
Test conditions for machining centres —

Part 3:

Geometric tests for machines with integral
indexable or continuous universal heads
(vertical Z-axis)

Conditions d'essai pour centres d'usinage —

*Partie 3: Essais géométriques des machines à têtes universelles intégrées
à indexage ou continues (axe Z vertical)*



Contents

Page

1	Scope	1
2	Normative reference	2
3	Preliminary remarks.....	2
3.1	Measuring units.....	2
3.2	Reference to ISO 230-1	2
3.3	Testing sequence.....	2
3.4	Tests to be performed.....	2
3.5	Measuring instruments.....	2
3.6	Diagrams.....	2
3.7	Pallets	3
3.8	Software compensation	3
3.9	Machine configurations	3
3.10	Designation	3
3.11	Minimum tolerance.....	3
4	Geometric tests	6
4.1	Straightness of linear motions.....	6
4.2	Angular deviations of linear motions.....	9
4.3	Squareness between linear motions.....	12
4.4	Spindle	15
4.5	Table or pallet	17
	Annex A (normative) Integral universal 45° split indexable heads	25
	Annex B (normative) Integral universal swivel heads	34
	Annex C (normative) Integral universal 45° split continuous heads	41
	Annex D (informative) Bibliography	48

© ISO 1998

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10791-3 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

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 and with accessory heads (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 feeds, speeds and interpolations*
- *Part 7: Accuracy of a finished test piece*
- *Part 8: Evaluation of the 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*
- *Part 11: Evaluation of the noise emission*

Annexes A B and C form an integral part of this part of ISO 10791. Annex D is for information only.

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 programme.

The object of ISO 10791 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.

ISO 10791 specifies, with reference to the relevant parts of ISO 230, *Test code for machine tools*, several families of tests for machining centres with horizontal or vertical spindle or with universal heads of different types, standing alone or integrated in flexible manufacturing systems. ISO 10791 also establishes the tolerances or maximum acceptable values for the test results corresponding to general purpose and normal accuracy machining centres.

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

STANDARDSISO.COM : Click to view the full PDF of ISO 10791-3:1998

Test conditions for machining centres —

Part 3:

Geometric tests for machines with integral indexable or continuous universal heads (vertical Z-axis)

1 Scope

This part of ISO 10791 specifies, with reference to ISO 230-1, the geometric tests for machining centres (or numerically controlled milling machines, boring machines, etc., where applicable) with integral indexable or continuous universal heads (vertical Z-axis).

This part of ISO 10791 applies to machining centres having basically six numerically controlled axes, of which three are linear (X, Y and Z) up to 2 000 mm in length, and three are rotary (A or D and B on the head, and C' on the table). 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 describes geometric tests for three possible types of accessory universal heads, in the annexes:

- annex A: Integral universal 45° split indexable heads (B and D axes), with mechanical indexing of the different angular positions of the two bodies (e.g. Hirth couplings): the relevant tests (AG1 to AG9) check only the resulting position of the spindle;
- annex B: Integral universal swivel heads (B and A axes), with two numerically controlled rotary axes perpendicular to each other (tests BG1 to BG7);
- annex C: Integral universal 45° split continuous heads (B and D axes), similar to the first type but provided with continuous positioning of the two numerically controlled rotary axes: the relevant tests (CG1 to CG7) check all the geometric features (planes and axes) which contribute to the resulting position of the spindle, excluding the positioning accuracy of the two rotary axes; these tests can also be used for a deeper investigation on the 45° indexable heads, if their movements and locks allow this.

This part of ISO 10791 deals only with the verification of accuracy of the machine and does not apply to the testing of the machine operation, which should generally be checked separately. Certain tests concerning the performance of the machine operating under no-load or finishing conditions are included in other parts of ISO 10791.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 10791. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10791 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 230-1:1996, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or finishing conditions.*

3 Preliminary remarks

3.1 Measuring 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, but in some cases microradians or arc seconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind:

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

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 accuracy of testing equipment.

In the "Observations" block of the tests described in clause 4 and annexes A to C, the instructions are followed by a reference to the corresponding clause in ISO 230-1 in cases where the test concerned is in compliance with the specifications of ISO 230-1.

3.3 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 may be performed in any order.

3.4 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 supplier/manufacturer, those tests relating to the components and/or the properties of the machine which are of interest. These tests are to be clearly stated when ordering a machine. Mere reference to this 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.

3.5 Measuring instruments

The measuring instruments indicated in the tests described in clause 4 and annexes A to C are examples only. Other instruments measuring the same quantities and having at least the same accuracy may be used. Dial gauges shall have a resolution of 0,001 mm or better.

3.6 Diagrams

In this part of ISO 10791, for reasons of simplicity, the diagrams associated with geometric tests illustrate only one type of machine.

3.7 Pallets

For machines working with several pallets, the tests concerning the intrinsic geometric features or their behaviour in relation to the axes of the machine (tests G12 to G19) are to be performed on only one representative pallet clamped in position, unless otherwise specified by a written agreement between the user and the supplier/manufacturer.

3.8 Software compensation

When software facilities are available for compensating certain geometric deviations, based on an agreement between the user and the supplier/manufacturer, the relevant test may be carried out with or without these compensations. When the software compensation is used, this shall be stated in the test results.

3.9 Machine configurations

The machines considered in this part of ISO 10791 are divided into 12 basic family configurations based on their architectures and the components moving along the linear axes. These families are identified by means of numbers from 01 to 12 as shown in Figure 1. The classification of these configurations is shown in Table 1¹⁾.

3.10 Designation

A designation is also supplied, as a short code, in order to define the architecture of a machining centre; this designation is given by the following elements, in the given order:

- a) "machining centre"
- b) the reference of this part of ISO 10791, i.e. ISO 10791-3;
- c) the letter "A" for type A heads (as specified in annex A);
- d) the letter "B" for type B heads (as specified in annex B);
- e) the letter "C" for type C heads (as specified in annex C);
- f) the number indicated in the relevant box of Figure 1 and the left-hand column of Table 1.

EXAMPLE

A machining centre, with universal integral head, with the column moving along the X-axis, the spindle head slide moving along the Z-axis and the table moving along the Y'-axis is designated as follows:

Machining centre ISO 10791-3 type A02

3.11 Minimum tolerance

When establishing the tolerance for a measuring length different from that given in this part of ISO 10791 (see 2.311 of ISO 230-1:1996), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

1) Some vertical machining centres are built with an architecture similar to type V10 (portal type) or V11 (gantry type) but with only one column. ISO 10791-3 is applicable to them as well. In this case, when necessary, the text should be modified by replacing the terms "portal" or "gantry" with "column", and "cross rail" with "arm".

