BRITISH STANDARD

BS ISO
10791-2:2001

Test conditions for machining centres —

Part 2: Geometric tests for machines with vertical spindle or universal heads with vertical primary rotary axis (vertical Z-axis)

ICS 25.080.

National foreword

This British Standard reproduces verbatim ISO 10791-2:2001 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee MTE/1, Machine tools, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 May 2001

Summary of pages

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INTERNATIONAL STANDARD

ISO 10791-2

First edition
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Test conditions for machining centres —

Part 2: Geometric tests for machines with vertical spindle or universal heads with vertical primary rotary axis (vertical Z-axis)

Conditions d'essai des centres d'usinage —

Partie 2: Essais géométriques des machines à broche verticale ou à têtes universelles à axe principal de rotation vertical (axe Z vertical)

Reference number
ISO 10791-2:2001(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this part of ISO 10791 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10791-2 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 a normative part of this part of ISO 10791.

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 purpose of ISO 10791 is to supply information as wide and comprehensive as possible on tests and checks which can be carried out for comparison, acceptance, maintenance or any other purpose.

ISO 10791 specifies, by 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.

Test conditions for machining centres —

Part 2: Geometric tests for machines with vertical spindle or universal heads with vertical primary rotary axis (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 vertical spindle (that is vertical Z-axis).

This part of ISO 10791 applies to machining centres having basically three numerically controlled axes, that is three linear axes (X, Y and Z) of up to 2 000 mm length, but also refers to supplementary motions, such as rotary axes (A′, B′ and C′), those of rams, quill, or universal heads. Motions 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 optional horizontal spindles as well as for two possible types of universal heads in the following annexes:

— annex A: optional horizontal spindles (tests AG1 to AG6);

— annex B: rotary heads, with one numerically controlled rotary axis (tests BG1 and BG2);

— annex C: swivel heads, with two numerically controlled rotary axes perpendicular to each other (tests CG1 to CG7).

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

2 Normative references

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this part of ISO 10791. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10791 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC 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*.

ISO 8526-1:1990, *Modular units for machine tools — Workholding pallets — Part 1: Workholding pallets up to 800 mm nominal size*.

ISO 8526-2:1990, *Modular units for machine tools — Workholding pallets — Part 2: Workholding pallets of nominal size greater than 800 mm*.

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 for the sake of clarity, microradians or arcseconds are used. 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.

When the operation concerned is in accordance with the specifications of ISO 230-1, the instructions in the "Observations" box of the operations described in clause 4 and annexes A to C are followed by a reference to the corresponding paragraph in 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. With a view to making 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 or 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 shall be clearly stated when ordering a machine. The 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 of the contracting parties.

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 at least 0,001 millimetres.

3.6 Diagrams

For reasons of simplicity, the diagrams in this part of ISO 10791 illustrate only a few types of machines.

3.7 Pallets

For the machines working with several pallets, the tests concerning the intrinsic geometric features or their behaviour related to the axes of the machine (tests G15 to G20) shall 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 some geometric deviations, based on an agreement between the user and the supplier/manufacturer, the relevant tests may be carried out with or without these compensations. When the software compensations are 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 families based on their architecture 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 for these families is shown in Table 1[1)].

3.10 Designation

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

a) “Machining centre”;

b) the reference to this part of ISO 10791, that is ISO 10791-2;

c) the letter V for “vertical spindle”;

d) the number indicated in the relevant box of Figure 1 and the left-hand column of Table 1.

EXAMPLE A machining centre, vertical spindle type, with the table moving along the X-axis, the column moving along the Y-axis and the spindle head moving along the Z-axis is designated as follows:

Machining centre ISO 10791-2 type V07

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. This part of ISO 10791 is applicable to them as well. In this case, and when necessary, the text should be modified by replacing the terms “portal” or “gantry” with “column”, and “cross rail” with “arm”.

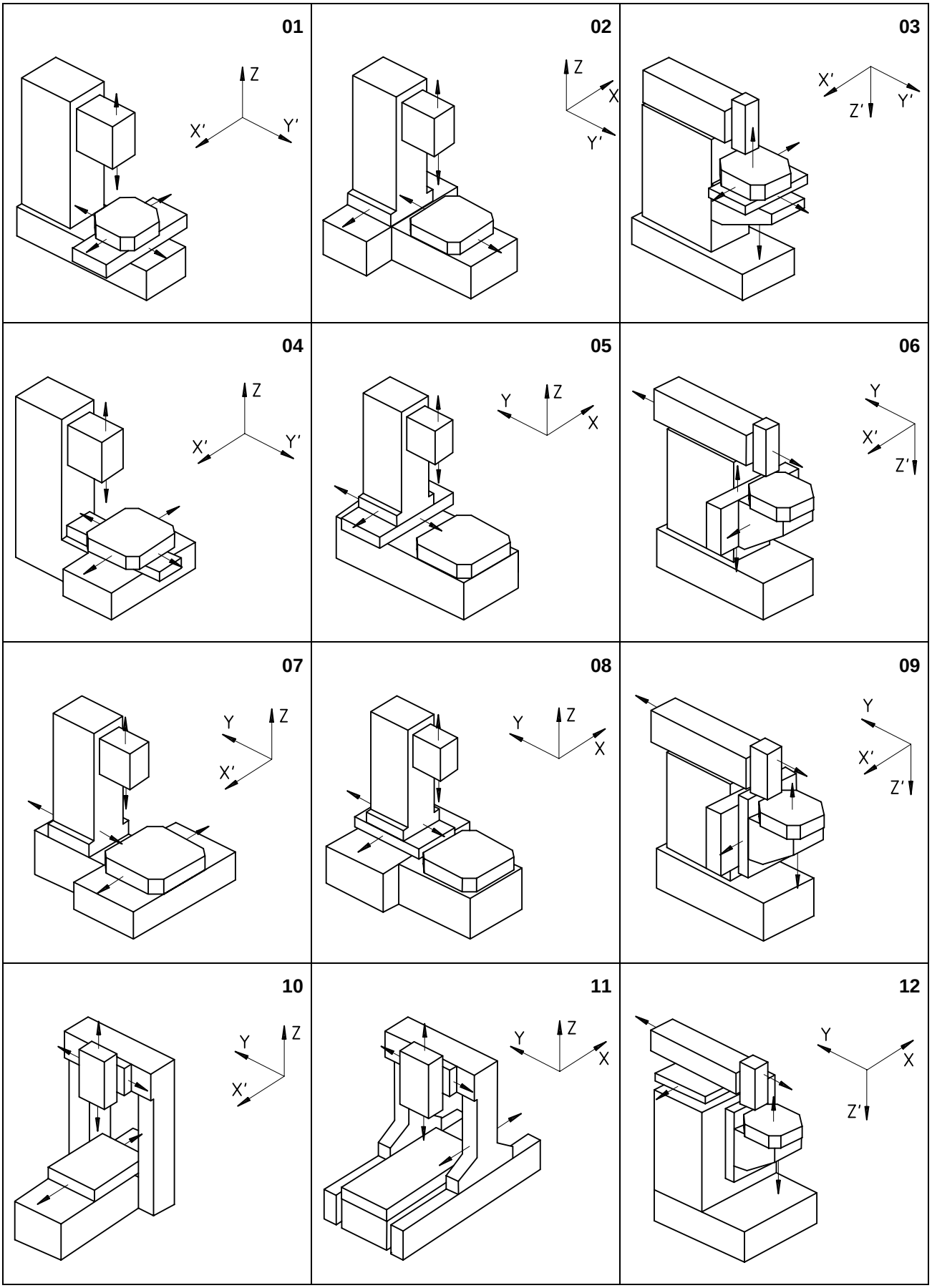


Figure 1

Table 1 — Classification of configurations of vertical spindle machining centres

	X	X′	Y	Y′	Z	Z′
01		Table on its saddle		Table saddle on the bed	Spindle head on the column	
02	Column on the bed			Table on the bed	Spindle head on the column	
03		Table on its saddle		Table saddle on the knee		Knee on the column
04		Table saddle on the bed		Table on its saddle	Spindle head on the column	
05	Column on its saddle		Column saddle on the bed		Spindle head on the column	
06		Knee on its saddle	Spindle head on the column			Knee saddle on the column
07		Table on the bed	Column on the bed		Spindle head on the column	
08	Column saddle on the bed		Column on its saddle		Spindle head on the column	
09		Knee saddle on the column	Spindle head on the column			Knee on its saddle
10		Table on the bed	Spindle head slide on the cross rail		Spindle head on its slide	
11	Gantry on the bed		Spindle head slide on the cross rail		Spindle head on its slide	
12	Spindle head slide on the column		Spindle head on its slide			Knee on the column

4 Geometric tests

4.1 Straightness of linear motions

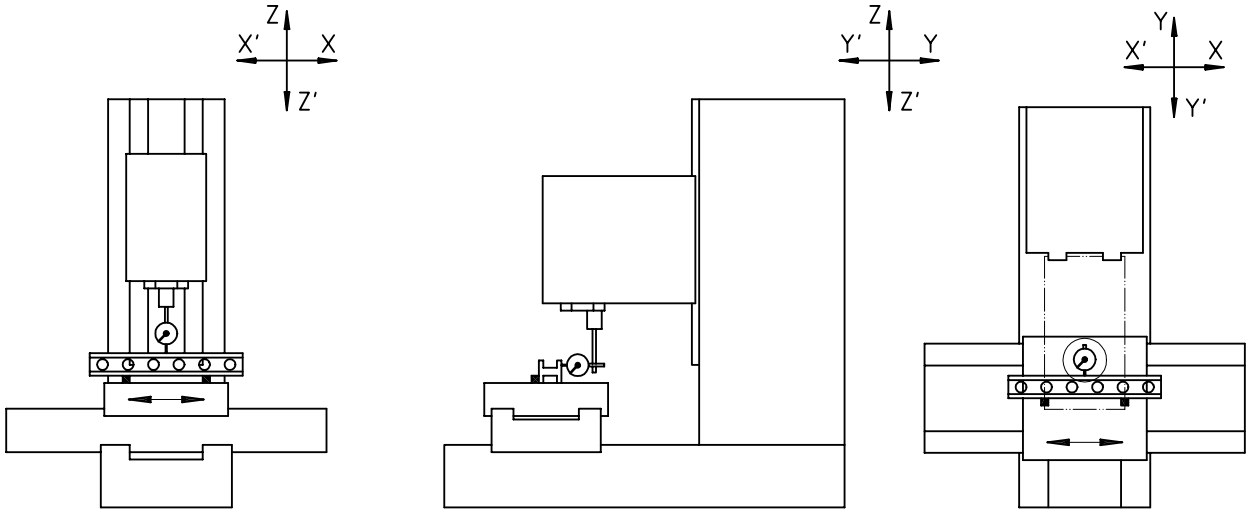
Object **G1**

Checking of straightness of the X-axis motion:

a) in the vertical ZX plane (EZX);

b) in the horizontal XY plane (EYX).

