— the centre line of the alignment holes (if longitudinal), or</li> <li>— the longitudinal edge locator of the table<sup>1)</sup>, with <math>B' = 0^\circ</math>,</li> </ul> <p>to the X-axis motion:</p> <p>a) <math>E_{B(0X)T}</math> with the table in the horizontal position (<math>A' = 0^\circ</math>)</p> <p>b) <math>E_{C(0X)T}</math> with the table in the vertical position (<math>A' = -90^\circ</math>)</p> <p><sup>1)</sup> Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p> <p>a) <span style="margin-left: 300px;">b)</span></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">for all types</p> <p style="text-align: center;">0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="margin-left: 300px;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Gauge blocks or master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>a) Z-axis to be locked, if possible.</p> <p>b) Y-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the <math>A'</math>-axis of rotation. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p>NOTE The result of this test includes the possible <math>E_{BB}</math> positioning error of the <math>B'</math>-axis at <math>0^\circ</math>.</p>	

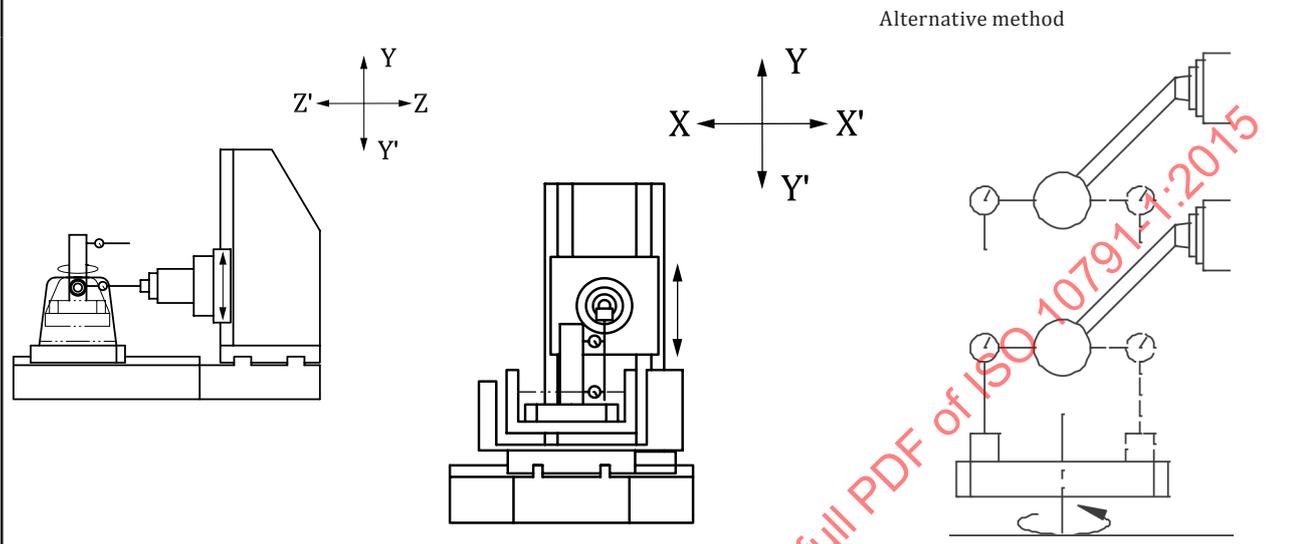
<b>Object</b>	<b>CG4</b>
<p>Checking of <math>E_{B(0Z)T}</math> parallelism error of</p> <ul style="list-style-type: none"> <li>— the centre line of the alignment holes (if transverse), or</li> <li>— the transverse edge locator of the table<sup>1)</sup> in horizontal position (<math>A' = 0^\circ</math>), with <math>B' = 0^\circ</math>,</li> </ul> <p>to the Z-axis motion</p> <p>1) Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>a)</p>  </div> <div style="text-align: center;"> <p>b)</p>  </div> </div>	
<b>Measured deviation</b>	
<b>Measuring instruments</b>	
Gauge blocks or master pins and dial gauge	
<b>Observations and references to ISO 230-1:2012, 12.3.2.5</b>	
<p>X-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a cross tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the centre of the table. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p>The result of this test includes the possible <math>E_{BB}</math> positioning error of the <math>B'</math>-axis at <math>0^\circ</math>.</p>	

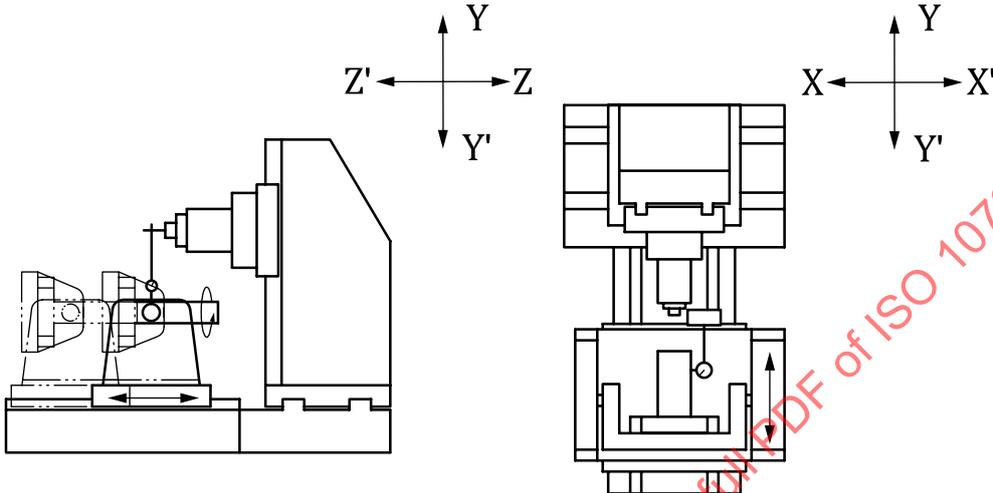
<b>Object</b>	<b>CG5</b>
<p>Checking of <math>E_{C(0Y)T}</math> parallelism error of</p> <ul style="list-style-type: none"> <li>— the centre line of the alignment holes (if transverse), or</li> <li>— the transverse edge locator of the table<sup>1)</sup> in vertical position (<math>A' = -90^\circ</math>), with <math>B' = 0^\circ</math>,</li> </ul> <p>to the Y-axis motion</p> <p><sup>1)</sup> Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge blocks or master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>X-axis locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a cross tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the centre of the table. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p>The result of this test includes the possible <math>E_{BB}</math> positioning error of the <math>B'</math>-axis at <math>0^\circ</math>.</p>	

<b>Object</b>	CG6
<p>Checking of squareness error of the <math>B'</math>-axis of rotation of the table, or receiver, to the X-axis motion:</p> <p>a) <math>E_{C(0X)B}</math> table in the horizontal position (<math>A' = 0^\circ</math>)</p> <p>b) <math>E_{B(0Y)B, A' = -90}</math> with the table in the vertical position (<math>A' = -90^\circ</math>)</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p>For a) and b) 0,040/1 000</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="float: right;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Gauge block and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>a) Y-axis to be locked, if possible.</p> <p>b) Z-axis to be locked, if possible.</p> <p>Place a gauge block on one edge of the table, in the X direction apart from the axis of rotation; fix the dial gauge on the spindle, if it can be locked, or on the spindle head; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by <math>180^\circ</math> and move the X-axis until the stylus again touches the gauge block in the same point. The dial gauge reading, divided by the X displacement, is the error to be reported.</p> <p>Note the direction of the error. The sign convention of the error shall correspond to the squareness sign according to ISO 230-1:2012, 3.6.7, Note 2.</p> <p>Test a) might be influenced by the <math>E_{YX}</math> vertical straightness error of the X-axis, and test b) by the <math>E_{ZX}</math> horizontal straightness error of the X-axis.</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than <math>90^\circ</math>, shall be noted.</p>	