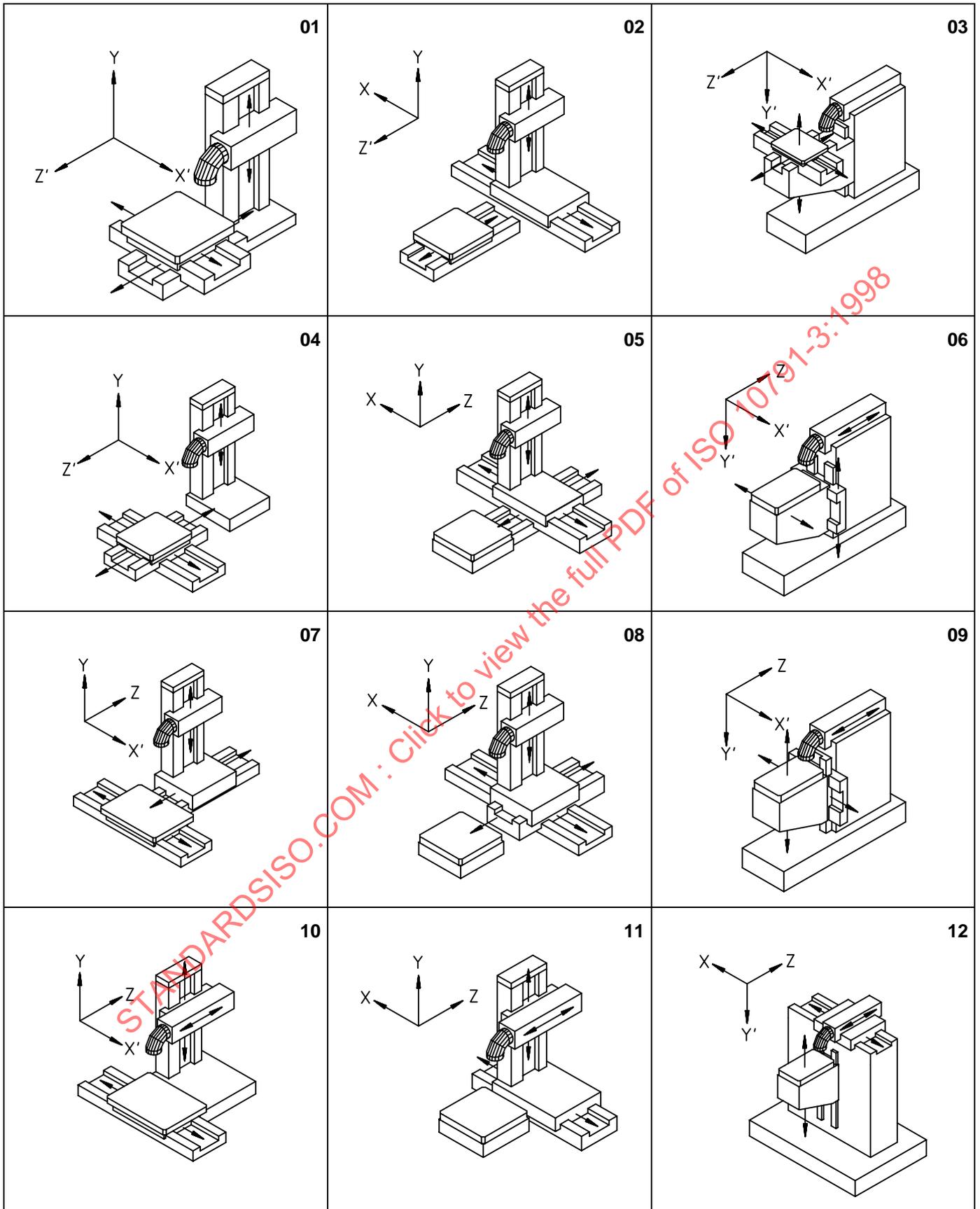
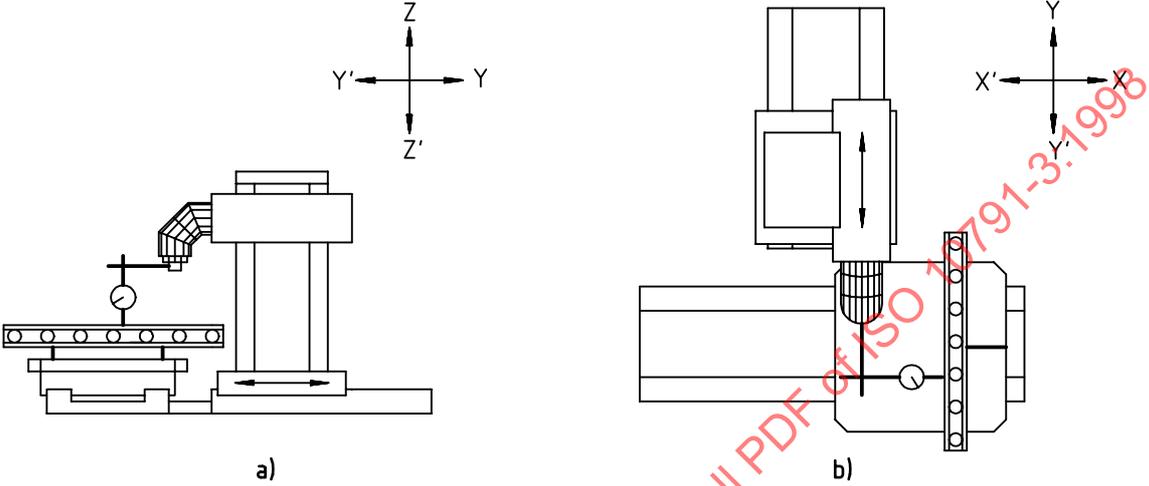
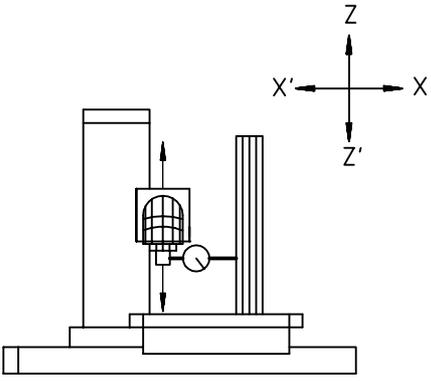
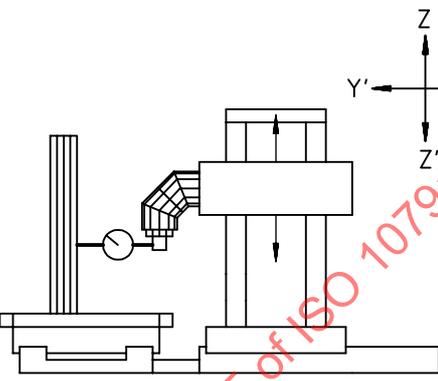


Figure 1

Table 1 — Classification of configurations of horizontal primary rotary axis machining centres

	X	X'	Y	Y'	Z	Z'
01		Table on its saddle	Spindle head			Table saddle
02	Column		Spindle head			Table
03		Table on its saddle		Knee		Table saddle
04		Table saddle	Spindle head			Table on its saddle
05	Column on its saddle		Spindle head		Column saddle	
06		Knee		Knee saddle	Spindle head	
07		Table	Spindle head		Column	
08	Column saddle		Spindle head		Column on its saddle	
09		Knee saddle		Knee	Spindle head	
10		Table	Spindle head slide		Spindle head on its slide	
11	Column		Spindle head slide		Spindle head on its slide	
12	Spindle head slide			Knee	Spindle head on its slide	

Object Checking of straightness of the Y-axis motion: a) in the vertical YZ plane (EZY); b) in the horizontal XY plane (EXY).	G2								
Diagram 									
Tolerance For a) and b): <table style="margin-left: 100px; border: none;"> <tr> <td style="padding-right: 20px;">$Y \leq 500$</td> <td style="padding-right: 20px;">0,010</td> </tr> <tr> <td>$500 < Y \leq 800$</td> <td>0,015</td> </tr> <tr> <td>$800 < Y \leq 1\ 250$</td> <td>0,020</td> </tr> <tr> <td>$1\ 250 < Y \leq 2\ 000$</td> <td>0,025</td> </tr> </table> Local tolerance: 0,007 for 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	Measured deviation for Y = a) b)
$Y \leq 500$	0,010								
$500 < Y \leq 800$	0,015								
$800 < Y \leq 1\ 250$	0,020								
$1\ 250 < Y \leq 2\ 000$	0,025								
Measuring instruments a) Straightedge and dial gauge or optical methods b) Straightedge and dial gauge or microscope and taut wire or optical methods									
Observations and references to ISO 230-1 <div style="float: right;">5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1</div> <p>For all machine configurations, either the straightedge, the taut wire or the straightness reflector shall be placed on the table. If the spindle can be locked, either the dial gauge, the microscope or the interferometer may 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 to the centre of the table as possible.</p>									