Diagram



a) b)

Tolerance

For a) and b)		X	⩽	500	0,010
	500	< X	⩽	800	0,015
	800	< X	⩽	1 250	0,020
	1 250	< X	⩽	2 000	0,025

Local tolerance: 0,007 for a measuring length of 300

Measured deviation

For X = ...

a)

b)

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 230-1:1996 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1

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.

The measuring line should pass as close to the centre of the table as possible.

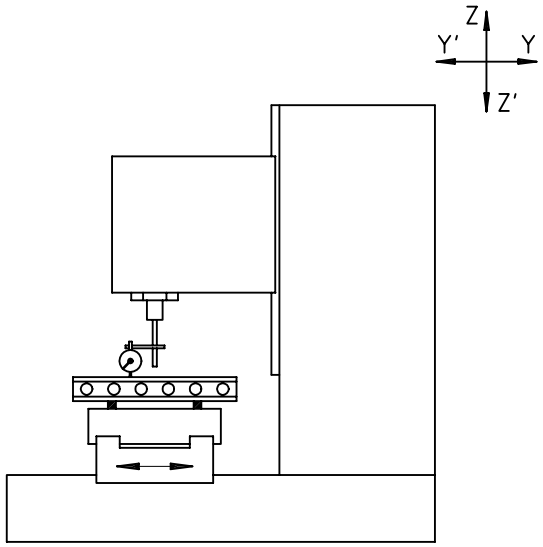
Object **G2**

Checking of straightness of the Y-axis motion:

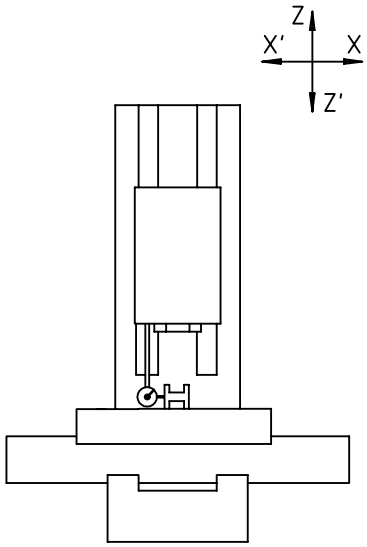
a) in the vertical YZ plane (EZY);

b) in the horizontal XY plane (EXY).

Diagram



a)



b)

Tolerance

For a) and b)			Y	⩽	500	0,010
	500	<	Y	⩽	800	0,015
	800	<	Y	⩽	1 250	0,020
	1 250	<	Y	⩽	2 000	0,025

Local tolerance: 0,007 for a measuring length of 300

Measured deviation

for Y = ...

a)

b)

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 230-1:1996 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1

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.

The measuring line should pass as close to the centre of the table as possible.

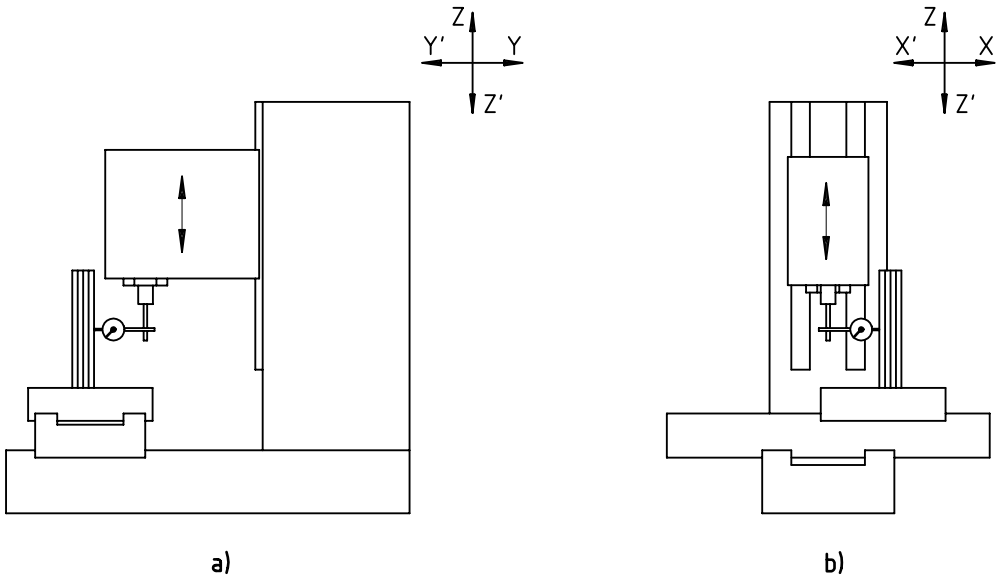
Object **G3**

Checking of straightness of the Z-axis motion:

a) in the vertical YZ plane (EYZ) parallel to the Y-axis;

b) in the vertical ZX plane (EXZ) parallel to the X-axis.

Diagram



Tolerance

For a) and b)			Z	⩽	500	0,010
	500	<	Z	⩽	800	0,015
	800	<	Z	⩽	1 250	0,020
	1 250	<	Z	⩽	2 000	0,025

Local tolerance: 0,007 for a measuring length of 300

Measured deviation

for Z = ...

a)

b)

Measuring instruments

For a) and b): Square and dial gauge or optical methods or microscope and taut wire

Observations and references to ISO 230-1:1996 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1

For all machine configurations, either the square or the taut wire shall be placed as close to the centre of the table as possible. If the spindle can be locked, either the dial gauge or the microscope may be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine.

4.2 Angular deviations of linear motions

Object **G4**

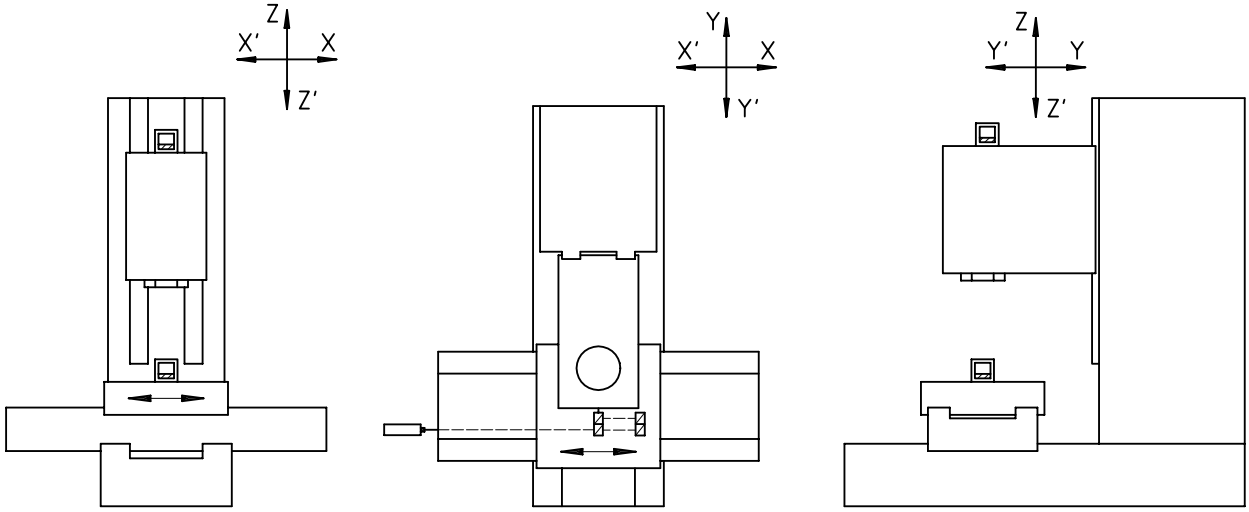
Checking of angular deviations of the X-axis motion:

a) in the vertical ZX plane parallel to the axis movement (pitch, EBX);

b) in the horizontal XY plane (yaw, ECX);

c) in the vertical YZ plane perpendicular to the axis movement (roll, EAX).

Diagram



a) b) c)

Tolerance	**Measured deviation**
For a), b) and c) 0,060/1 000 (or 60 μrad or 12″)	a) b) c)

Measuring instruments

a) (pitch, EBX) Precision level or optical angular deviation measuring instruments

b) (yaw, ECX) Optical angular deviation measuring instruments

c) (roll, EAX) Precision level

Observations and references to ISO 230-1:1996 5.231.3, 5.232.2 and 5.233.2

The measuring instrument shall be placed on the moving component (spindle head or workholding table):

a) (pitch, EBX) longitudinally

b) (yaw, ECX) horizontally

c) (roll, EAX) transversely

When X-axis motion causes an angular movement of both the spindle head and the 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 allow for the difference between the angular positions of the tool holding and workholding components to be measured.

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.