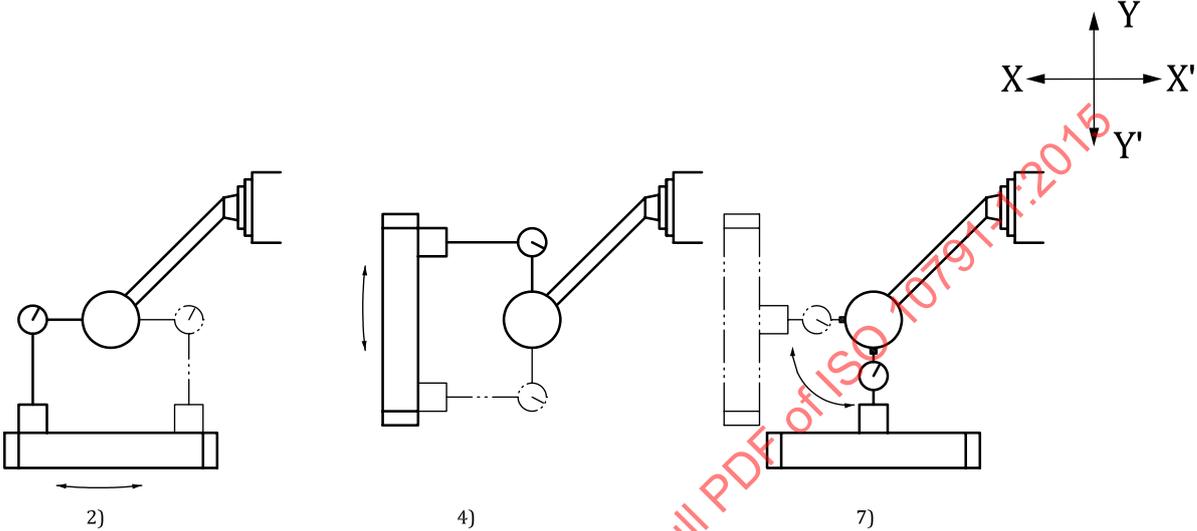
<b>Object</b>	CG7
Checking of $E_{A(0Z)B}$ squareness error of the B'-axis of rotation of the table, or receiver, in the horizontal position ( $A' = 0^\circ$ ), to the Z-axis motion	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,040/1 000</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge block and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>Y-axis locked, if possible.</p> <p>Place a gauge block on one edge of the table, in the Z-direction apart from the axis of rotation; fix the dial gauge on the spindle, if it can be locked, or on the spindle head; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by <math>180^\circ</math> and move the Z-axis until the stylus again touches the gauge block in the same point.</p> <p>The dial gauge reading, divided by the Z displacement, is the error to be reported.</p> <p>Note the direction of the error. The sign convention of the error shall correspond to the squareness sign between B' and Z-axes according to ISO 230-1:2012, 3.6.7, Note 2.</p> <p>The result of this test includes the possible <math>E_{AA}</math> positioning error of the A'-axis at <math>0^\circ</math>.</p> <p>This test might be influenced by the <math>E_{YZ}</math> vertical straightness error of the Z-axis.</p>	

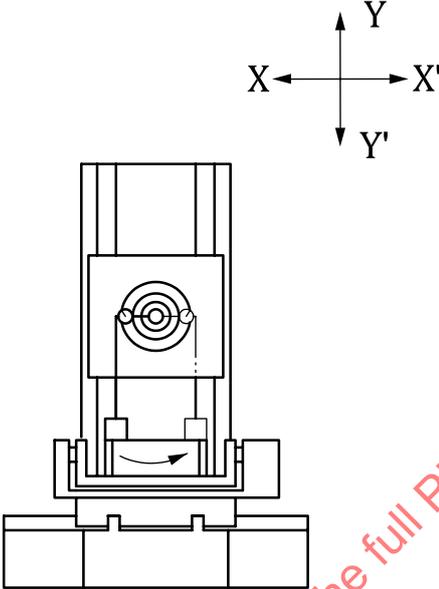
<b>Object</b>	<b>CG8</b>
Checking of squareness error $E_{A(0Y)B, A' = -90}$ of the B'-axis of rotation of the table, or receiver, in the vertical position ( $A' = -90^\circ$ ), to the Y-axis motion	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,040/1 000</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge block and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>Z-axis locked, if possible.</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 spindle, if it can be locked, or on the spindle head; 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 again touches the gauge block in the same point.</p> <p>The dial gauge reading, divided by the Y displacement, is the error to be reported.</p> <p>Note the direction of the error. The sign convention of the error shall correspond to the squareness sign according to ISO 230-1:2012, 3.6.7, Note 2.</p> <p>The result of this test includes the possible <math>E_{AA}</math> positioning error of the A'-axis at <math>-90^\circ</math>.</p> <p>This test might be influenced by the <math>E_{ZY}</math> straightness error of the Y-axis.</p>	

<b>Object</b>	CG9
Checking of parallelism error of the B'-axis of rotation of the table, or receiver, in the horizontal position ( $A' = 0^\circ$ ), to the Y-axis motion:	
a) $E_{A(0Y)B}$ in the vertical YZ plane b) $E_{C(0Y)B}$ in the vertical XY plane	
<b>Diagram</b> 	
<b>Tolerance</b>	
For a) and b) 0,040/1 000 (= 0,020/500)	
<b>Measured deviation</b>	
a) b)	
<b>Measuring instrument</b>	
Cylinder square with flange base, or test sphere as an alternative, and dial gauge	
Observations and references to ISO 230-1:2012, 3.6.3, 10.1.4, 10.1.4.3, or 10.1.4.4 as alternative	
a) Z-axis to be locked, if possible. The result of test a) includes the possible $E_{AA}$ positioning error of the A'-axis at $0^\circ$ . b) X-axis to be locked, if possible. 1) Fix a cylinder square with a flange base on the table, and centre it on approximately on the axis of rotation. 2) Fix the dial gauge on the spindle head with the stylus oriented in the Z-axis direction for a) and X-axis direction for b). 3) Touch the cylinder square by the stylus, close to the cylinder bottom, and find the maximum dial gauge reading by small movements along the X-axis for a) and along Z-axis for b). Zero the dial gauge. 4) Move the head apart from the table along the Y-axis, and touch again the cylinder close to its top. Note the Y travel length. Find the maximum dial gauge reading by small movements along the X-axis for a) and along Z-axis for b) and note the new reading. 5) Turn the table by $180^\circ$ , and repeat steps 3) and 4). 6) For both measurements a) and b), the average value (half the algebraic sum) of the two dial gauge readings on top of the cylinder, divided by the Y travel length, is the error to be reported. The sign convention of the error shall correspond to the parallelism sign between B' and Y-axis according to ISO 230-1:2012, 3.6.3 Note 2.	
Alternative method. A test sphere shall be mounted on the spindle head of the machine and the dial gauge shall be mounted on the table. The test sphere shall be centred with respect to the B'-axis average line by moving X and Z-axes, while rotating the B'-axis. The Y-axis shall then be moved to another location. The dial gauge is re-positioned to read against the test sphere at this new location. The error in the centre position shall be recorded as half the difference of the readings of the dial gauge at opposite points on the sphere. This alternative method can be used when it is possible to touch a complete horizontal circumference of the sphere.	

<b>Object</b>	<b>CG10</b>
<p>Checking of parallelism error of the B'-axis of rotation of the table, or receiver, in the vertical position (<math>A' = -90^\circ</math>), to the Z-axis motion:</p> <p>a) <math>E_{A(0Z)B}</math> in the vertical YZ plane</p> <p>b) <math>E_{B(0Z)B}</math> in the horizontal ZX plane</p>	
<p><b>Diagram</b></p>  <p>NOTE: Alternative method mentioned in CG9 is not used to fixturing difficulties.</p>	
<p><b>Tolerance</b></p> <p>For a) and b) <math>0,050/1\ 000 (= 0,025/500)</math></p>	
<p><b>Measured deviation</b></p> <p>a) <span style="margin-left: 200px;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Cylinder square with flange base, or test sphere as an alternative, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 3.6.3, 10.1.4, 10.1.4.3, or 10.1.4.4 as alternative</b></p> <p>a) Y-axis to be locked, if possible. The result of test a) includes the possible <math>E_{AA}</math> positioning error of the <math>A'</math>-axis at <math>-90^\circ</math>.</p> <p>b) X-axis to be locked, if possible.</p> <ol style="list-style-type: none"> <li>1) Fix a cylinder square with a flange base on the table, and centre it on approximately on the axis of rotation.</li> <li>2) Fix the dial gauge on the spindle head with the stylus oriented in the Y-axis direction for a) and X-axis direction for b).</li> <li>3) Touch the cylinder square by the stylus, close to the cylinder bottom, and find the maximum dial gauge reading by small movements along the X-axis for a) and along Y-axis Y-axis for b). Zero the dial gauge.</li> <li>4) Move the head apart from the table along the Z-axis, and touch again the cylinder close to its top. Note the Z travel length. Find the maximum dial gauge reading by small movements along the X-axis for a) and along Y-axis Y-axis for b) and note the new dial gauge reading.</li> <li>5) Turn the table by <math>180^\circ</math>, and repeat steps 3) and 4).</li> <li>6) For both measurements a) and b), the average value (half the algebraic sum) of the two dial gauge readings on top of the cylinder, divided by the Z travel length, is the error to be reported. The sign convention of the error shall correspond to the parallelism sign between B' and Z-axis according to ISO 230-1:2012, 3.6.3 Note 2.</li> </ol>	