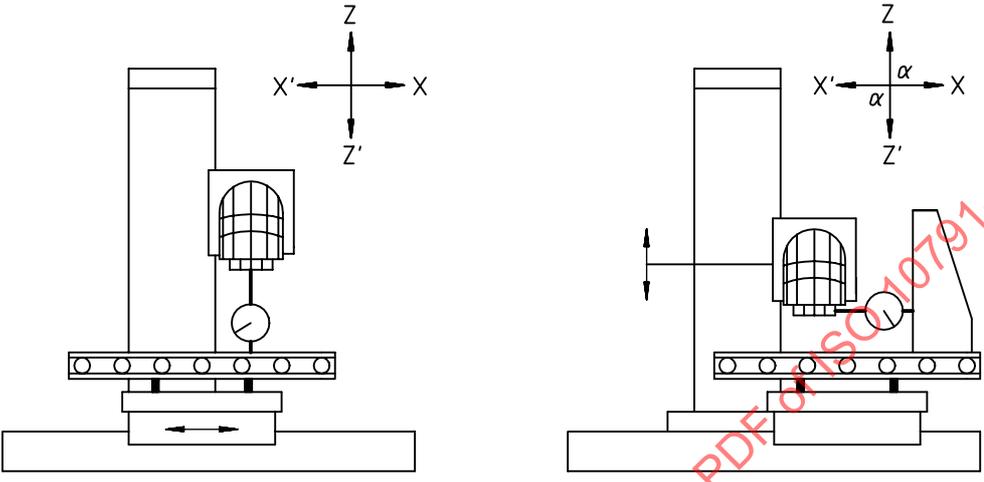
<p>Object</p> <p>Checking of straightness of the Z-axis motion:</p> <p>a) in the vertical XZ plane (EXZ); b) in the horizontal YZ plane (EYZ).</p>	<div style="border: 1px solid black; padding: 5px; display: inline-block;">G3</div>								
<p>Diagram</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>a)</p> </div> <div style="text-align: center;">  <p>b)</p> </div> </div>									
<p>Tolerance</p> <p>For a) and b):</p> <table style="margin-left: 40px; border: none;"> <tr> <td style="padding-right: 20px;">$Z \leq 500$</td> <td style="padding-right: 20px;">0,010</td> </tr> <tr> <td>$500 < Z \leq 800$</td> <td>0,015</td> </tr> <tr> <td>$800 < Z \leq 1\ 250$</td> <td>0,020</td> </tr> <tr> <td>$1\ 250 < Z \leq 2\ 000$</td> <td>0,025</td> </tr> </table> <p>Local tolerance: 0,007 for a measuring length of 300</p>	$Z \leq 500$	0,010	$500 < Z \leq 800$	0,015	$800 < Z \leq 1\ 250$	0,020	$1\ 250 < Z \leq 2\ 000$	0,025	<p>Measured deviation</p> <p>for Z =</p> <p>a)</p> <p>b)</p>
$Z \leq 500$	0,010								
$500 < Z \leq 800$	0,015								
$800 < Z \leq 1\ 250$	0,020								
$1\ 250 < Z \leq 2\ 000$	0,025								
<p>Measuring instruments</p> <p>For a) and b): Square and dial gauge or microscope and taut wire or optical methods</p>									
<p>Observations and references to ISO 230-1 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1</p> <p>For all machine configurations, either the square, the taut wire or the straightness reflector shall be placed as close to the centre of the table as possible. If the spindle can be locked, either the dial gauge, the microscope or the interferometer may be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine.</p>									

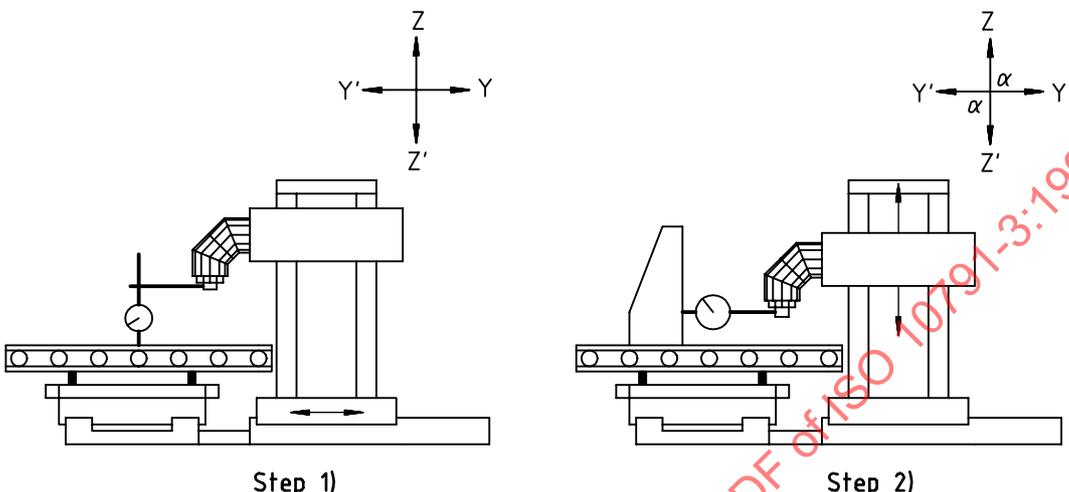
4.2 Angular deviations of linear motions

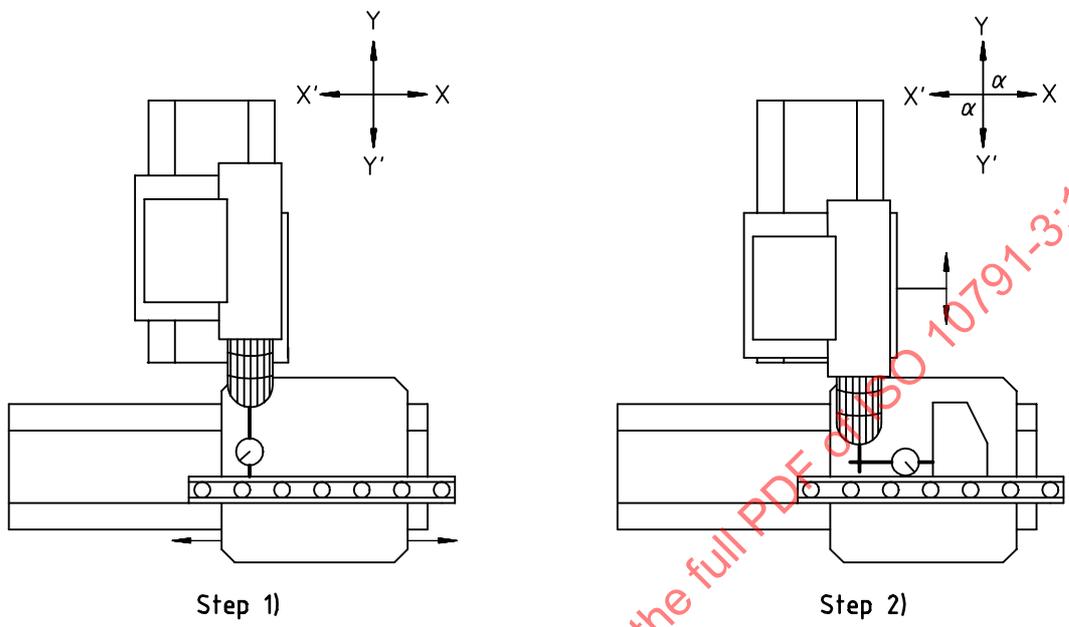
<p>Object</p>		<p>G4</p>
<p>Checking of angular deviations of the X-axis motion:</p> <ul style="list-style-type: none"> a) in the vertical XZ plane parallel to the direction of motion (pitch EBX); b) in the horizontal XY plane (yaw ECX); c) in the vertical YZ plane perpendicular to the direction of motion (roll EAX). 		
<p>Diagram</p>		
<p>Tolerance</p> <p>For a), b) and c): 0,060/1 000 (or 60 μrad or 12'')</p>	<p>Measured deviation</p> <p>for X =</p> <ul style="list-style-type: none"> a) b) c) 	
<p>Measuring instruments</p> <ul style="list-style-type: none"> a) (pitch EBX) Precision level or optical angular-deviation measuring instruments b) (yaw ECX) Optical angular-deviation measuring instruments c) (roll EAX) Precision level 		
<p>Observations and references to ISO 230-1 5.231.3, 5.232.2 and 5.233.2</p> <p>The instrument shall be placed on the moving component (spindle head or workholding table):</p> <ul style="list-style-type: none"> a) (pitch, EBX) longitudinally; b) (yaw, ECX) horizontally; c) (roll, EAX) transversely <p>When X-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>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 readings shall not exceed the tolerance.</p>		