Object **G5**

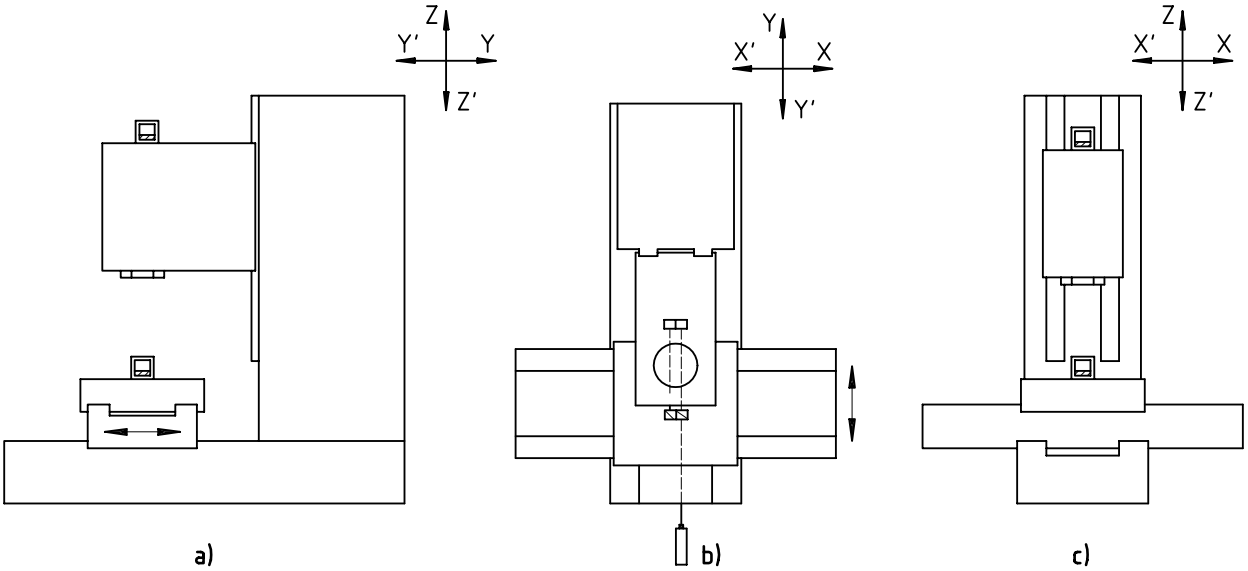
Checking of angular deviations of the Y-axis motion:

a) in the vertical YZ plane parallel to the movement (pitch, EAY);

b) in the horizontal XY plane (yaw, ECY);

c) in the vertical ZX plane perpendicular to the movement (roll, EBY).

Diagram



Tolerance	**Measured deviation**
For a), b) and c) 0,060/1 000 (or 60 μrad or 12″)	a) b) c)

Measuring instruments

a) (pitch, EAY) Precision level or optical angular deviation measuring instruments

b) (yaw, ECY) Optical angular deviation measuring instruments

c) (roll, EBY) Precision level

Observations and references to ISO 230-1:1996 5.231.3, 5.232.2 and 5.233.2

The measuring instrument shall be placed on the moving component (spindle head or workholding table):

a) (pitch, EAY) longitudinally

b) (yaw, ECY) horizontally

c) (roll, EBY) transversely

When Y-axis motion causes an angular movement of both the spindle head and the 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 allow for the difference between the angular positions of the tool-holding and the work-holding components to be measured.

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.

Object **G6**

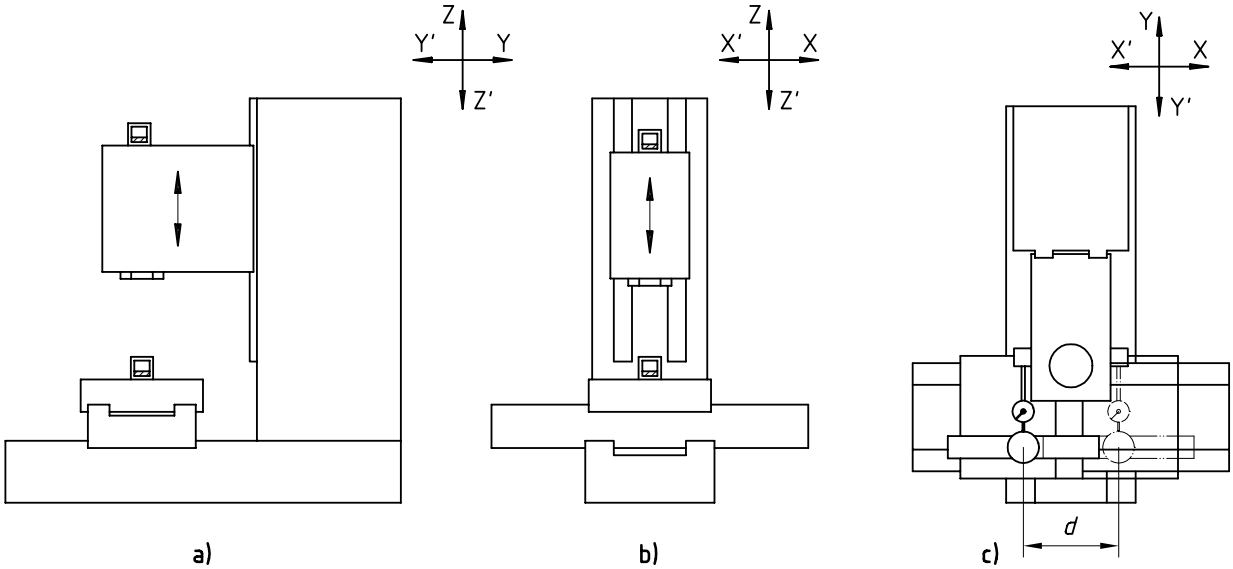
Checking of angular deviations of the Z-axis motion:

a) in the vertical YZ plane (EAZ);

b) in the vertical ZX plane (EBZ);

c) in the horizontal XY plane (roll, ECZ).

Diagram



Tolerance	**Measured deviation**
For a), b) and c) 0,060/1 000 (or 60 μrad or 12″)	a) b) c)

Measuring instruments

a) and b): Precision level or optical angular deviation measuring instruments

c) Straightedge, cylindrical square and dial gauge

Observations and references to ISO 230-1:1996 5.231.3, 5.232.2 and 5.233.2

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.

The instrument shall be placed on the moving component (spindle head or workholding table):

a) in the Y′ direction for angular deviation (EAZ);

b) in the X′ direction for angular deviation (EBZ).

When the Z-axis motion causes an angular movement of both the 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 allow for the difference between the angular positions of the tool-holding and work-holding components to be measured.

For c) (roll ECZ), place a cylindrical square on the straightedge 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 as 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

$$\frac{\text{Maximum difference} - \text{minimum difference}}{d}$$

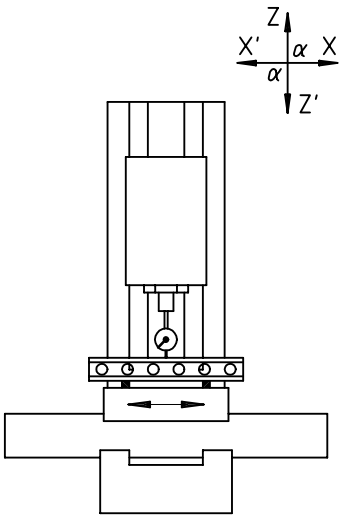
shall not exceed the tolerance, "d" being the distance between the two positions of the dial gauge.

4.3 Squareness between linear motions

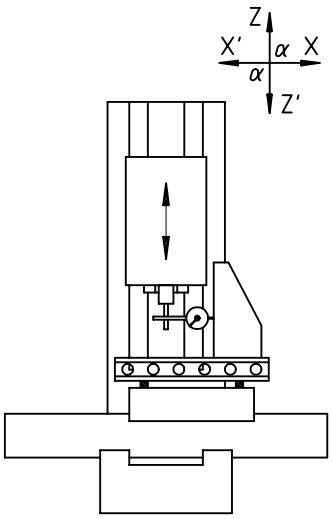
Object **G7**

Checking of squareness between Z-axis motion and the X-axis motion.

Diagram



Step 1



Step 2

Tolerance	**Measured deviation**
0,02 for a measuring length of 500	

Measuring instruments

Straightedge or surface plate, square and dial gauge

Observations and references to ISO 230-1:1996 5.522.4

In step 1), the straightedge or the surface plate shall be set parallel to the X-axis. When the cylindrical square is used, the face of the straightedge or the surface plate shall also be parallel to the X-axis.

In step 2), the Z-axis shall then be checked by means of a square standing on the straightedge or on the surface plate.

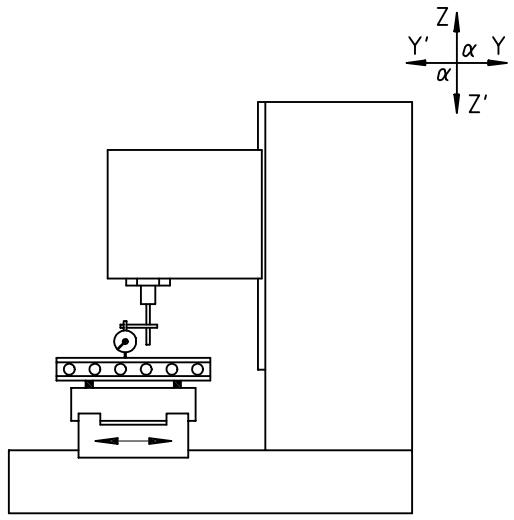
If the spindle can be locked, the dial gauge may be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

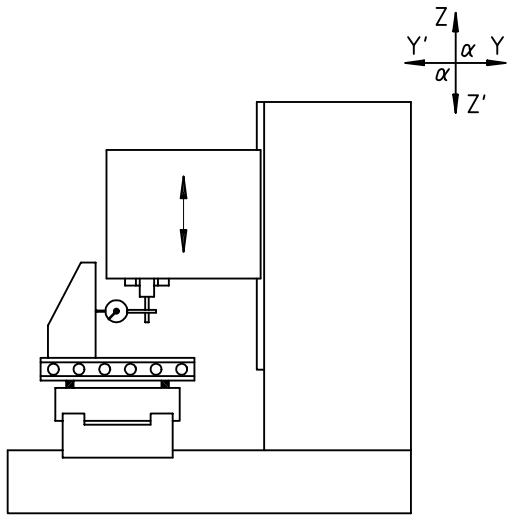
Object **G8**

Checking of squareness between the Z-axis motion and the Y-axis motion.