<b>Object</b>	<b>CG12</b>
<p>Checking that the <math>B'</math>-axis of the table rotation and the <math>A'</math>-axis of the cradle tilting lie in the same plane (for table surfaces lower than the <math>A'</math>-axis) <math>E_{Z(0A)B}</math> (only for machines with nominally zero offset between <math>A'</math> and <math>B'</math>-axis and without compensation facilities for any offset deviation)</p>	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,03</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p>	
<p>Test sphere and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.4.3</b></p> <ol style="list-style-type: none"> <li>1) Fix the sphere support in the spindle, if it can be locked, or on the spindle head. Fix the dial gauge on the table with the stylus parallel to the table surface in radial direction.</li> <li>2) With the table in horizontal position (<math>A' = 0^\circ</math>), align the <math>B'</math>-axis of the table rotation on the sphere centre, by means of rotations around <math>B'</math> and adjustments along X and Z.</li> <li>3) Lock the X- and Z-axes.</li> <li>4) Turn the table to the vertical position (<math>A' = -90^\circ</math>) and again align the <math>B'</math>-axis of the table rotation on the sphere centre, by means of rotations around <math>B'</math> and adjustments along Y.</li> <li>5) Lock the Y-axis.</li> <li>6) With the table in horizontal position (<math>A' = 0^\circ</math>), place a dial gauge, with flat tip, on top of the table, with the stylus oriented in the vertical direction, touch the sphere and zero the dial gauge.</li> <li>7) Turn the table to the vertical position (<math>A' = -90^\circ</math>) and note the dial gauge reading.</li> </ol> <p>Half of the new reading on the dial gauge is the error to be reported. Note the direction of the error.</p> <p>The dial gauge arm shall be stiff enough so as to prevent any possible reading errors due to its opposite deflections in the different measurement positions.</p>	

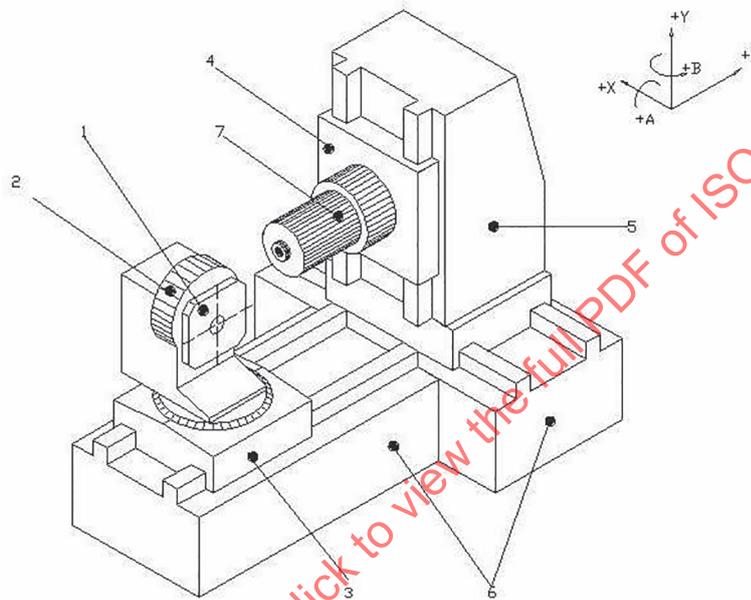
<b>Object</b>	<b>CG13</b>
<p>Checking that the B'-axis of rotation of the table and the spindle axis lie in the same YZ plane at a predefined position, with the table in the horizontal position (<math>A' = 0^\circ</math>) (i.e. measuring the <math>E_{X[0(C)]B}</math> deviation in the X direction)</p>	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,010</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Test mandrel and dial gauge</p>	
<p><b>Observations and references to ISO 230-1</b></p> <ol style="list-style-type: none"> <li>1) Adjust the A'-axis of the cradle rotation until the B'-axis of the table rotation is perpendicular to the Z-axis.</li> <li>2) Move the X-axis to the central position where the B'-axis of rotation of the table and the spindle axis should lie in the same YZ plane.</li> <li>3) Fix the test mandrel in the spindle and the dial gauge on the table with the stylus parallel to the table surface in radial direction.</li> <li>4) With the dial gauge stylus oriented in the X-axis direction touch the test mandrel, close to the spindle nose, and find the maximum dial gauge reading by small movements along the Y-axis. Zero the dial gauge.</li> <li>5) Move up the head along the Y direction, in order to take the test mandrel off the dial gauge. Turn both the table and the spindle by <math>180^\circ</math>, and again bring the test mandrel into contact with the dial gauge by means of Y-axis movements.</li> <li>6) Find the maximum dial gauge reading by small movements along the Y-axis.</li> <li>7) Half of the new reading on the dial gauge is the error to be reported.</li> </ol> <p>NOTE 1 If this test is carried out in different positions of the Z-axis it is affected by the <math>E_{B(0Z)(C)}</math> parallelism error between the spindle axis and the Z-axis and by the <math>E_{XZ}</math> horizontal straightness error of the Z-axis.</p> <p>NOTE 2 If this test is carried out in different positions of the Y-axis it is affected by the <math>E_{C(0Y)B}</math> parallelism error between the B' axis of rotation of the table and the Y-axis and by the <math>E_{XY}</math> straightness error of the Y-axis.</p>	



## Annex D (normative)

### Tables rotating around a horizontal $A'$ axis and swivelling around a vertical $B'$ axis

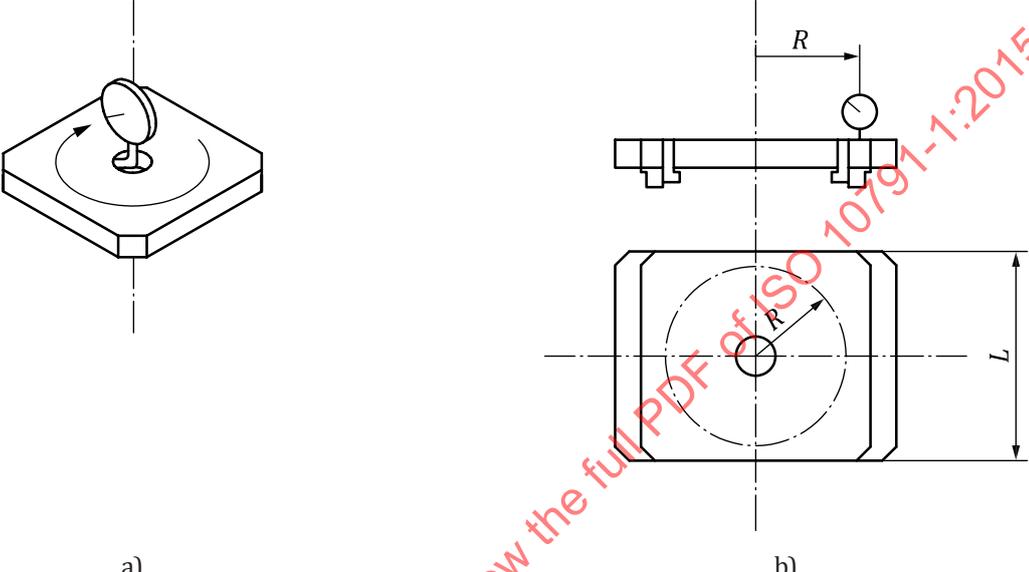
Figure D.1 shows a typical example of a machining centre with horizontal spindle and a vertical table, rotating around a horizontal  $A'$  axis and tilting around a vertical  $B'$  axis.