<p>Object</p> <p>Checking of angular deviations of the Z-axis motion:</p> <ul style="list-style-type: none"> a) in the vertical YZ plane (pitch, EAZ); b) in the vertical ZX plane (yaw, EBZ); c) in the horizontal XY plane (roll, ECZ). 	<p>G6</p>
<p>Diagram</p>	
<p>Tolerance</p> <p>For a), b) and c): 0,060/1 000 (or 60 μrad or 12'')</p>	<p>Measured deviation</p> <p>for Z =</p> <ul style="list-style-type: none"> a) b) c)
<p>Measuring instruments</p> <p>a) and b): Precision level or optical angular deviation measuring instruments</p> <p>c) (roll ECZ): Cylindrical square, precision level and dial gauge, or precision cube and dial gauges</p>	
<p>Observations and references to ISO 230-1 5.231.3, 5.232.2 and 5.233.2</p> <p>Measurements shall be taken at five positions equally spaced along the direction of travel, in both directions of movement and at every position. The difference between the maximum and the minimum readings shall not exceed the tolerance.</p> <p>The instrument shall be placed on the moving component (spindle head or workholding table):</p> <ul style="list-style-type: none"> a) (pitch, EAZ) longitudinally; b) (yaw, EBZ) horizontally. <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> <p>For c) (roll, ECZ); place a cylindrical square on the table, approximately parallel to the Z-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 table along 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. The dial gauge shall be zeroed again and the new measurements shall be taken at the same heights of the previous ones, and noted. For each measurement height, calculate the difference of the two readings. The maximum and the minimum of these differences shall be selected and the result of</p> $\frac{\text{maximum difference} - \text{minimum difference}}{d}$ <p>shall not exceed the tolerance, "d" being the distance between the two positions of the dial gauge.</p>	

4.3 Squareness between linear motions

<p>Object</p>		<p>G7</p>
<p>Checking of squareness between Z-axis motion and the X-axis motion.</p>		
<p>Diagram</p>  <p>The diagram illustrates the procedure in two steps. In Step 1, a dial gauge is mounted on a machine table. A coordinate system is defined with the X-axis parallel to the table's linear motion and the Z-axis perpendicular to it. In Step 2, the dial gauge is rotated by an angle α relative to the X-axis to measure the squareness of the Z-axis motion.</p>		
<p>Tolerance</p> <p>0,02 for a measuring length of 500</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Straightedge or surface plate, square and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.522.4</p> <p>In Step 1), the straightedge or the surface plate shall be set parallel to the X-axis.</p> <p>In Step 2), the Z-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 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>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>		

Object Checking of squareness between the Y-axis motion and the Z-axis motion.	G8
Diagram 	
Tolerance 0,02 for a measuring length of 500	Measured deviation
Measuring instruments Straightedge or surface plate, square and dial gauge	
Observations and references to ISO 230-1 5.522.4 <p>In Step 1), the straightedge or the surface plate shall be set parallel to the Y-axis.</p> <p>In Step 2), the Z-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 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>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>	

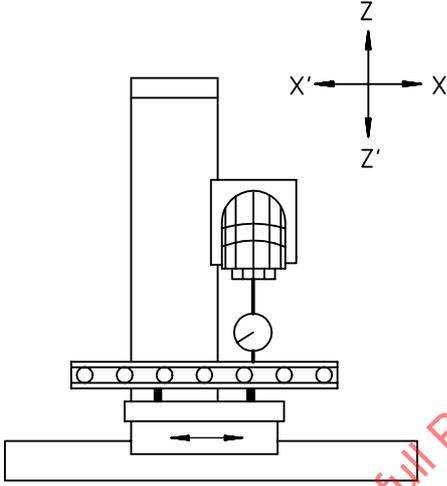
<p>Object</p>		<p>G9</p>
<p>Checking of squareness between the X-axis motion and the Y-axis motion.</p>		
<p>Diagram</p>  <p>The diagram illustrates the procedure in two steps. In Step 1, a dial gauge is used to measure a straightedge that is parallel to the X-axis. The coordinate system shows X and Y axes, and X' and Y' axes. In Step 2, the straightedge is rotated 90 degrees to check the Y-axis. The angle between the X and X' axes is labeled as alpha.</p>		
<p>Tolerance</p> <p>0,02 for a measuring length of 500</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Straightedge, square and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.522.4</p> <p>In Step 1), the straightedge shall be set parallel to the X (or Y)-axis.</p> <p>In Step 2), the Y (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 also 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 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>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>		

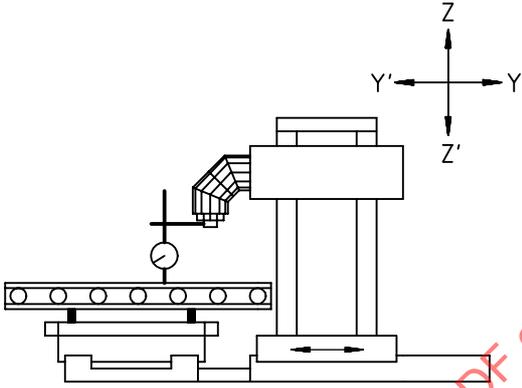
4.4 Spindle

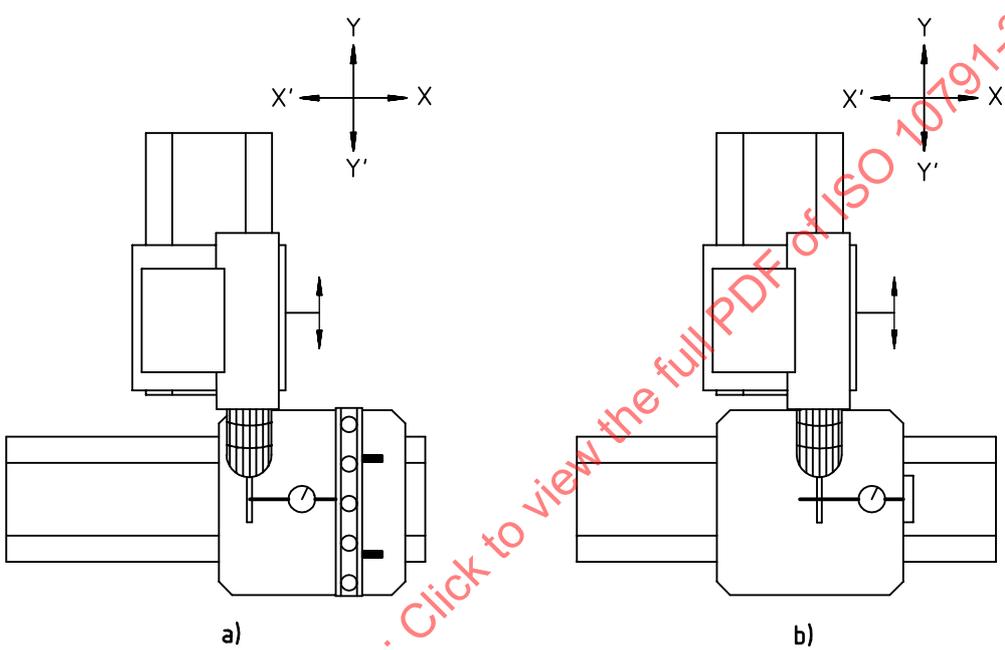
Object		G10
Checking of periodic axial slip of the spindle.		
Diagram		
Tolerance	0,005	Measured deviation
Measuring instruments		
Dial gauge		
Observations and references to ISO 230-1		5.621.1 and 5.622.2
This test shall be performed on all working spindles of the machine.		