Diagram



Step 1



Step 2

Tolerance	**Measured deviation**
0,02 for a measuring length of 500	

Measuring instruments

Straightedge or surface plate, square and dial gauge

Observations and references to ISO 230-1:1996 5.522.4

In step 1), the straightedge or the surface plate shall be set parallel to the Y-axis. When the cylindrical square is used, the face of the straightedge or the surface plate shall also be parallel to the X-axis.

In step 2), the Z-axis shall then be checked by means of a square standing on the straightedge or on the surface plate.

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.

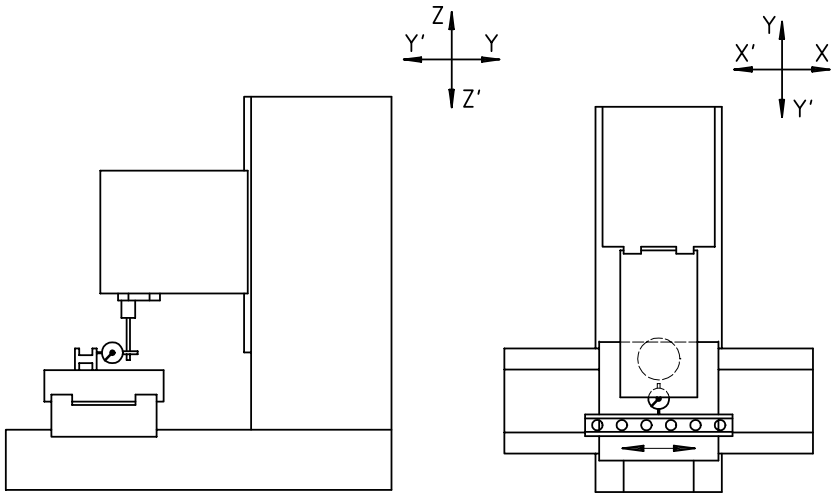
The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

For the portal type (10) and the gantry type (11) machines provided with movable cross-rail, repeat this check for three different positions of cross-rail on the column (down position, middle position, and upper position).

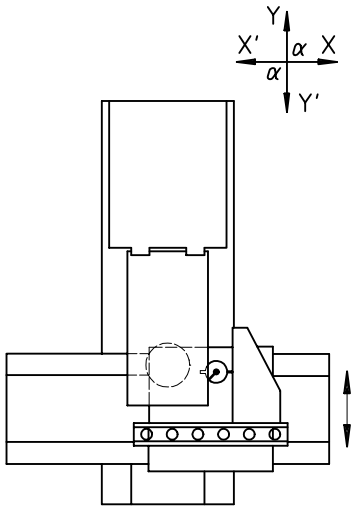
Object **G9**

Checking of squareness between the Y-axis motion and the X-axis motion.

Diagram



Step 1



Step 2

Tolerance	**Measured deviation**
0,02 for a measuring length of 500	

Measuring instruments

Straightedge, square and dial gauge

Observations and references to ISO 230-1:1996 5.522.4

In step 1), the straightedge shall be set parallel to the X-(or Y-) axis.

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.

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.

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.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

4.4 Spindle

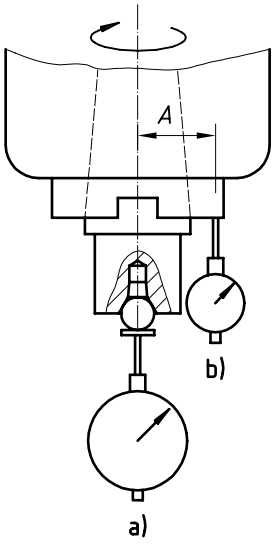
Object **G10**

Checking of:

a) periodic axial slip of the spindle;

b) caming of spindle nose surface.

Diagram



Tolerance	**Measured deviation**
a) 0,005	a)
b) 0,010	b)

Measuring instruments

Dial gauge

Observations and references to ISO 230-1:1996 5.621.2, 5.622.2, 5.631, and 5.632

This test shall be performed on all working spindles of the machine.

When non-preloaded bearings are used, an axial force shall be applied.

The distance A should be as large as possible.

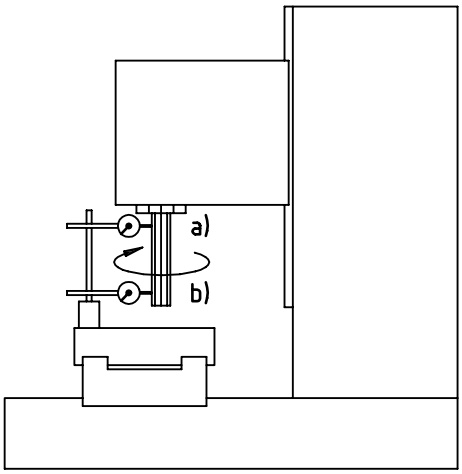
Object **G11**

Checking of run-out of internal taper of the spindle:

a) at the spindle nose;

b) at a distance of 300 mm from the spindle nose.

Diagram



Tolerance	**Measured deviation**
a) 0,01	a)
b) 0,02	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1:1996 5.612.3

This test shall be performed on all working spindles of the machine.

This test shall be carried out over at least two revolutions in accordance with the note in 5.611.4 of ISO 230-1:1996.

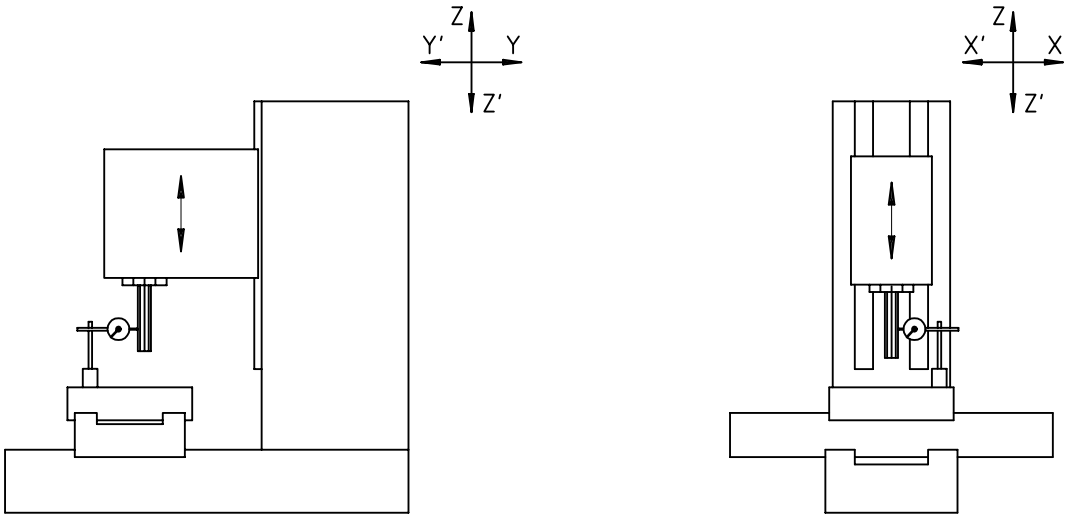
Object **G12**

Checking of parallelism between the spindle axis and the Z-axis motion:

a) in the vertical YZ plane;

b) in the vertical ZX plane.

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b)	a)
0,015 for a measuring length of 300	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1:1996 5.412.1 and 5.422.3

a) Y-axis to be locked , if possible.

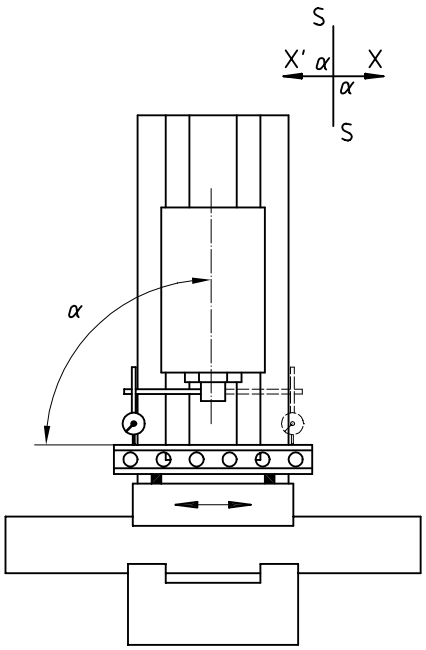
b) X-axis to be locked, if possible.

For the portal type (10) and the gantry type (11) machines provided with movable cross-rail, repeat this check for three different positions of cross-rail on the column (down position, middle position, and upper position).

Object **G13**

Checking of squareness between the spindle axis and the X-axis motion.

Diagram



Tolerance	**Measured deviation**
0,02/300	

Measuring instruments

Straightedge, special arm and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32, 5.512.4 and 5.512.42

Z-axis to be locked, if possible.

The straightedge shall be set parallel to the X-axis.

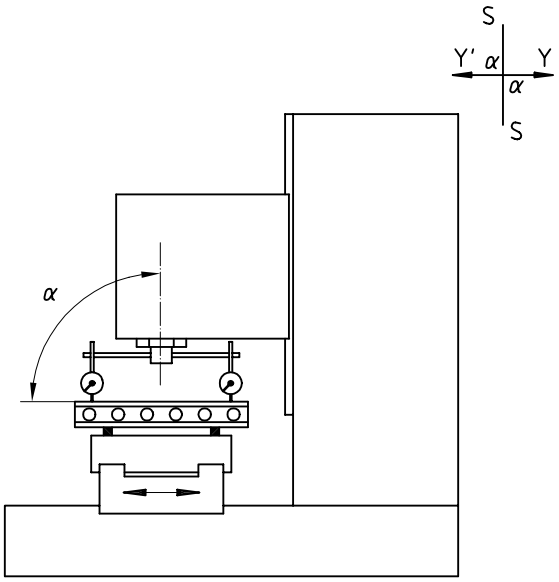
This squareness deviation can also be derived from tests G7 and G12 b), provided that the sum of the relevant deviations does not exceed the tolerance shown here.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

Object **G14**

Checking of squareness between the spindle axis and the Y-axis motion.