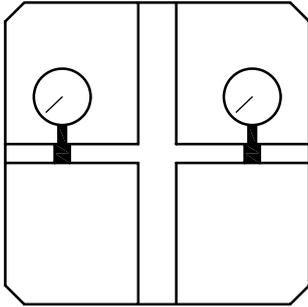
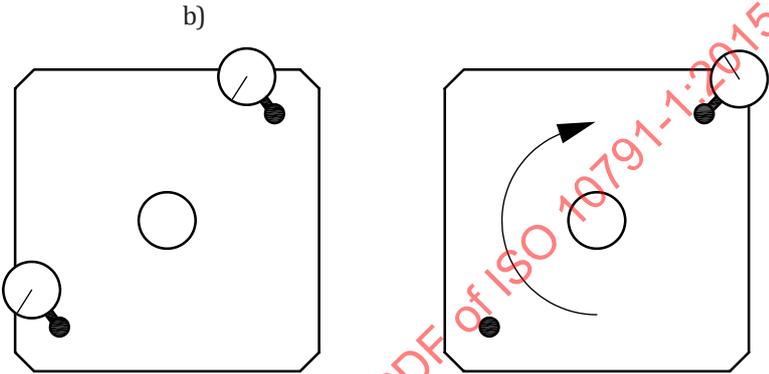


**Key**

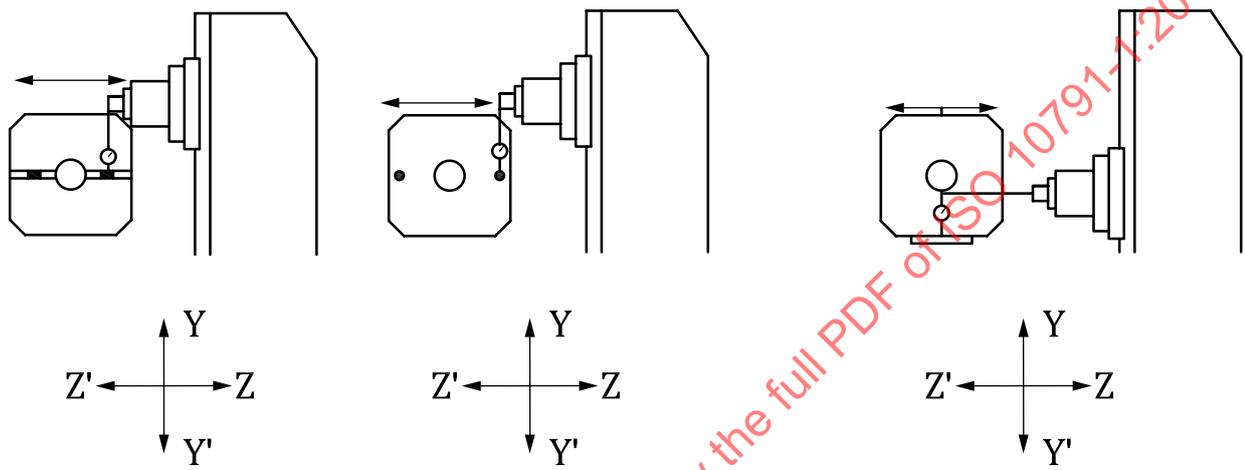
- 1 rotary table ( $A'$ -axis)
- 2 swivelling table ( $B'$ -axis)
- 3 table saddle ( $Z'$ -axis)
- 4 spindle head ( $Y$ -axis )
- 5 column ( $XX$ -axis )
- 6 bed (b)
- 7 spindle [(C)]

**Figure D.1**— Typical example of horizontal five-axis machining centre with a vertical table rotating around a horizontal  $A'$  axis and tilting around a vertical  $B'$  axis  
Machining centre ISO 10791-1 H [w  $A'$   $B'$   $Z'$  b X Y (C) t] (see 3.12)

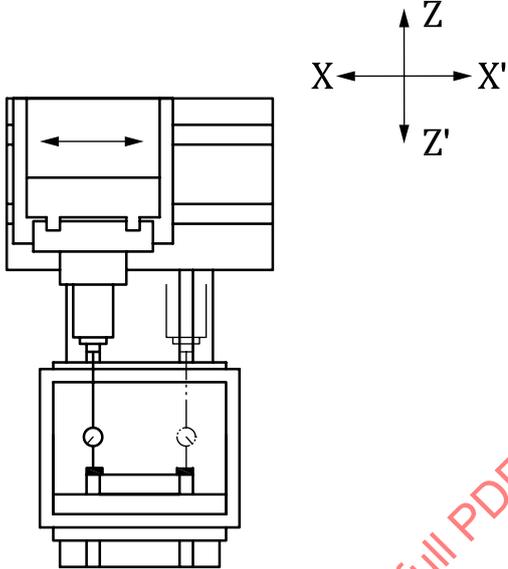
<b>Object</b>	<b>DG1</b>
<p>Checking of</p> <p>a) run-out of the centre hole of the table<sup>1)</sup> (when the centre hole is used for locating purposes), and</p> <p>b) face error motion of the table<sup>1)</sup> surface.</p> <p>1) Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p>  <p>a) b)</p>	
<p><b>Tolerance</b></p> <p>a) 0,025</p> <p>b) <math>L \leq 500</math> 0,030</p> <p><math>500 &lt; L \leq 800</math> 0,040</p> <p><math>800 &lt; L \leq 1\ 250</math> 0,050</p> <p><math>1\ 250 &lt; L \leq 2\ 000</math> 0,060</p> <p>where <math>L</math> is the length of the shorter side of the table or pallet.</p>	
<p><b>Measured deviation</b></p> <p>For <math>L = \dots</math></p> <p>a) b)</p>	
<p><b>Measuring instruments</b></p> <p>a) Dial gauge b) Gauge blocks and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 9.1 (see also ISO 230-7)</b></p> <p>For a) and b), if the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>For b), the radius <math>R</math> shall be as large as possible. Test b) can also be carried out without continuous contact between stylus and table surface, by using an intermediate gauge block and measuring in discrete positions (e.g. 8 points at 45° steps).</p> <p>See also test GR1 in <a href="#">Annex G</a>.</p>	

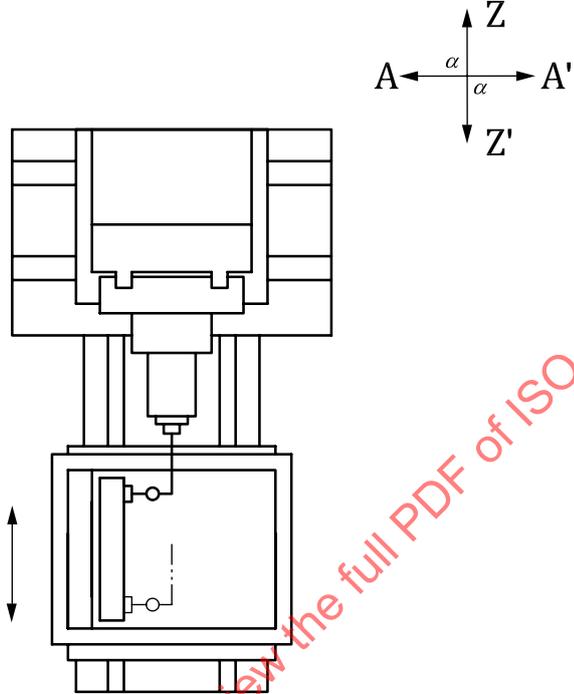
Object	DG2
<p>Checking of</p> <p>a) intersection of the centre line of the longitudinal median T-slot, or of the cross tenon slot (when existing) or the line between the alignment holes, with the <math>A'</math>-axis of rotation of the table, and</p> <p>b) equidistance of the alignment holes with the <math>A'</math>-axis of rotation of the table<sup>1)</sup>.</p> <p>1) Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p> <p>a) </p> <p>b) </p>	
<p><b>Tolerance</b></p> <p>For a) and b) 0,030</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="margin-left: 300px;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>a) Straightedge, gauge blocks or master pins and dial gauge</p> <p>b) Master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1.</b></p> <p>a) When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the axis of rotation. Adjust the <math>A'</math>-axis in order to have the T-slot parallel to the X-axis (or Z-axis). Parallel means that the two readings on the gauge blocks are the same. The dial gauge, placed on a fixed part of the spindle head, is then zeroed. Turn the table by 180° and again adjust the <math>A'</math>-axis in order to have the same dial gauge readings on both gauge blocks, without resetting the dial gauge. Half the new reading on the dial gauge is the error to be reported.</p> <p>When the alignment holes are provided, two master pins which fit in the holes and have protruding parts of the same diameter shall be used instead of the gauge blocks. The same procedure as above is then to be followed.</p> <p>b) The dial gauge readings to be compared are the maximum radial readings on each master pin, which might also not precisely correspond to readings at 180° from each other, because of the error read in a).</p>	