4.5 Table or pallet

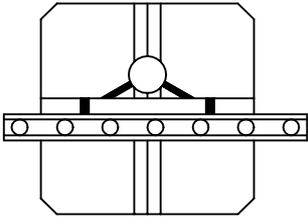
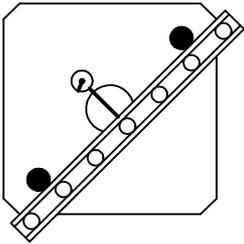
<p>Object</p> <p>Checking of flatness of the table¹⁾ surface.</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>		<p>G12</p>								
<p>Diagram</p>										
<p>Tolerance</p> <table style="margin-left: auto; margin-right: auto;"> <tr> <td>$L \leq 500$</td> <td>0,020</td> </tr> <tr> <td>$500 < L \leq 800$</td> <td>0,025</td> </tr> <tr> <td>$800 < L \leq 1\ 250$</td> <td>0,030</td> </tr> <tr> <td>$1\ 250 < L \leq 2\ 000$</td> <td>0,040</td> </tr> </table> <p>where L is the length of the shorter side of the table or pallet. The surface shall not be convex. Local tolerance: 0,012 for a measuring length of 300</p>		$L \leq 500$	0,020	$500 < L \leq 800$	0,025	$800 < L \leq 1\ 250$	0,030	$1\ 250 < L \leq 2\ 000$	0,040	<p>Measured deviation</p> <p>for $L = \dots$</p>
$L \leq 500$	0,020									
$500 < L \leq 800$	0,025									
$800 < L \leq 1\ 250$	0,030									
$1\ 250 < L \leq 2\ 000$	0,040									
<p>Measuring instruments</p> <p>Precision level or straightedge and slip gauges and dial gauge or optical methods.</p>										
<p>Observations and references to ISO 230-1</p> <p>X and Y-axes are to be in centre of travel.</p> <p>The flatness of the table shall be checked twice, the first time with the rotary table clamped, then not clamped (if applicable). In either case, measured deviations shall not exceed the tolerance.</p>		<p>5.322, 5.323 and 5.324</p>								

<p>Object</p>		<p>G13</p>								
<p>Checking of parallelism between the table¹⁾ surface, in the four rotary positions at 90° from each other, and the X-axis motion.</p> <p>_____</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>										
<p>Diagram</p> 										
<p>Tolerance</p> <table border="0" style="margin-left: 40px;"> <tr> <td>$X \leq 500$</td> <td>0,020</td> </tr> <tr> <td>$500 < X \leq 800$</td> <td>0,025</td> </tr> <tr> <td>$800 < X \leq 1\ 250$</td> <td>0,030</td> </tr> <tr> <td>$1\ 250 < X \leq 2\ 000$</td> <td>0,040</td> </tr> </table>	$X \leq 500$	0,020	$500 < X \leq 800$	0,025	$800 < X \leq 1\ 250$	0,030	$1\ 250 < X \leq 2\ 000$	0,040	<p>Measured deviation</p> <p>for X =</p>	
$X \leq 500$	0,020									
$500 < X \leq 800$	0,025									
$800 < X \leq 1\ 250$	0,030									
$1\ 250 < X \leq 2\ 000$	0,040									
<p>Measuring instruments</p> <p>Straightedge, gauge blocks and dial gauge</p>										
<p>Observations and references to ISO 230-1 5.422.1 and 5.422.2</p> <p>Z-axis to be locked, if possible.</p> <p>The stylus of the dial gauge is to be placed approximately at the working position of the tool. The measurement may be made on a straightedge laid parallel to the table surface.</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>										

Object		G14								
<p>Checking of parallelism between the table¹⁾ surface, in the four rotary positions at 90° from each other, and the Y-axis motion.</p> <p>_____</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>										
<p>Diagram</p> 										
<p>Tolerance</p> <table border="0"> <tr> <td>$Y \leq 500$</td> <td>0,020</td> </tr> <tr> <td>$500 < Y \leq 800$</td> <td>0,025</td> </tr> <tr> <td>$800 < Y \leq 1\ 250$</td> <td>0,030</td> </tr> <tr> <td>$1\ 250 < Y \leq 2\ 000$</td> <td>0,040</td> </tr> </table>	$Y \leq 500$	0,020	$500 < Y \leq 800$	0,025	$800 < Y \leq 1\ 250$	0,030	$1\ 250 < Y \leq 2\ 000$	0,040	<p>Measured deviation</p> <p>for Y =</p>	
$Y \leq 500$	0,020									
$500 < Y \leq 800$	0,025									
$800 < Y \leq 1\ 250$	0,030									
$1\ 250 < Y \leq 2\ 000$	0,040									
<p>Measuring instruments</p> <p>Straightedge, gauge blocks and dial gauge</p>										
<p>Observations and references to ISO 230-1 5.422.1 and 5.422.2</p> <p>Z-axis to be locked, if possible.</p> <p>The stylus of the dial gauge is to be placed approximately at the working position of the tool. The measurement may be made on a straightedge laid parallel to the table surface.</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>Object</p> <p>Checking of parallelism between:</p> <ul style="list-style-type: none"> a) the centreline of the alignment holes (if transverse), or b) the transverse edge locator <p>of the table¹⁾ in the 0° position and the Y-axis motion.</p> <p>_____</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>		<p>G17</p>
<p>Diagram</p>  <p>The diagram consists of two schematic drawings, labeled a) and b), illustrating the measurement setup. Both drawings show a machine tool with a spindle and a dial gauge. In drawing a), the dial gauge is positioned to measure the centerline of alignment holes. In drawing b), the dial gauge is positioned to measure a transverse edge locator. Above each drawing, a set of coordinate axes is shown: X and Y are horizontal and vertical respectively, while X' and Y' are rotated 90 degrees relative to X and Y. A vertical double-headed arrow next to the spindle in both drawings indicates the Y-axis motion.</p>		
<p>Tolerance</p> <p>For a) and b) 0,015 for a measuring length of 300</p>	<p>Measured deviation</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>Dial gauge and, if necessary, straightedge and master pins</p>		
<p>Observations and references to ISO 230-1 5.422.1 and 5.422.2</p> <p>X-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 the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used, and a straightedge shall be placed against them.</p>		