Diagram



Tolerance	**Measured deviation**
0,02/300	

Measuring instruments

Straightedge, special arm and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

Z-axis to be locked, if possible.

The straightedge shall be set parallel to the Y-axis.

This squareness deviation can also be derived from tests G8 and G12 a), provided that the sum of the relevant deviations does not exceed the tolerance shown here.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

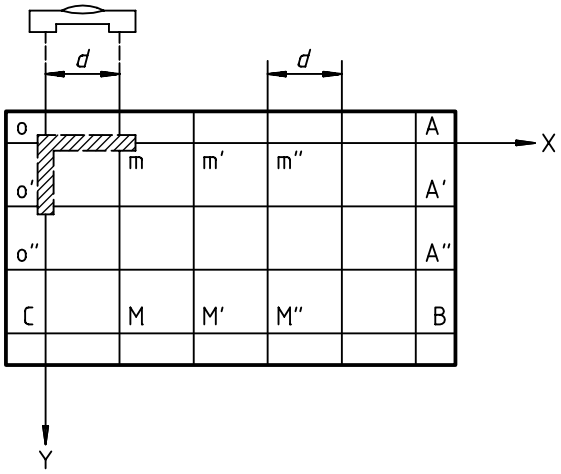
4.5 Table or pallet

Object **G15**

Checking of flatness of the table[1)] surface.

1) Built-in rotary table or one representative pallet clamped in position.

Diagram



Tolerance

		L	$\leqslant$ 500	0,020
500	<	L	$\leqslant$ 800	0,025
800	<	L	$\leqslant$ 1 250	0,030
1 250	<	L	$\leqslant$ 2 000	0,040

where L is the length of the shortest side of the table or pallet.

Local tolerance: 0,012 for a measuring length of 300

Measured deviation

for L = ...

Measuring instruments

Precision level or straightedge, gauge blocks and dial gauge or optical methods

Observations and references to ISO 230-1:1996 5.322, 5.323 and 5.324

X and Y axes shall be in the centre of travel.

The flatness of the table shall be checked twice, the first time with the rotary table clamped and the second time with the table unclamped (if possible). Both measured deviations shall not exceed the tolerance.

This test applies to pallets with dimensions specified in ISO 8526-1 and ISO 8526-2.

Object

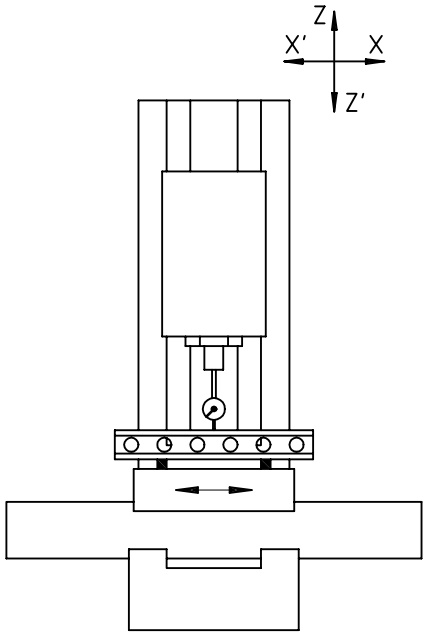
G16

Checking of parallelism between the table[1)] surface and the X-axis motion.

_____

1) Built-in rotary table or one representative pallet clamped in position.

Diagram



Tolerance

		X	⩽	500	0,020
500	<	X	⩽	800	0,025
800	<	X	⩽	1 250	0,030
1 250	<	X	⩽	2 000	0,040

Measured deviation

for X = ...

Measuring instruments

Straightedge, gauge blocks and dial gauge

Observations and references to ISO 230-1:1996 5.422.1 and 5.422.2

Y- and Z-axis to be locked, if possible.

The stylus of the dial gauge shall be placed approximately at the working position of the tool. The measurement may be made on a straightedge laid parallel to the table surface.

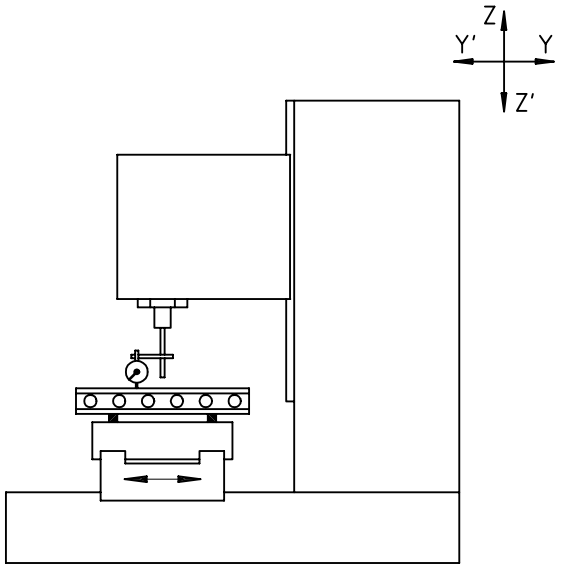
If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.

Object **G17**

Checking of parallelism between the table[1)] surface and the Y-axis motion.

1) Built-in rotary table or one representative pallet clamped in position.

Diagram



Tolerance					**Measured deviation**
		Y	⩽ 500	0,020	for Y =
500	<	Y	⩽ 800	0,025	
800	<	Y	⩽ 1 250	0,030	
1 250	<	Y	⩽ 2 000	0,040	

Measuring instruments

Straightedge, gauge blocks and dial gauge

Observations and references to ISO 230-1:1996 5.422.1 and 5.422.2

X- and Z-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 may be made on a straightedge laid parallel to the table surface.

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.

Object **G18**

Checking of parallelism between:

a) the longitudinal median or reference T-slot; or

b) the centreline of the alignment holes (if longitudinal); or

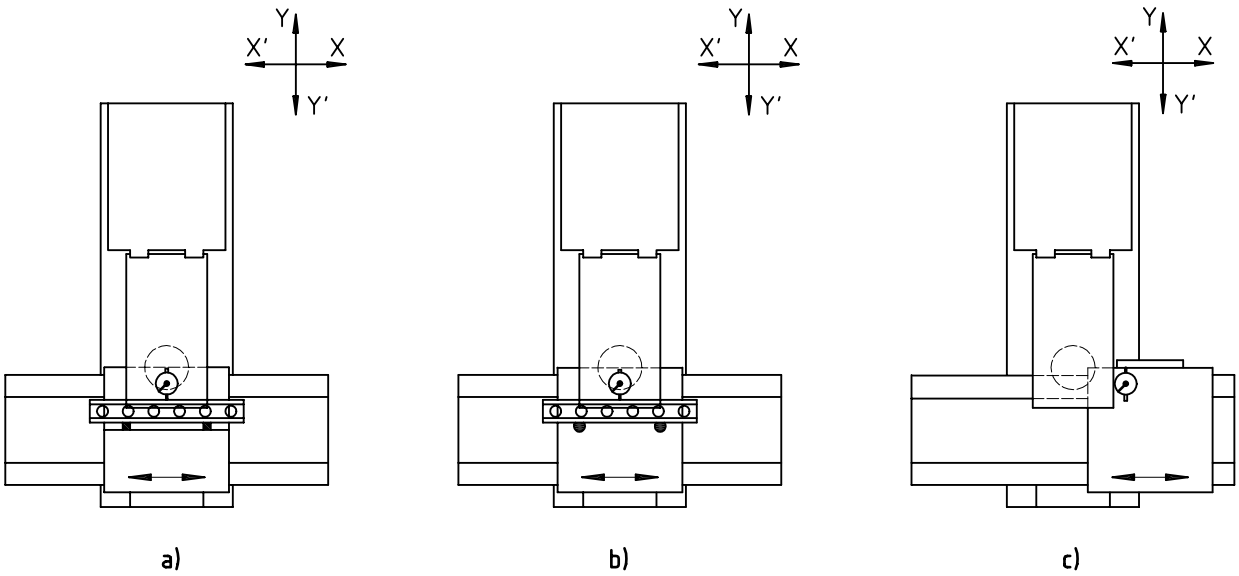
c) the longitudinal edge locator;

of the table[1)] in the 0^{o} position and the X-axis motion.

_____

1) Built-in rotary table or a representative pallet clamped in position.

Diagram



Tolerance	**Measured deviation**
For a), b) and c)	a)
0,015 for a measuring length of 300	b)
	c)

Measuring instruments

Dial gauge and, if necessary, straightedge and master pins

Observations and references to ISO 230-1:1996 5.422.1 and 5.422.2

Y-axis 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 the spindle head of the machine.

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.