<b>Object</b>	<b>DG3</b>
<p>Checking of <math>E_{C(OX)T}</math> parallelism error of</p> <ul style="list-style-type: none"> <li>— the longitudinal median or reference T-slot, or</li> <li>— the centre line of the alignment holes (if longitudinal), or</li> <li>— the longitudinal edge locator of the table<sup>1)</sup>, set perpendicular to the spindle axis (<math>B' = 90^\circ</math>), with <math>A' = 0^\circ</math>, to the X-axis motion.</li> </ul> <p>1) Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p>	
<p><b>Tolerance</b></p> <p style="text-align: center;">for all types 0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p>	
<p>Dial gauge and gauge blocks or master pins</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>Y-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge can be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the <math>A'</math>-axis of rotation. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p>The result of this test includes the possible <math>E_{AA}</math> positioning error of the <math>A'</math>-axis at <math>0^\circ</math>.</p>	

Object	DG4
<p>Checking of <math>E_{A(OZ)T}</math> parallelism error of</p> <ul style="list-style-type: none"> <li>— the longitudinal median or reference T-slot, or</li> <li>— the centre line of the alignment holes (if longitudinal), or</li> <li>— the longitudinal edge locator of the table<sup>1)</sup>, set parallel to the spindle axis (<math>B' = 0^\circ</math> or <math>180^\circ</math>), with <math>A' = 0^\circ</math>, to the Z-axis motion.</li> </ul> <p><sup>1)</sup> Built-in rotary table or one representative pallet clamped in position</p>	
<p><b>Diagram</b></p>  <p>The diagram consists of three schematic drawings of a machine table with a dial gauge. Each drawing shows a different measurement setup. Below each drawing is a 3D coordinate system with three axes: Y (vertical), Z (horizontal), and Z' (rotational axis). The first diagram shows a dial gauge measuring a longitudinal median. The second shows a dial gauge measuring the center line of alignment holes. The third shows a dial gauge measuring a longitudinal edge locator.</p>	
<p><b>Tolerance</b></p> <p style="text-align: center;">for all types 0,025 over a measuring length of 500</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge blocks or master pins and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 12.3.2.5</b></p> <p>Y-axis to be locked, if possible.</p> <p>If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <p>When a reference T-slot or a tenon slot is provided, insert two gauge blocks in the slot, at the same distance from the <math>A'</math>-axis of rotation. Zero the dial gauge against one of the gauge blocks. The dial gauge reading on the second gauge block, divided by the distance between the gauge blocks, is the error to be reported. Note the direction of the error.</p> <p>When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used.</p> <p>The result of this test includes the possible <math>E_{AA}</math> positioning error of the <math>A'</math>-axis at <math>0^\circ</math>.</p>	



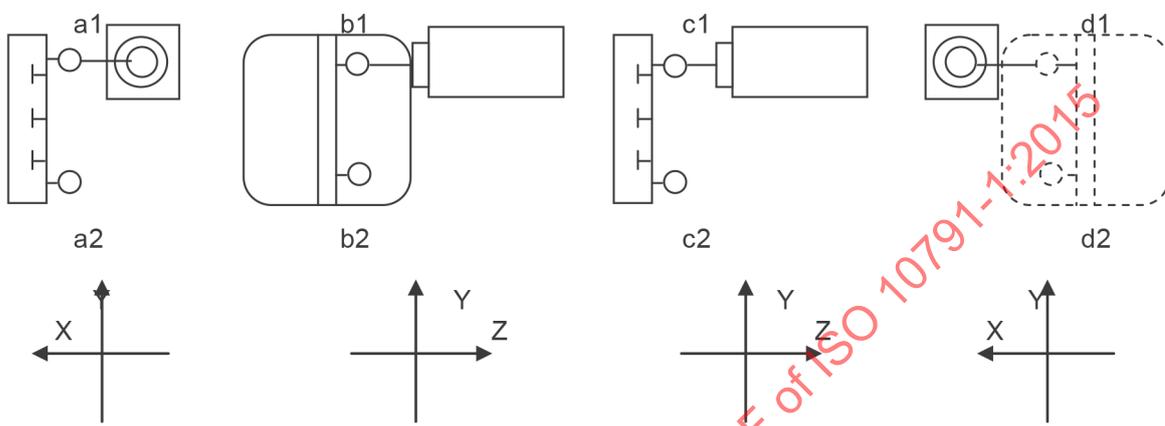
<b>Object</b>	<b>DG6</b>
Checking of $E_{B(0X)A}$ squareness error of the $A'$ -axis of rotation of the table, or receiver, with the table perpendicular to the spindle axis ( $B' = 90^\circ$ ), to the X-axis motion	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: right;">0,040/1 000</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge block and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>Z-axis to be locked, if possible. The result of this test includes the possible positioning deviation of the <math>B'</math>-axis.</p> <p>Place a gauge block on one edge of the table, in the X direction apart from the axis of rotation; fix the dial gauge on the spindle, if it can be locked, or on the spindle head; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by <math>180^\circ</math> and move the X-axis until the stylus again touches the gauge block in the same point. The dial gauge reading, divided by the X displacement, is the error to be reported.</p> <p>Note the direction of the error. The sign convention of the error shall correspond to the squareness sign according to ISO 230-1:2012, 3.6.7, Note 2.</p> <p>This test might be influenced by the <math>E_{ZX}</math> horizontal straightness error of the X-axis.</p> <p>The result of this test includes the possible <math>E_{BB}</math> positioning error of the <math>B'</math>-axis at <math>90^\circ</math>.</p>	

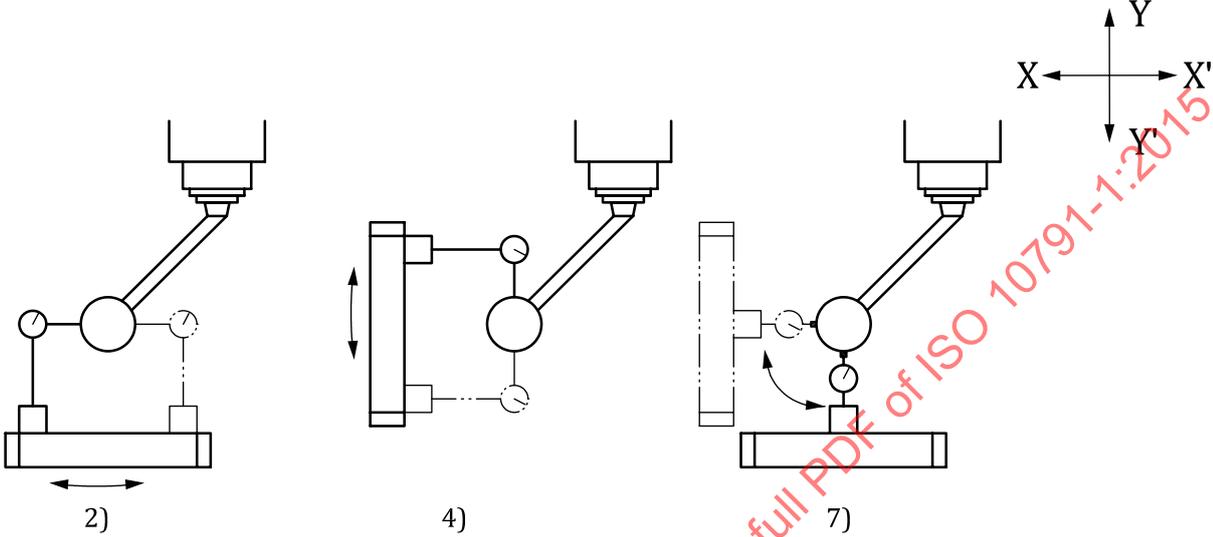
<b>Object</b>	<b>DG7</b>
Checking of $E_{B(OZ)A}$ squareness error of the $A'$ -axis of rotation of the table, or receiver, with the table parallel to the spindle axis ( $B' = 0^\circ$ , or $B' = 180^\circ$ as shown in the diagram), to the Z-axis motion	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p style="text-align: right;">0,040/1 000</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Gauge block and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.3 and 10.3.3</b></p> <p>X-axis to be locked, if possible. The result of test a) includes the possible positioning deviation of the <math>B'</math>-axis.</p> <p>Place a gauge block on one edge of the table, in the Z direction apart from the axis of rotation; fix the dial gauge on the spindle, if it can be locked, or on the spindle head; bring the stylus into contact with the gauge block and zero the dial gauge. Rotate the table by <math>180^\circ</math> and move the Z-axis until the stylus again touches the gauge block in the same point. The dial gauge reading, divided by the Z displacement, is the error to be reported.</p> <p>Note the direction of the error. The sign convention of the error (<math>\alpha</math>) shall correspond to the squareness sign according to ISO 230-1:2012, 3.6.7, Note 2.</p> <p>The result of this test includes the possible <math>E_{BB}</math> positioning error of the <math>B'</math>-axis (at <math>0^\circ</math> or at <math>180^\circ</math>).</p> <p>The value of angle <math>\alpha</math>, being less than, equal to or greater than <math>90^\circ</math>, shall be noted.</p>	