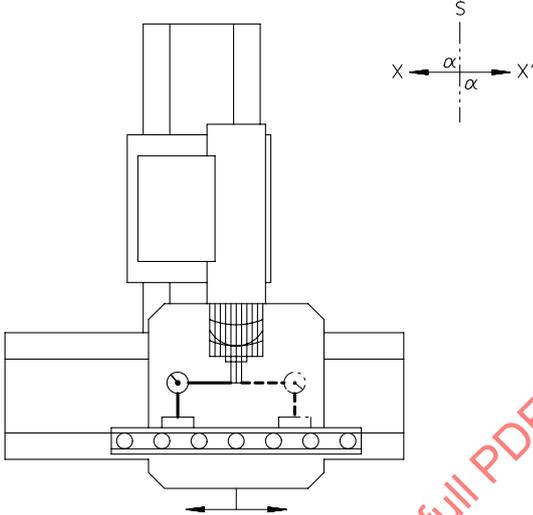
Object		G18
<p>Checking of</p> <p>a) run-out of the centre hole of the table¹⁾ (when the centre hole is used for locating purposes);</p> <p>b) camming of the table surface²⁾.</p> <p>1) Built-in rotary table or one representative pallet clamped in position.</p> <p>2) For indexing tables, check at least four positions at 90° from each other.</p>		
Diagram		
Tolerance		Measured deviation
a) 0,025	b) $L \leq 500$ 0,030 $500 < L \leq 800$ 0,040 $800 < L \leq 1\,250$ 0,050 $1\,250 < L \leq 2\,000$ 0,060	a) b) for $L = \dots$
<p>where L is the length of the shorter side of the table or pallet.</p>		
Measuring instruments		
a) Dial gauge b) Gauge blocks and dial gauge		
Observations and references to ISO 230-1		
a) 5.612.3 X and Y-axes to be locked, if possible. 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 a fixed part of the machine.		
b) 5.632 Z-axis to be locked, if possible. The radius R shall be as large as possible.		
These tests shall be performed on all workholding tables, rotating around vertical or horizontal axes, changing the nomenclature of the axes accordingly.		

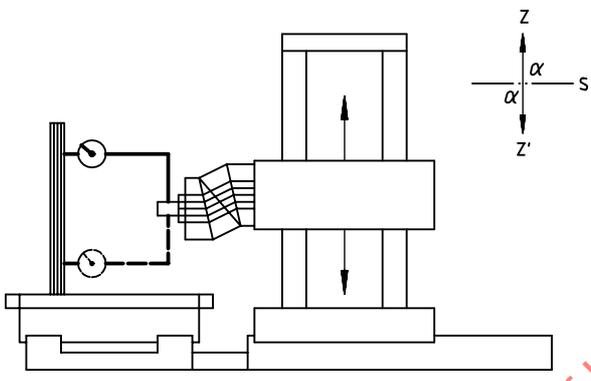
<p>Object</p>		<p>G19</p>
<p>Checking of</p> <ul style="list-style-type: none"> a) intersection of the centreline of the longitudinal median T-slot, or between the alignment holes, or of the cross tenon slot (when existing) with the axis of rotation of the table. b) equidistance of the alignment holes with the axis of rotation of the table¹⁾. <hr style="width: 10%; margin-left: 0;"/> <p>1) Built-in rotary table or one representative pallet clamped in position.</p>		
<p>Diagram</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>a)</p> </div> <div style="text-align: center;">  <p>b)</p> </div> </div>		
<p>Tolerance</p> <p>For a) and b) 0,030</p>	<p>Measured deviation</p> <p>a) b)</p>	
<p>Measuring instruments</p> <ul style="list-style-type: none"> a) Straightedge, gauge blocks or master pins and dial gauge b) Master pins and dial gauge 		
<p>Observations and references to ISO 230-1</p> <ul style="list-style-type: none"> a) The dial gauge, placed on a fixed part of the machine, is zeroed against the straightedge which is then removed and the table is rotated 180°. The straightedge is then re-placed against the other side of the gauge blocks, or master pins, and the new dial gauge reading shall not exceed the tolerance. b) When the alignment holes exist, two master pins which fit in the holes and have protruding parts of the same diameter shall be used instead of the gauge blocks. <p>These tests shall be performed on all workholding tables, rotating around vertical or horizontal axes, changing the nomenclature of the axes accordingly.</p>		

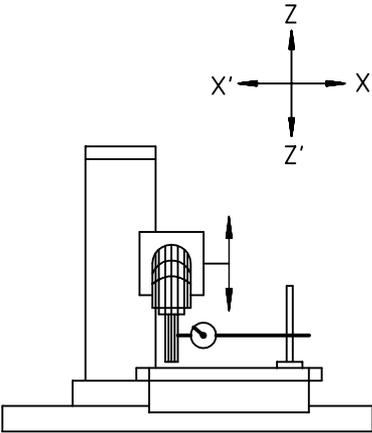
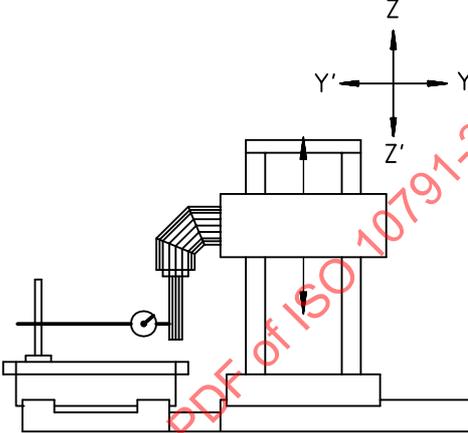
Annex A
(normative)

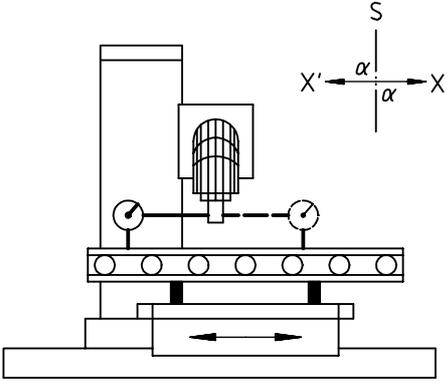
Integral universal 45° split indexable heads

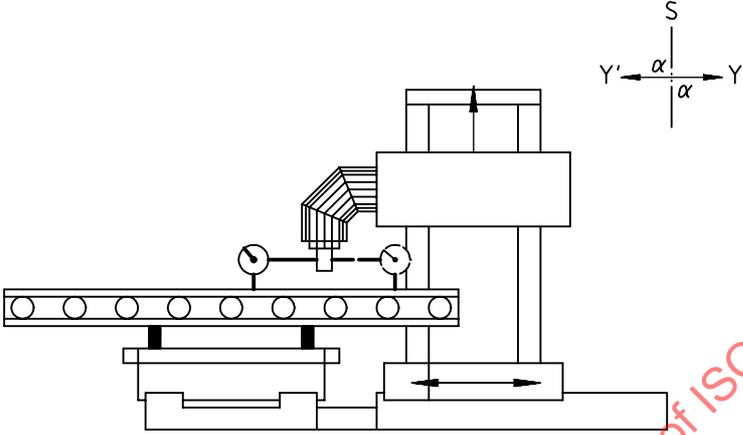
<p>Object</p>		<p>AG1</p>
<p>Checking of parallelism between the spindle axis and the Y-axis motion:</p> <p>a) in the vertical YZ plane; b) in the horizontal XY plane.</p>		
<p>Diagram</p> <p>Diagram a) shows a side view of the spindle and Y-axis. The spindle is on the left, and the Y-axis is on the right. Coordinate axes are shown: Z (vertical up), Z' (vertical down), Y (horizontal right), and Y' (horizontal left). Diagram b) shows a top view of the spindle and Y-axis. The spindle is in the center, and the Y-axis is on the right. Coordinate axes are shown: X (horizontal right), X' (horizontal left), Y (vertical up), and Y' (vertical down).</p>		
<p>Tolerance</p> <p>For a) and b) 0,025 for a measuring length of 300</p>	<p>Measured deviation</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>Test mandrel and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.412.1 and 5.422.3</p> <p>X-axis should be in the centre of the direction of travel.</p> <p>For a), Z-axis to be locked, if possible.</p> <p>For b), X-axis to be locked, if possible.</p>		