4.6 Supplementary axis (W-axis) parallel to the Z-axis

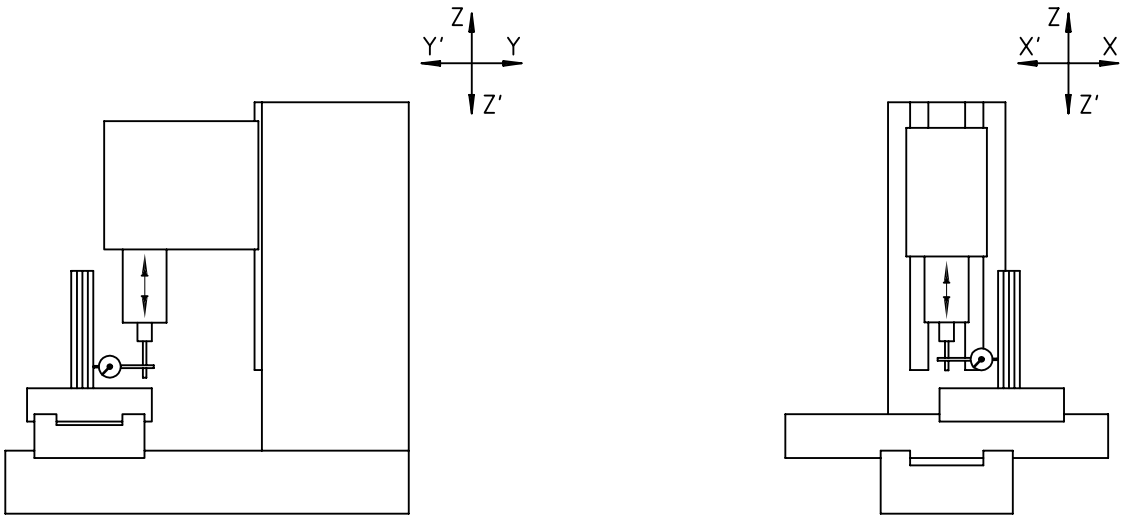
Object **G19**

Checking of the straightness of the W-axis motion:

a) in the vertical YZ plane;

b) in the vertical ZX plane.

Diagram



Tolerance	**Measured deviation**
For a) and b)	a)
0,015 for a measuring length of 300	b)

Measuring instruments

Cylindrical square and dial gauge

Observations and references to ISO 230-1:1996 5.211, 5.231.2, 5.232.1, 5.233.1

a) Y-axis to be locked, if possible.

b) X-axis 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 the spindle head of the machine.

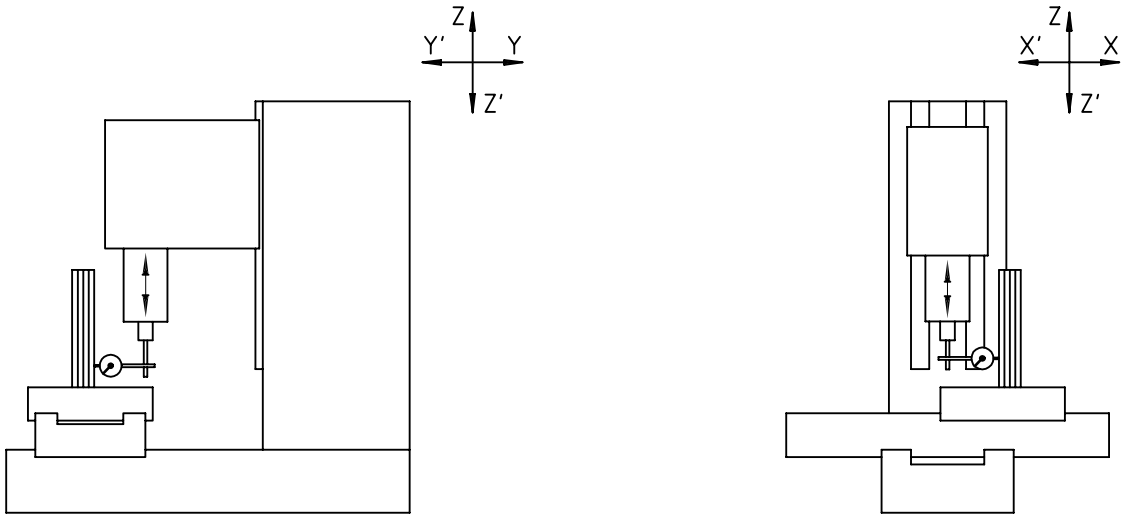
Object **G20**

Checking of parallelism between the W-axis motion and the Z-axis motion:

a) in the vertical YZ plane;

b) in the vertical ZX plane.

Diagram



Tolerance	**Measured deviation**
For a) and b) 0,025 for a measuring length of 300	a) b)

Measuring instruments

Square and dial gauge

Observations and references to ISO 230-1 5.422.2 and 5.422.5

a) Y-axis to be locked, if possible.

b) X-axis to be locked, if possible.

If the two motions can be operated together, move the two parts by the same amount so that the stylus always touches the square at the same point.

If this is not possible, the square may be set parallel to the W-axis, or the lack of parallelism shall be taken into account in the measurement.

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.

Annex A
(normative)

Optional horizontal spindles

A.1 Supplementary spindle parallel to the X-axis

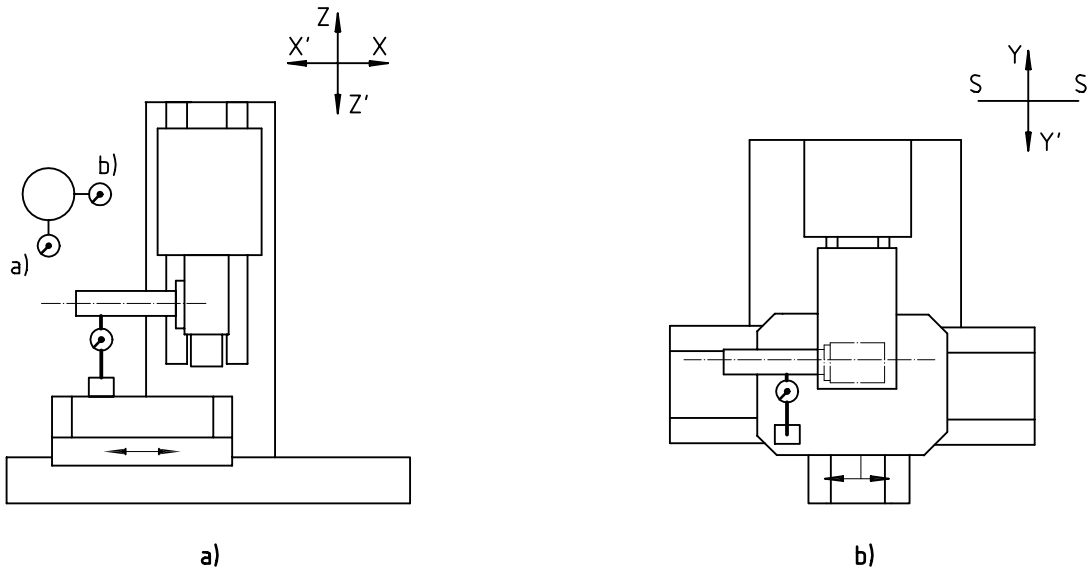
Object **AG1**

Checking of parallelism between the spindle axis and the X-axis motion:

a) in the vertical ZX plane;

b) in the horizontal XY plane.

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b)	a)
0,020 for a measuring length of 300	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1:1996 5.412.1 and 5.422.3

Y-axis in centre of the travel.

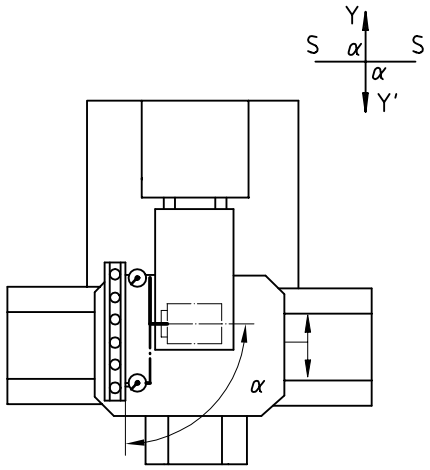
For a), Z-axis to be locked, if possible.

For b), Y-axis to be locked, if possible.

Object **AG2**

Checking of squareness between the spindle axis and the Y-axis motion.

Diagram



Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Straightedge, special arm and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

X-axis to be locked, if possible.

The straightedge shall be set parallel to the Y-axis.

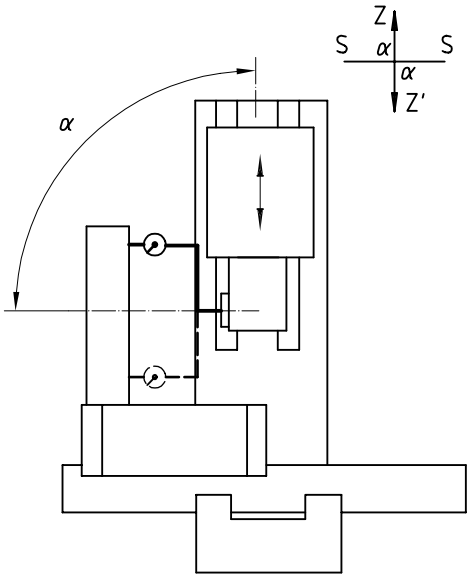
This squareness deviation can also be derived from tests G9 and AG1 b), provided that the sum of the relevant deviations does not exceed the tolerance shown here.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

Object **AG3**

Checking of squareness of the spindle axis to the Z-axis motion.

Diagram



Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Square, special arm and dial gauge

Observations and references to ISO 230-1:1996 5.512.1 and 5.512.32

X-axis to be locked, if possible.

The measurement side of the square should be set parallel to the Z-axis, or the lack of parallelism shall be taken into account in the measurement.