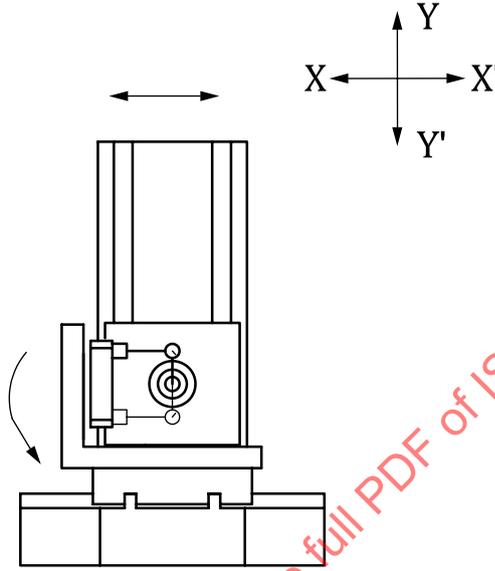


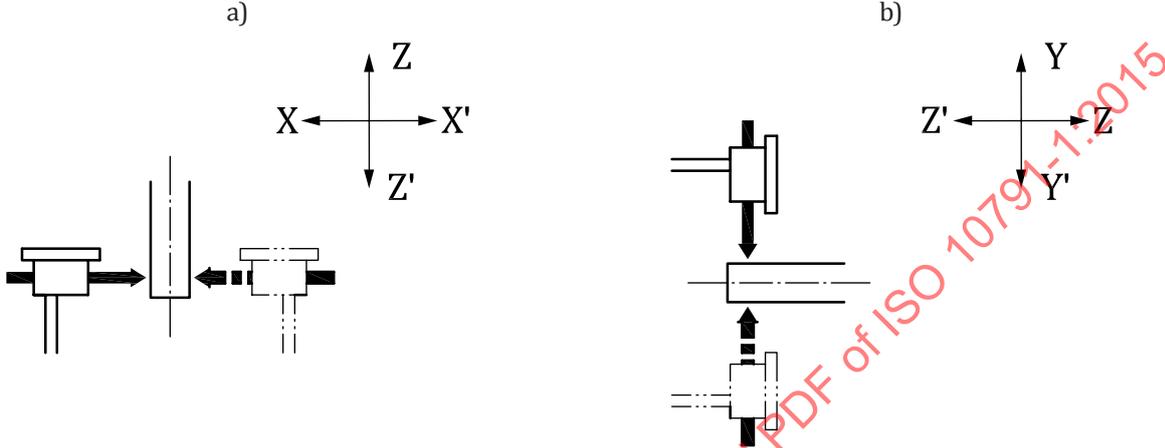
<b>Object</b>	<b>DG9</b>
<p>Checking of parallelism error of the <math>A'</math>-axis of rotation of the table, or receiver, with the table perpendicular to the spindle axis (<math>B' = 90^\circ</math>), to the Z-axis motion:</p> <p>a) <math>E_{A(0Z)A}</math> in the vertical YZ plane</p> <p>b) <math>E_{B(0Z)A}</math> in the horizontal ZX plane</p>	
<p><b>Diagram</b></p>	
<p><b>Tolerance</b></p> <p style="text-align: center;">For a) and b) 0,040/1 000 (= 0,020/500)</p>	
<p><b>Measured deviation</b></p> <p>a) <span style="margin-left: 200px;">b)</span></p>	
<p><b>Measuring instruments</b></p> <p>Cylinder square with flange base, or test sphere as an alternative, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 3.6.3, 10.1.4, 10.1.4.3, or 10.1.4.4 as alternative</b></p> <p>a) Y-axis to be locked, if possible.</p> <p>b) X-axis to be locked, if possible. The result of test b) includes the possible <math>E_{BB}</math> positioning deviation of the <math>B'</math>-axis at <math>90^\circ</math>.</p> <ol style="list-style-type: none"> <li>1) Fix a cylinder square with a flange base on the table, and centre it on approximately on the axis of rotation.</li> <li>2) Fix the dial gauge on the spindle head with the stylus oriented in the Y-axis direction for a) and X-axis direction for b).</li> <li>3) Touch the cylinder square by the stylus, close to the cylinder bottom, and find the maximum dial gauge reading by small movements along the X-axis for a) and along Y-axis for b). Zero the dial gauge.</li> <li>4) Move the head apart from the table along the Z-axis, and touch again the cylinder close to its top. Note the Z travel length. Find the maximum dial gauge reading by small movements along the X-axis for a) and along Y-axis for b) and note the new dial gauge reading.</li> <li>5) Turn the table by <math>180^\circ</math> and repeat steps 3) and 4).</li> <li>6) For both measurements a) and b), the average value (half the algebraic sum) of the two dial gauge readings on top of the cylinder, divided by the Z travel length, is the error to be reported. The sign convention of the error shall correspond to the parallelism sign between <math>A'</math> and Z-axes according to ISO 230-1:2012, 3.6.3 Note 2.</li> </ol>	

<b>Object</b>	<b>DG10</b>
<p>Checking of parallelism error of the <math>A'</math>-axis of rotation of the table, or receiver, with the table parallel to the spindle axis (<math>B' = 0^\circ</math>, or <math>B' = 180^\circ</math> as shown in the diagram), to the X-axis motion:</p> <p>a) <math>E_{C(OX)A}</math> in the vertical XY plane</p> <p>b) <math>E_{B(OX)A}</math> in the horizontal ZX plane</p>	
<p><b>Diagram</b></p>	
<p><b>Tolerance</b></p> <p>For a) and b) 0,040/1 000 (= 0,020/500)</p>	
<p><b>Measured deviation</b></p> <p>a) b)</p>	
<p><b>Measuring instruments</b></p> <p>Cylinder square with flange base, or test sphere as an alternative, and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 3.6.3, 10.1.4, and 10.1.4.3</b></p> <p>a) Y-axis to be locked, if possible.</p> <p>b) Z-axis to be locked, if possible. The result of test b) includes the possible <math>E_{BB}</math> positioning deviation of the <math>B'</math>-axis at <math>0^\circ</math>.</p> <p>If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.</p> <ol style="list-style-type: none"> <li>1) Fix a cylinder square with a flange base on the table, and centre it on approximately on the axis of rotation.</li> <li>2) Fix the dial gauge on the spindle head with the stylus oriented in the Y-axis direction for a) and Z-axis direction for b).</li> <li>3) Touch the cylinder square by the stylus, close to the cylinder bottom, and find the maximum dial gauge reading by small movements along the Z-axis for a) and along Y-axis for b). Zero the dial gauge.</li> <li>4) Move the head apart from the table along the X-axis, and touch again the cylinder close to its top. Note the X travel length. Find the maximum dial gauge reading by small movements along the Z-axis for a) and along Y-axis for b) and note the new dial gauge reading.</li> <li>5) Turn the table by <math>180^\circ</math> and repeat steps 3) and 4).</li> <li>6) For both measurements a) and b), the average value (half the algebraic sum) of the two dial gauge readings on top of the cylinder, divided by the Z travel length, is the error to be reported. The sign convention of the error shall correspond to the parallelism sign between <math>A'</math> and X-axis according to ISO 230-1:2012, 3.6.3 Note 2.</li> </ol>	