<p>Object</p>		<p>AG2</p>
<p>Checking of squareness between the spindle axis, S, in the horizontal position along the Y-direction and the X-axis motion.</p>		
<p>Diagram</p> 		
<p>Tolerance</p> <p style="text-align: center;">0,025/300</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Straightedge, special arm and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.512.1 and 5.512.42</p> <p>Y-axis to be locked, if possible.</p> <p>The straightedge shall be set parallel to the X-axis.</p> <p>This squareness deviation can also be derived from tests G9 and AG1 b).</p> <p>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>		

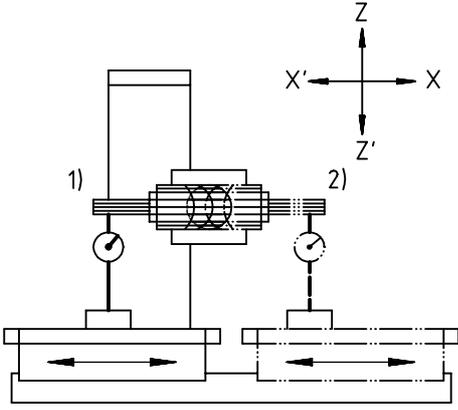
Object	AG3
<p>Checking of squareness between the spindle axis, S, in the horizontal position along the Y-direction and the Z-axis motion.</p>	
<p>Diagram</p> 	
<p>Tolerance</p> <p style="text-align: center;">0,025/300</p>	<p>Measured deviation</p>
<p>Measuring instruments</p> <p>Square, special arm and dial gauge</p>	
<p>Observations and references to ISO 230-1 5.512.1, 5.512.32 and 5.512.42</p> <p>Y-axis to be locked, if possible.</p> <p>The measurement side of the square should be set parallel to the Z-axis, or the lack of parallelism shall be considered in the measurement.</p> <p>This squareness deviation can also be derived from tests G8 and AG1 a).</p> <p>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>	

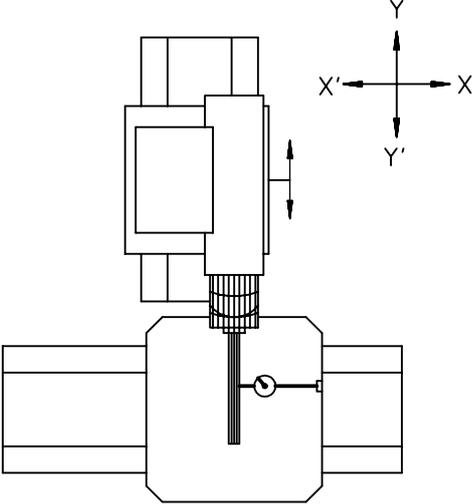
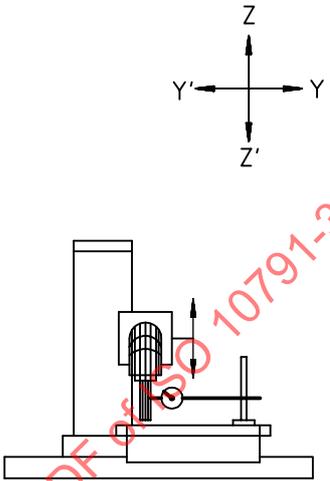
<p>Object</p> <p>Checking of parallelism between the spindle axis in the vertical position and the Z-axis motion:</p> <p>a) in the vertical ZX plane; b) in the vertical YZ plane.</p>		<p>AG4</p>
<p>Diagram</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>a)</p> </div> <div style="text-align: center;">  <p>b)</p> </div> </div>		
<p>Tolerance</p> <p>For a) and b) 0,025 for a measuring length of 300</p>	<p>Measured deviation</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>Test mandrel and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.412.1 and 5.422.3</p> <p>X-axis should be in the centre of the direction of travel.</p> <p>For a), X-axis to be locked, if possible.</p> <p>For b), Y-axis to be locked, if possible.</p>		

Object	AG5
Checking of squareness between the spindle axis in the vertical position and the X-axis motion.	
Diagram 	
Tolerance 0,025/300	Measured deviation
Measuring instruments Straightedge, special arm and dial gauge	
Observations and references to ISO 230-1 5.512.1 and 5.512.42 Z-axis to be locked, if possible. The straightedge shall be set parallel to the X-axis. This squareness deviation can also be derived from tests G7 and AG4 a). The value of angle α , being less than, equal to or greater than 90° , should be noted for information and possible corrections.	

<p>Object</p>		<p>AG6</p>
<p>Checking of squareness between the spindle axis in the vertical position and the Y-axis motion.</p>		
<p>Diagram</p> 		
<p>Tolerance</p> <p>0,025/300</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Straightedge, special arm and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.512.1 and 5.512.42</p> <p>Z-axis to be locked, if possible.</p> <p>The straightedge shall be set parallel to the Y-axis.</p> <p>This squareness deviation can also be derived from tests G8 and AG4 b).</p> <p>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>		

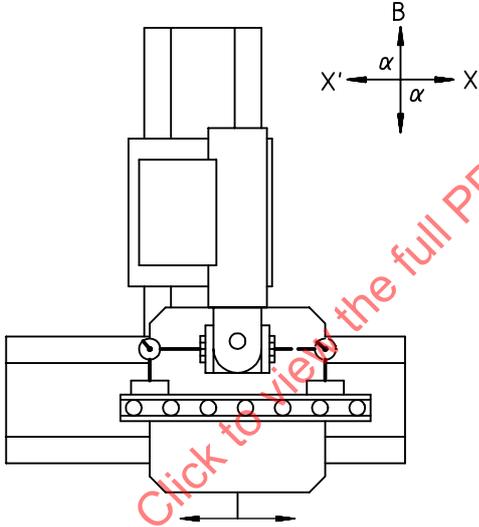
<p>Object</p>		<p>AG7</p>
<p>Checking of parallelism between the spindle axis in either of the two horizontal positions along the X-direction and the X-axis motion:</p> <p>1) With the spindle in the left position: 2) With the spindle in the right position:</p> <p style="margin-left: 40px;">a) in the vertical ZX plane; a) in the vertical ZX plane;</p> <p style="margin-left: 40px;">b) in the horizontal XY plane. b) in the horizontal XY plane.</p>		
<p>Diagram</p>		
<p>Tolerance</p> <p>For a) and b) 0,025 for a measuring length of 300</p>	<p>Measured deviation</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>Test mandrel and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.412.1 and 5.422.3</p> <p>For a), Z-axis to be locked, if possible.</p> <p>For b), Y-axis to be locked, if possible.</p>		

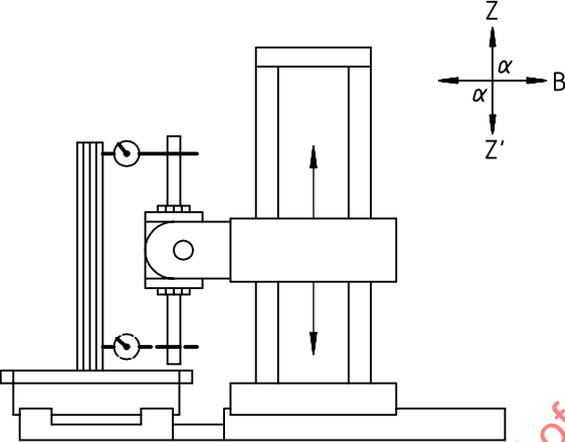
<p>Object</p>		<p>AG8</p>
<p>Checking of difference between the spindle heights in the two horizontal positions in the X-direction. (Intersection of rotary axis B and spindle axis S)</p>		
<p>Diagram</p> 		
<p>Tolerance</p> <p style="text-align: center;">0,03</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Test mandrel and dial gauge</p>		
<p>Observations and references to ISO 230-1</p> <p>This deviation can be derived from measurements 1 a) and 2 a) of test AG7, taking the readings at the spindle nose only, in order to ignore the parallelism deviations.</p>		