This squareness deviation can also be derived from tests G7 and AG1 a), provided that the sum of the relevant deviations does not exceed the tolerance shown here.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

A.2 Supplementary spindle parallel to the Y-axis

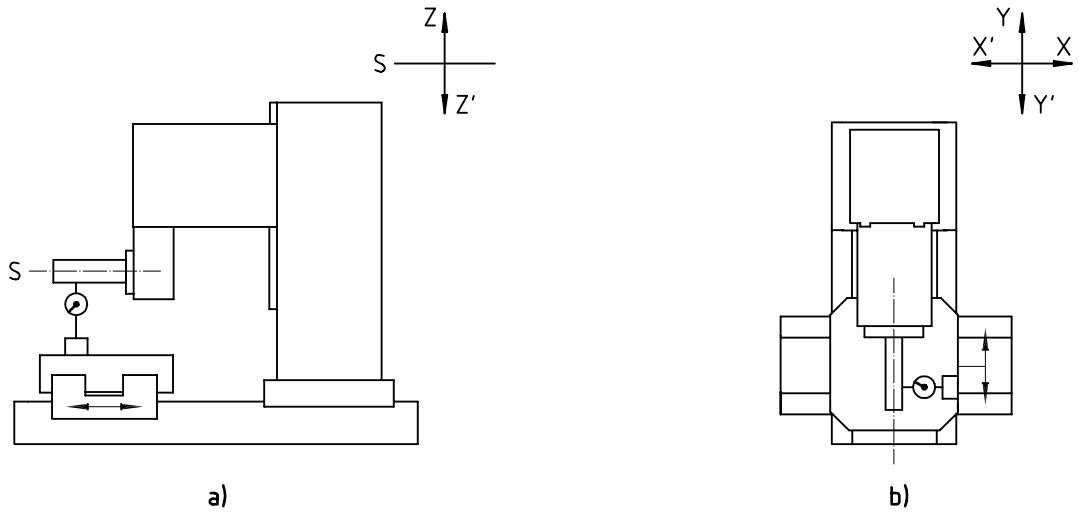
Object **AG4**

Checking of parallelism of the spindle axis and the Y-axis motion:

a) in the vertical YZ plane;

b) in the horizontal XY plane.

Diagram



Tolerance	**Measured deviation**
For a) and b)	a)
0,020 for a measuring length of 300	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1:1996 5.412.1 and 5.422.3

X-axis in centre of the travel.

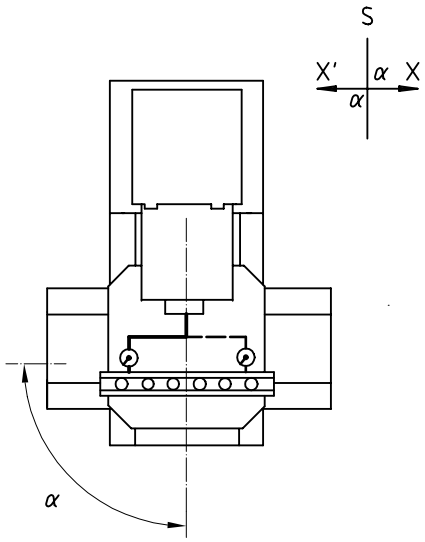
For a), Z-axis to be locked, if possible.

For b), X-axis to be locked, if possible.

Object **AG5**

Checking of squareness of the spindle axis to the X-axis motion.

Diagram



Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Straightedge, special arm and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

Y-axis to be locked, if possible.

The straightedge shall be set parallel to the X-axis.

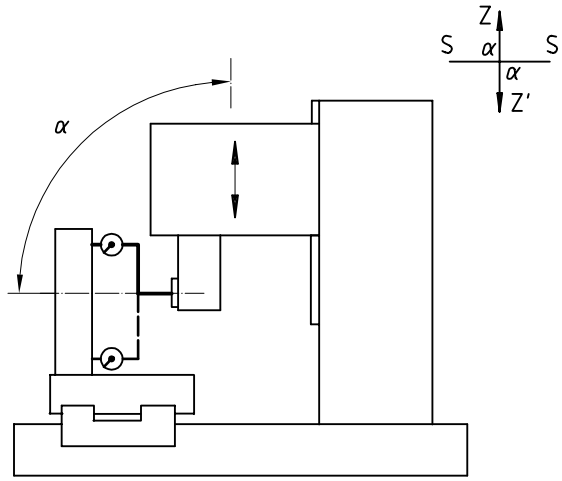
This squareness deviation can also be derived from tests G7 and AG4 b), provided that the sum of the relevant deviations does not exceed the tolerance shown here.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

Object **AG6**

Checking of squareness of the spindle axis to the Z-axis motion.

Diagram



Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Square, special arm and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

X-axis in centre of the travel.

Y-axis to be locked, if possible.

The square shall be set parallel to the Z-axis.

This squareness deviation can also be derived from tests G8 and AG4 a), provided that the sum of the relevant deviations does not exceed the tolerance shown here.

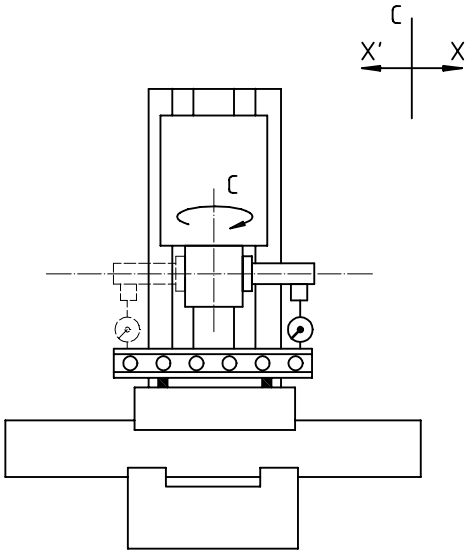
The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

Annex B
(normative)

Rotary heads

Object	**BG1**
Checking of squareness between the axis of rotation of the head (or parallelism of its plane of rotation) and the XY plane.	

Diagram



Tolerance	**Measured deviation**
0,015/300	

Measuring instruments

Surface plate and dial gauge

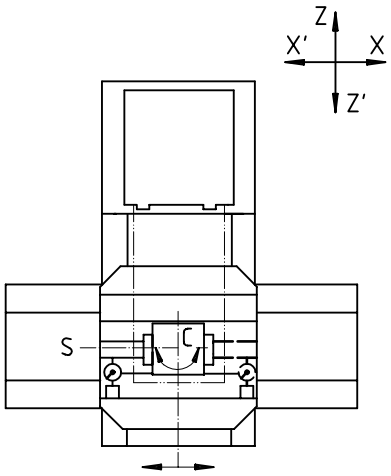
Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

The surface plate shall be set parallel to the XY plane.

Object **BG2**

Checking of intersection of the horizontal spindle axis with the vertical axis of rotation of the rotary head.

Diagram



Tolerance	**Measured deviation**
0,030	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1

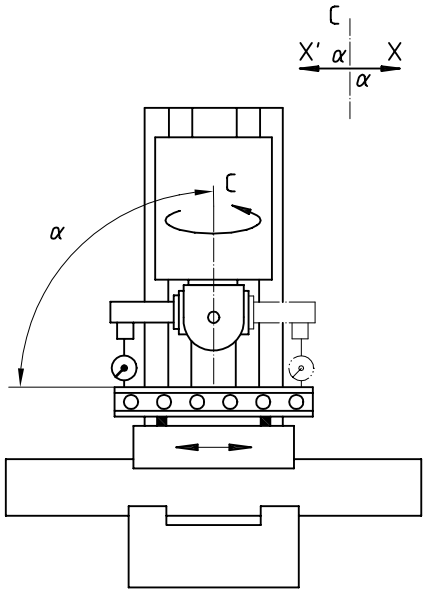
Adjust the rotary head so that the spindle axis is parallel to the X- (or Y-) axis in the horizontal XY plane and zero the dial gauge. Rotate the head 180° and adjust it so that the spindle axis is again parallel to the X- (or Y-) axis without re-setting the dial gauge and moving the X- (or Y-) and Z-axes only. Take the new reading. Half of this reading shall not exceed the tolerance. The result of this test may also be used for compensation purposes.

Annex C
(normative)

Swivel heads

Object	**CG1**
Checking of squareness between the C-axis of the yoke rotation and the X-axis motion.	

Diagram



Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Straightedge, or surface plate and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

Z-axis and A-axis to be locked, if possible.

The straightedge shall be set parallel to the X-axis.

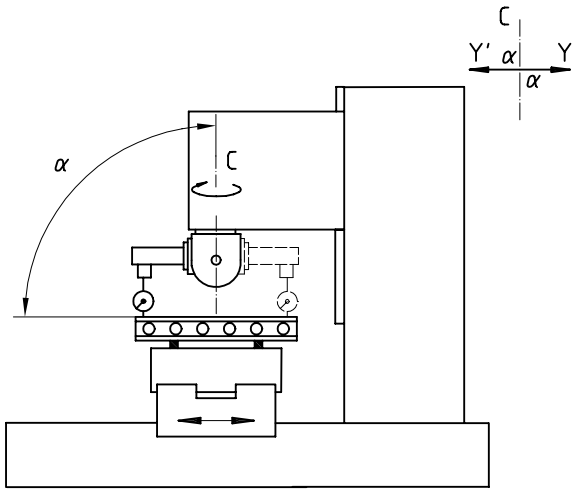
The dial gauge may be mounted either on the yoke body or on the spindle head, setting in this case the spindle perpendicular to the Z-axis.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

Object **CG2**

Checking of squareness between the C-axis of the yoke rotation and the Y-axis motion.

Diagram



Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Straightedge or surface plate and dial gauge

Observations and references to ISO 230-1:1996 5.512.1, 5.512.32 and 5.512.42

Z-axis and A-axis to be locked, if possible.

The straightedge shall be set parallel to the Y-axis.