<b>Object</b>	<b>DG11</b>
<p>Checking of parallelism error of the <math>B'</math>-axis of rotation of the swivelling table, to the Y-axis motion:</p> <p>a) <math>E_{C(0Y)B}</math> in the vertical XY plane</p> <p>b) <math>E_{A(0Y)B}</math> in the vertical YZ plane</p>	
<p><b>Diagram</b></p>  <p><b>Tolerance</b></p> <p style="text-align: right;">0,050/1 000</p>	
<b>Measured deviation</b>	
<b>Measuring instruments</b> Gauge blocks and dial gauge	
<p><b>Observations and references to ISO 230-1</b></p> <p>1) Set the table parallel to the spindle axis (<math>B' = 180^\circ</math> in the diagram). Fix a straightedge on the table, approximately parallel to the Y-axis with both reference planes. Let the dial gauge mounted on the spindle touch the straightedge top face in the X direction. Measure at both ends of the measurement distance <math>L</math>, read the dial gauge in <math>a1</math> and <math>a2</math> and note the difference <math>\Delta a = (a2 - a1)</math>.</p> <p>2) Turn the dial gauge into the Z direction and touch the straightedge side face. Measure at both ends of the measurement distance <math>L</math>, read the dial gauge in <math>b1</math> and <math>b2</math> and note the difference <math>\Delta b = (b2 - b1)</math>.</p> <p>3) Swivel the <math>B'</math>-axis to <math>90^\circ</math> position (table perpendicular to the spindle axis). With the dial gauge in the Z direction touch the straightedge top face in the same two points as in 1), take the readings <math>c1</math> and <math>c2</math> and note the difference <math>\Delta c = (c2 - c1)</math>.</p> <p>4) Turn the dial gauge into the X direction and touch the straightedge side face. Measure in the same two points as in 2), take the readings <math>d1</math> and <math>d2</math> and note the difference <math>\Delta d = (d2 - d1)</math>.</p> <p>a) Parallelism error in the vertical XY plane is given by the following formula:  <math display="block">E_{C(0Y)B} = 1/2(\Delta a + \Delta b - \Delta c - \Delta d)</math> divided by the measurement distance <math>L</math></p> <p>b) Parallelism error in the vertical YZ plane is given by the following formula:  <math display="block">E_{A(0Y)B} = 1/2(-\Delta a + \Delta b + \Delta c - \Delta d)</math> divided by the measurement distance <math>L</math>.</p>	

<b>Object</b>	<b>DG12</b>
<p>Checking that the <math>A'</math>-axis of the table rotation and the <math>B'</math>-axis of the table swivelling lie in the same plane          (for tables with the <math>B'</math>-axis outside the table surface): <math>E_{Z(0B)A}</math> (only for machines with nominally zero offset between <math>A'</math> and <math>B'</math>-axis and without compensation facilities for any offset deviation)</p>	
<p><b>Diagram</b></p>  <p>The diagram illustrates the measurement setup in three stages: 2) The table is parallel to the spindle axis (<math>B' = 0^\circ</math> or <math>180^\circ</math>). A sphere is mounted on the spindle, and a dial gauge is positioned on the table with its stylus parallel to the table surface in the radial direction. 4) The table is rotated to be perpendicular to the spindle axis (<math>B' = 90^\circ</math>). The dial gauge is used to align the <math>A'</math>-axis of the table rotation with the sphere's center. 7) The table is rotated back to be parallel to the spindle axis (<math>B' = 0^\circ</math> or <math>180^\circ</math>). A coordinate system is defined with <math>X</math> and <math>Y</math> axes on the table, and <math>X'</math> and <math>Y'</math> axes on the spindle.</p>	
<p><b>Tolerance</b></p> <p style="text-align: center;">0,03</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p>	
<p>Test sphere and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.4.3</b></p> <ol style="list-style-type: none"> <li>1) Fix the sphere support in the spindle, if it can be locked, or on the spindle head. Fix the dial gauge on the table with the stylus parallel to the table surface in radial direction.</li> <li>2) With the table parallel to the spindle axis (<math>B' = 0^\circ</math>, or <math>B' = 180^\circ</math>), align the <math>A'</math>-axis of the table rotation on the sphere centre, by means of rotations around <math>A'</math> and adjustments along <math>Y</math> and <math>Z</math>.</li> <li>3) Lock the <math>Y</math>- and <math>Z</math>-axes.</li> <li>4) Turn the table to be perpendicular to the spindle axis (<math>B' = 90^\circ</math>) and again align the <math>A'</math>-axis of the table rotation on the sphere centre, by means of rotations around <math>A'</math> and adjustments along <math>X</math>.</li> <li>5) Lock the <math>X</math>-axis.</li> <li>6) With the table perpendicular to the spindle axis (<math>B' = 90^\circ</math>), place a dial gauge, with flat tip, on top of the table, with the stylus parallel to the spindle axis, touch the sphere and zero the dial gauge.</li> <li>7) Turn the table to be parallel to the spindle axis (<math>B' = 0^\circ</math>, or <math>B' = 180^\circ</math>), and note the dial gauge reading. Half of the new reading on the dial gauge is the error to be reported. Note the direction of the error.</li> </ol> <p>The dial gauge arm shall be stiff enough so as to prevent any possible reading errors due to its opposite deflections in the different measurement positions.</p>	

<b>Object</b>	<b>DG13</b>
<p>Checking that the <math>A'</math>-axis of rotation of the table and the spindle axis lie in the same ZX plane at a predefined position, with the table parallel to the spindle axis (<math>B' = 0^\circ</math>, or <math>B' = 180^\circ</math>) (i.e. measuring the <math>E_{Y(0(C))A}</math> deviation in the Y direction)</p>	
<p><b>Diagram</b></p> 	
<p><b>Tolerance</b></p> <p>0,010</p>	
<p><b>Measured deviation</b></p>	
<p><b>Measuring instruments</b></p> <p>Test mandrel and dial gauge</p>	
<p><b>Observations and references to ISO 230-1</b></p> <ol style="list-style-type: none"> <li>1) Adjust the <math>B'</math>-axis of the swivelling table until the <math>A'</math>-axis of rotation of the table is perpendicular to the Z-axis.</li> <li>2) Move the Y-axis to the vertical position where the <math>A'</math>-axis of rotation of the table and the spindle axis should lie in the same ZX plane.</li> <li>3) Fix the test mandrel in the spindle, and the dial gauge on the table with the stylus parallel to the table surface in radial direction.</li> <li>4) With the dial gauge stylus oriented vertically in the Y-axis direction touch the test mandrel, close to spindle nose, and find the maximum dial gauge reading by small movements along the X-axis. Zero the dial gauge.</li> <li>5) Move the X-axis, in order to take the test mandrel off the dial gauge. Turn both the table and the spindle by <math>180^\circ</math>, and again bring the test mandrel into contact with the dial gauge by means of X-axis movements.</li> <li>6) Find the maximum dial gauge reading by small movements along the X-axis.</li> <li>7) Half of the new reading on the dial gauge is the error to be reported.</li> </ol> <p>The dial gauge arm shall be stiff enough so as to prevent any possible reading errors due to its opposite deflections in the different measurement positions.</p> <p>NOTE 1 If this test is carried out in different positions of the Z-axis it is affected by the <math>E_{A(0Z)(C)}</math> parallelism error between the spindle axis and the Z-axis and by the <math>E_{YZ}</math> vertical straightness error of the Z-axis.</p> <p>NOTE 2 If this test is carried out in different positions of the X-axis it is affected by the <math>E_{C(0Z)A}</math> parallelism error between the <math>A'</math> axis of rotation of the table and the X-axis and by the <math>E_{YX}</math> vertical straightness error of the X-axis.</p>	