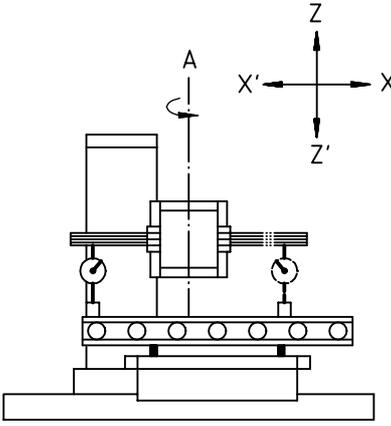
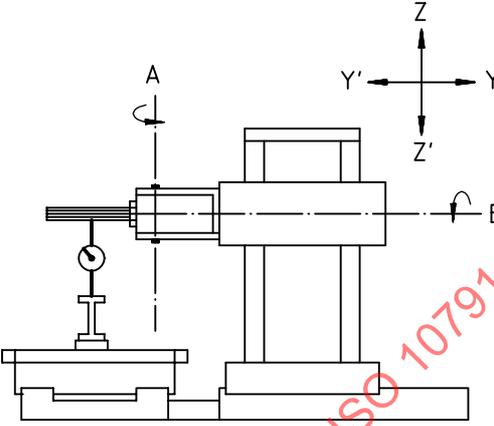
Object		AG9
Checking that the spindle axis S and rotary axis D at 45° lie in the same plane.		
Diagram <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Step 1)</p> </div> <div style="text-align: center;">  <p>Step 2)</p> </div> </div>		
Tolerance	Measured deviation	
0,020		
Measuring instruments Test mandrel and dial gauge		
Observations and references to ISO 230-1 X-axis to be locked, if possible. Step 1) Set the spindle in the horizontal position along the Y-direction. Zero the dial gauge touching the test mandrel close to the spindle nose. Lock the dial gauge on the table. Step 2) In order to avoid interferences with the dial gauge drive away the head by means of movements along the Y and Z-axes only. Rotate the D-axis to set the spindle axis in the vertical position, and again bring the test mandrel into contact with the dial gauge by means of Y and Z-axes movement. When the movements in Step 2) have been completed, half of the reading on the dial gauge shall not exceed the tolerance. The deviation of this test can be measured by performing test AG4 a) after AG1 b), without moving the X-axis and without resetting the dial gauge.		

Annex B
(normative)

Integral universal swivel heads

<p>Object</p> <p>Checking of squareness between the B-axis of the yoke rotation and the X-axis motion.</p>		<p>BG1</p>
<p>Diagram</p>  <p>The diagram shows a cross-sectional view of a swivel head assembly. A coordinate system is defined with a vertical axis labeled 'B' and a horizontal axis labeled 'X'. A secondary horizontal axis 'X'' is shown at an angle α to the 'X' axis. The assembly includes a spindle head, a yoke, and a base with rollers. A double-headed arrow at the bottom indicates the X-axis motion.</p>		
<p>Tolerance</p> <p>0,025/500</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Straightedge and dial gauge</p>		
<p>Observations and references to ISO 230-1 5.512.1, 5.512.32 and 5.512.42</p> <p>Y-axis to be locked, if possible.</p> <p>The straightedge shall be set parallel to the X-axis.</p> <p>The dial gauge may be mounted either on the yoke body or on the spindle head, in this case setting the spindle perpendicular to the Y-axis.</p> <p>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>		

Object Checking of squareness between the B-axis of the yoke rotation and the Z-axis motion.	BG2
Diagram 	
Tolerance 0,025/500	Measured deviation
Measuring instruments Square and dial gauge	
Observations and references to ISO 230-1 <p>5.512.1, 5.512.32 and 5.512.42</p> <p>Y-axis to be locked, if possible.</p> <p>The square shall be set parallel to the Z-axis.</p> <p>The dial gauge may be mounted either on the yoke body or on the spindle head, in this case setting the spindle perpendicular to the Y-axis.</p> <p>The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.</p>	

Object		BG3
Checking of squareness between the A-axis of the head rotation and the B-axis of the yoke rotation.		
Diagram <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Step 1)</p> </div> <div style="text-align: center;">  <p>Step 2)</p> </div> </div>		
Tolerance 0,035/500	Measured deviation	
Measuring instruments Straightedge or surface plate, test mandrel and dial gauge		
Observations and references to ISO 230-1 Z-axis to be locked, if possible. The straightedge shall be set parallel to the X-axis. Step 1) Adjust the angular position of the yoke (B-axis) until the two dial gauge readings, with the spindle in the right and in the left position, are equal (A-axis is perpendicular to X-axis). Then zero the dial gauge and mark the contact point on the test mandrel. Step 2) Rotate the head (A-axis) 90° in order to set the spindle horizontal along the Y-direction (in the YZ plane) and move the Y-axis (and the dial gauge on the straightedge) until the stylus touches the test mandrel again in the marked point. Note the reading. Step 3) Rotate the yoke (B-axis) 180°, repeat adjustment Step 1) and measurement Step 2). Half of the difference between the two measurements Step 2); divided by the distance between the dial gauge and the A-axis of the head rotation, shall not exceed the tolerance. NOTE — Half of the sum of the two measurements in Step 2), i.e. their mean value, divided by the distance between the dial gauge and the A-axis of the head rotation, gives the parallelism deviation between the B-axis and the Y-axis in the vertical YZ plane, corresponding to the combination of tests G8 and BG2. The squareness deviation between the spindle axis S and the A-axis, to be measured by test BG4, is bypassed by zeroing the dial gauge during the adjustment Step 1).		

<p>Object</p>		<p>BG4</p>
<p>Checking of squareness between the spindle axis S and the A-axis of the head rotation.</p>		
<p>Diagram</p> <p>The diagram illustrates the setup for checking squareness. It shows a machine tool with a spindle axis S and a head rotation axis A. A coordinate system is defined with X and X' as horizontal axes and Z and Z' as vertical axes. In Step 1, the spindle axis S is shown in a vertical position. In Step 2, the spindle axis S is shown in a horizontal position, and a dial gauge is used to measure its parallelism deviation relative to the X-axis.</p>		
<p>Tolerance</p> <p style="text-align: center;">0,040/500</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Straightedge or surface plate, test mandrel and dial gauge</p>		
<p>Observations and references to ISO 230-1</p> <p>Z-axis to be locked, if possible.</p> <p>The straightedge shall be set parallel to the X-axis.</p> <p>Step 1) Use the adjustment carried out in Step 1) of the previous test (BG3).</p> <p>Step 2) Measure the parallelism deviation between the spindle axis S in the vertical ZX plane in any of the two horizontal positions of the spindle. This deviation is equal to the squareness deviation between the spindle axis S and the A-axis.</p>		

<p>Object</p> <p>Checking that the spindle axis S and the A-axis of the head rotation lie in the same plane.</p>		<p>BG5</p>
<p>Diagram</p>		
<p>Tolerance</p> <p style="text-align: center;">0,020</p>	<p>Measured deviation</p>	
<p>Measuring instruments</p> <p>Test mandrel and dial gauge</p>		
<p>Observations and references to ISO 230-1</p> <p>Y-axis to be locked, if possible.</p> <p>Turn the head crosswise on one side, and adjust the A-axis until the test mandrel is parallel to the X-axis in the horizontal XY plane.</p> <p>Zero the dial gauge and lock it on the table.</p> <p>In order to avoid interferences with the dial gauge, drive away the head by means of movements along the X and Z-axes only. Rotate the A-axis 180°, and again bring the test mandrel into contact with the dial gauge by means of the X and Z-axes movement.</p> <p>Adjust the A-axis until the test mandrel is again parallel to the X-axis on the other side, without resetting the dial gauge.</p> <p>Half of the new reading shall not exceed the tolerance.</p>		