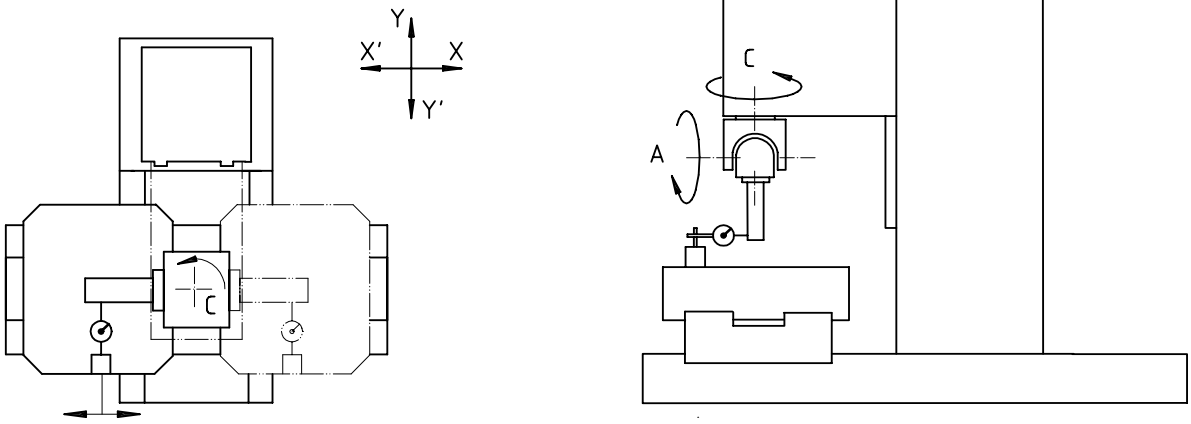
The dial gauge may be mounted either on the yoke or on the spindle head, setting in this case the spindle perpendicular to the Z-axis.

The value of angle α, being less than, equal to or greater than 90^{o}, should be noted for information and possible correction.

Object **CG3**

Checking of squareness between the A-axis of the head rotation and the C-axis of the yoke rotation.

Diagram



Step 1) **Step 2)**

Tolerance	**Measured deviation**
0,035/300	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1

Y-axis to be locked, if possible.

Step 1) Adjust the angular position of the yoke (C-axis) until the two dial gauge readings with the spindle in the right and in the left position are equal to each other (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^{o} in order to set the spindle vertical (in the YZ-plane) and move the Z- and X-axes until the stylus touches the test mandrel again in the marked point. Note the reading.

Step 3) Rotate the yoke (C-axis) 180^{o}, repeat adjustment in Step 1) and measurement in Step 2).

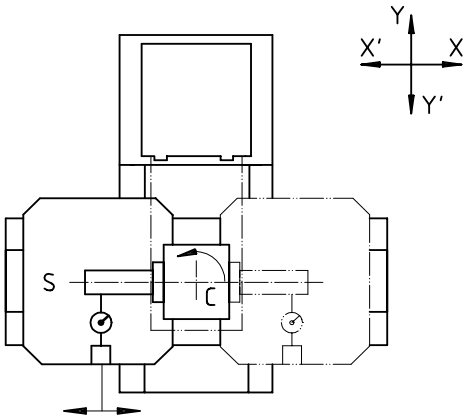
Half of the difference between the two measurements done in Step 2), divided by the distance between the dial gauge and the A-axis of the head rotation, shall not exceed the tolerance.

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 C-axis and the Z-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 CG4, is by-passed by zeroing the dial gauge during the adjustment in Step 1).

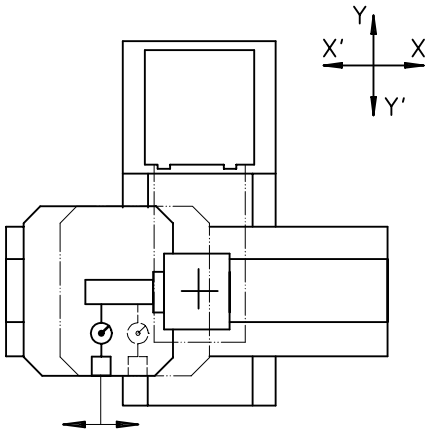
Object **CG4**

Checking of squareness between the spindle axis S and the A-axis of the head rotation.

Diagram



Step 1)



Step 2)

Tolerance	**Measured deviation**
0,025/300	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1

Y-axis to be locked, if possible.

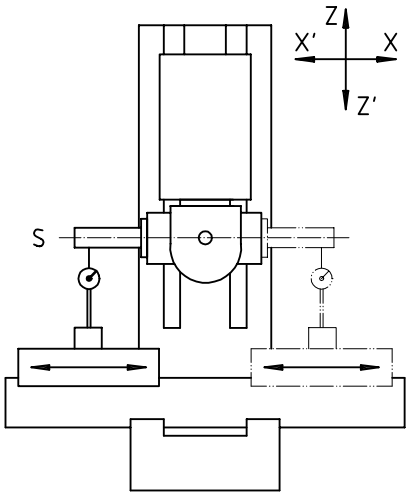
Step 1) Use the adjustment carried out in Step 1) of the previous test (CG3).

Step 2) Measure the parallelism deviation between the spindle axis and the X-axis in the horizontal XY plane in any of the two opposite horizontal positions of the spindle. This deviation is equal to the squareness deviation between the spindle axis S and the A-axis.

Object **CG5**

Checking that the spindle axis S and the A-axis of the head rotation shall be in the same plane.

Diagram



Tolerance	**Measured deviation**
0,020	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1

Z-axis to be locked, if possible.

Turn the head crosswise on one side, and adjust the A-axis until the test mandrel is parallel to the X-axis in the vertical ZX plane.

Zero the dial gauge and lock it on the table.

In order to avoid interferences with the dial gauge, drive away the head by means of movements along the X- and Y-axes only. Rotate the A-axis 180°, and bring the test mandrel back in contact with the dial gauge by means of X- and Y-axes movements.

Adjust the A-axis until the test mandrel is again parallel to the X-axis on the other side, without resetting the dial gauge.

Half of the new reading shall not exceed the tolerance.

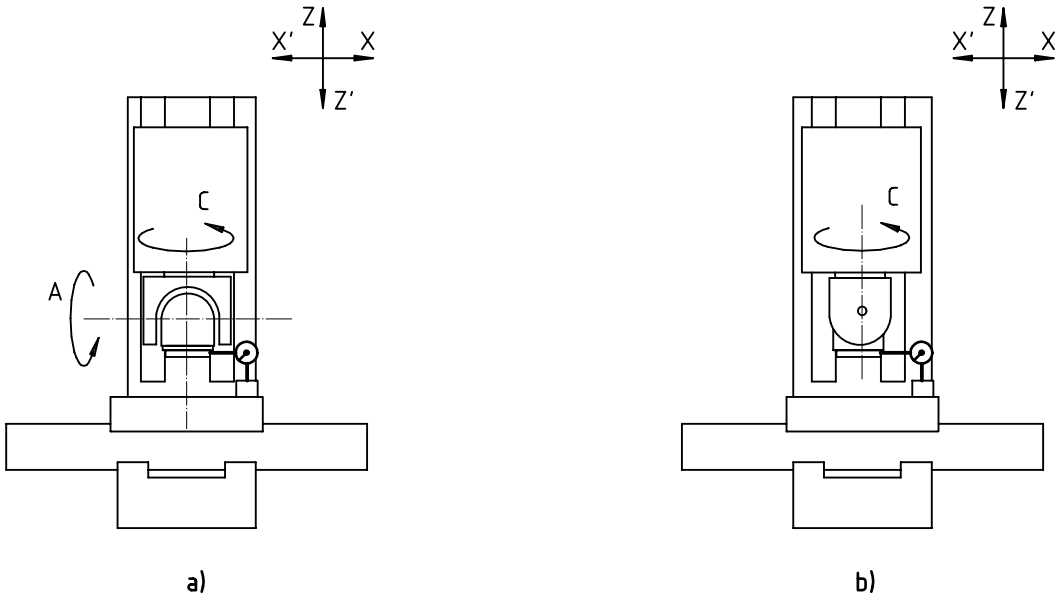
Object **CG6**

Checking of coincidence of the spindle axis S in vertical position along the Z direction with the C-axis of the yoke rotation:

a) in the vertical AC plane containing both A and C-axes;

b) in the vertical plane perpendicular to the AC plane.

Diagram



Tolerance	**Measured deviation**
a) 0,015	a)
b) 0,030	b)

Measuring instruments

Dial gauge, or test mandrel and dial gauge

Observations and references to ISO 230-1

Adjust the A-axis of the head rotation to minimize the parallelism deviation between the spindle axis S and the C-axis. The stylus shall touch the external surface of the spindle or a test mandrel close to the spindle nose. Rotate the C-axis 90^{o} four times.

The readings taken in the two a) and b) planes shall be divided by two and compared with the tolerances.

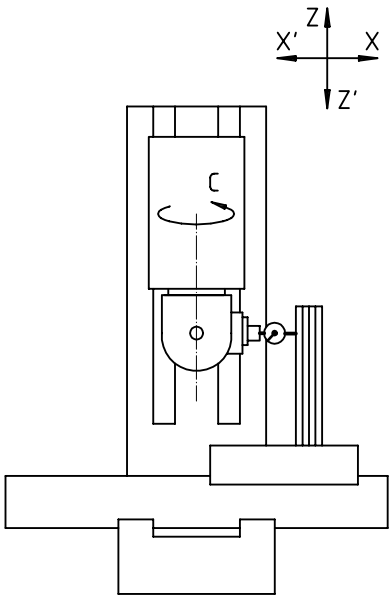
The measurement b) in the plane perpendicular to the A-axis includes the distance between the spindle axis S and the A-axis checked by test CG5 and the distance between the A-axis and the C-axis to be checked by test CG7.

For this test, both S and C axes shall be parallel to the Z-axis.

Object **CG7**

Checking that the A-axis of the head rotation and the C-axis of the yoke rotation are in the same plane.

Diagram



Tolerance	**Measured deviation**
0,020	

Measuring instruments

Dial gauge and plate

Observations and references to ISO 230-1

X-axis to be locked, if possible.

The surface plate shall be set parallel to the YZ plane.

If the spindle can be locked, the dial gauge may be mounted on it.

Adjust the A and C-axes so as the spindle is perpendicular to the surface plate. Zero the dial gauge.

Turn both A- and C-axes 180^{o} and take the new reading.

Half of the new reading shall not exceed the tolerance.

Bibliography

[1] ISO 841:—[2] *Industrial automation systems — Numerical control of machines — Coordinate system and motion nomenclature.*

2) To be published. (Revision of ISO 841:1974)

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