<b>Object</b>	<b>DG14</b>
<p>Checking of coincidence of the <math>A'</math>-axis of rotation of the table and the spindle axis at a predefined position, with the table parallel to the X-axis:</p> <p>a) <math>E_{X(0(C))A}</math> along the horizontal X-axis</p> <p>b) <math>E_{Y(0(C))A}</math> along the vertical Y-axis</p>	
<p><b>Diagram</b></p>  <p>The diagram consists of two parts, a) and b). Part a) shows a side view of a spindle with a test mandrel mounted on it. A dial gauge is positioned on the table surface, with its stylus touching the mandrel. A coordinate system is defined with X and X' as horizontal axes and Z and Z' as vertical axes. Part b) shows a similar setup from a different perspective, with Y and Y' as vertical axes and Z and Z' as horizontal axes.</p>	
<p><b>Tolerance</b> 0,010</p>	
<p><b>Measured deviation</b> a) along the X-axis                      b) along the Y-axis</p>	
<p><b>Measuring instruments</b> Test mandrel and dial gauge</p>	
<p><b>Observations and references to ISO 230-1:2012, 10.2</b></p> <ol style="list-style-type: none"> <li>1) Adjust the <math>B'</math>-axis of the swivelling table until the <math>A'</math>-axis of the table rotation is parallel to the Z-axis.</li> <li>2) Move the X-axis and the Y-axis to the theoretical position where the <math>B'</math>-axis of the swivelling table and the spindle axis should coincide.</li> <li>3) Fix the test mandrel in the spindle, and the dial gauge on the table with the stylus parallel to the table surface in radial direction.</li> <li>4) With the dial gauge stylus oriented in the X-axis direction for a) and in the Y-axis direction for b), touch the test mandrel, close to the spindle nose, and find the maximum dial gauge reading by small movements [along the Y-axis for a) and along the X-axis for b)]. Zero the dial gauge.</li> <li>5) Turn both the table and the spindle by 180°.</li> <li>6) Find the maximum dial gauge reading as in point 4).</li> <li>7) Half of the new reading on the dial gauge is the error to be reported.</li> </ol> <p>The dial gauge arm shall be stiff enough so as to prevent any possible reading errors due to its opposite deflections in the different measurement positions.</p> <p>NOTE If this test is carried out in different positions of the Z-axis it is affected by the parallelism errors between the spindle axis and the Z-axis and between the <math>A'</math> axis of rotation of the table and the Z-axis, in both ZX and YZ planes.</p>	

## Annex E (informative)

### Error motions of tool holding spindle and work holding rotary table axes

#### E.1 Error motions of tool holding spindle (C) axis

<b>Object</b>	<b>ER1</b>			
Axis of rotation error motion for tool holding spindle(s) (C) a) radial error motion $E_{XY(C)}$ b) axial error motion $E_{Z(C)}$ c) tilt error motion $E_{AB(C)}$				
<b>Diagram</b>				
<b>Tolerance<sup>1)</sup></b>				
at percentage of maximum speed				
<table style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 0 10px;">10 %</td> <td style="padding: 0 10px;">50 %</td> <td style="padding: 0 10px;">100 %</td> </tr> </table>		10 %	50 %	100 %
10 %	50 %	100 %		
a) total radial error motion value $E_{xy(C)}$				
b) total axial error motion value $E_{z(C)}$				
c) total tilt error motion value $E_{AB(C)}$				
<b>NOTE</b> If the minimum speed is larger than 10 % of the maximum speed, then the spindle should be operated at minimum speed instead.				
Different spindle speeds can be selected based on mutual agreement between the manufacturer/supplier and the user.				
<sup>1)</sup> If the manufacturer/supplier and the user would decide, by mutual agreement, to include this test in the contractual machine acceptance procedures, then they should also define, by mutual agreement, the corresponding tolerances to be applied. A future edition of this part of ISO 10791 can provide tolerances for this test when solid data from such measurements for table performance in industrial environment are available.				

**Measured deviation**

- a)
- b)
- c)

**Measuring instruments**

Test mandrel, non-contacting probes, and angular measuring device or two precision spheres located slightly eccentric to table average line and non-contacting probes

**Observations and references to ISO 230-7**

This test is a table test with rotating sensitive direction (ISO 230-7:—, 5.4).

After set up of the measuring instrument, the spindle shall be warmed up at 50 % of the maximum spindle speed for a time period of 10 min, if not otherwise agreed between manufacturer/supplier and user.

Total error motion is defined in ISO 230-7:—, 3.2.4, total error motion value in ISO 230-7:—, 3.5.1.

- a) total radial error motion value  $E_{XY(C)}$  (using probes 4 and 5)

Radial error motion measurement is described in ISO 230-7:—, 5.4.2. The radial error motion shall be measured as close as possible to the table surface (sensors 4 and 5 in the diagram of this test).

For the radial error motion  $E_{XY(C)}$ , a total error motion polar plot (ISO 230-7:—, 3.3.1) with a least squares circle (LSC) centre (ISO 230-7:—, 3.4.3) shall be provided.

- b) total axial error motion value  $E_{Z(C)}$  (using probe 3)

Axial error motion measurement is described in ISO 230-7:—, 5.4.4.

For the axial error motion  $E_{Z(C)}$ , a total error motion polar plot (ISO 230-7:—, 3.3.1) with a polar chart (PC) centre (ISO 230-7:—, 3.4.1) shall be provided.

- c) total tilt error motion values  $E_{AB(C)}$  (using probes 1,2,4,5)

Tilt error motion measurement is described in ISO 230-7:—, 5.4.3. The tilt error motion can be also be checked with just two non-contacting probes (see ISO 230-7:—, 5.4.3.1 and 5.4.3.2).

For the tilt error motion  $E_{AB(C)}$ , a total error motion polar plot (ISO 230-7:—, 3.3.1) with a polar chart (PC) centre (ISO 230-7:—, 3.4.1) shall be provided.

For these tests, the following parameters shall be stated:

- a the radial, axial, or face locations at which the measurements are made;
- b identification of all artefacts, targets, and fixtures used;
- c the location of the measurement setup;
- d the position of any linear or rotary positioning stages that are connected to the device under test;
- e the direction angle of the sensitive direction, e.g. axial, radial or intermediate angles as appropriate;
- f presentation of the measurement result, for example: error motion value, polar plot, time based plot, frequency content plot;
- g the rotational speed of the table (zero for static error motion);
- h the time duration in seconds or number of table rotations;
- i appropriate warm up or break-in procedure;
- j the frequency response of the instrumentation, given as hertz or cycles per rev, including roll off characteristics of any electronic filters. In the case of digital instrumentation, the displacement resolution and sampling rate;
- k the structural loop, including the position and orientation of sensors relative to the table housing from which the error motion is reported, specified objects with respect to which the table axes and the reference coordinate axes are located and the elements connecting these objects (see ISO 230-1:2012, 3.3.1);
- l time and date of measurement;
- m type and calibration status of all measurement instrumentation;
- n other operating conditions which can influence the measurement such as ambient temperature.

If the tilt measurements are not needed (by agreement between the supplier and the user), then only three displacement sensors are used (3, 4, and 5) and test mandrel can be replaced by precision test sphere.

**E.2 Error motions of work holding rotary table (see Annex B)**

<b>Object</b>	ER2			
<p>Axis of rotation error motion for workholding table</p> <p>a) radial error motion in the X direction <math>E_{XB}</math></p> <p>b) radial error motion in the Z direction <math>E_{ZB}</math></p> <p>c) axial error motion <math>E_{YB}</math></p> <p>d) tilt error motion around X-axis <math>E_{AB}</math></p> <p>e) tilt error motion around Z axis <math>E_{CB}</math></p>				
<p><b>Diagram</b></p>				
<p><b>Tolerance<sup>1)</sup></b></p> <p>at percentage of maximum speed</p> <table style="margin-left: 40px;"> <tr> <td>10 %</td> <td>50 %</td> <td>100 %</td> </tr> </table> <p>a) total radial error motion value <math>E_{XB}</math></p> <p>b) total radial error motion value <math>E_{ZB}</math></p> <p>c) total axial error motion value <math>E_{YB}</math></p> <p>d) total tilt error motion value <math>E_{AB}</math></p> <p>e) total tilt error motion value <math>E_{CB}</math></p> <p>NOTE If the minimum speed is larger than 10 % of the maximum speed, then the table should be operated at minimum speed instead. Different table speeds may be selected based on mutual agreement between the manufacturer/supplier and the user.</p> <p><sup>1)</sup> If the manufacturer/supplier and the user would decide, by mutual agreement, to include this test in the contractual machine acceptance procedures, then they should also define, by mutual agreement, the corresponding tolerances to be applied. A future edition of this part of ISO 10791 can provide tolerances for this test when solid data from such measurements for rotary table performance in industrial environment are available.</p> <p><b>Measured deviation</b></p> <p>a)</p> <p>b)</p> <p>c)</p> <p>d)</p> <p>e)</p>		10 %	50 %	100 %
10 %	50 %	100 %		