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Test conditions for machining centres —

Part 1:
Geometric tests for machines with horizontal spindle and with accessory heads (horizontal Z-axis)

Conditions d'essai pour centres d'usinage —

Partie 1: Essais géométriques des machines à broche horizontale et à têtes accessoires (axe Z horizontal)

Reference number
ISO 10791-1:1998(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.

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 10791-1 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*

— *Part 12: Evaluation of the vibration severity*

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.

Test conditions for machining centres —

Part 1:
Geometric tests for machines with horizontal spindle and with accessory heads (horizontal Z-axis)

1 Scope

This part of 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 horizontal spindle (i.e. horizontal Z-axis).

This part of ISO 10791 applies to machining centres having basically four numerically controlled axes, of which three are linear (X, Y and Z) up to 2 000 mm in length, and one is rotary (B'), but refers also to supplementary movements, such as those of sliding spindles, rams, or accessory universal heads. Movements other than those mentioned are considered as special features and the relevant tests are not included in this part of ISO 10791.

This part of ISO 10791 takes into consideration, in annexes A, B and C, three possible types of accessory universal heads, described as follows:

— annex A: 45° split indexable heads , 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: swivel heads, with two numerically controlled rotary axes perpendicular to each other (tests BG1 to BG7);

— annex C: 45° split continuous heads, 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 of the 45° indexable heads, if their movements and locks allow this.

This part of ISO 10791 deals only with the verification of geometric accuracy of the machine and does not apply to the testing of the machine operation, which should generally be checked separately. 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 as the primary method, 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 that standard.

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 Machining tests

Machining tests shall be made with finishing cuts only, not with roughing cuts which are liable to generate appreciable cutting forces.

3.7 Diagrams

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

3.8 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 G15 to G22) are to be performed on only one representative pallet clamped in position, unless otherwise specified by an agreement between the user and the supplier/manufacturer.

3.9 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 tests may be carried out with or without these compensations. When the software compensation is used, this shall be stated in the test results.

3.10 Machine configurations

The machines considered in this part of ISO 10791 are divided into 12 basic family configurations 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 of these configurations is shown in Table 1.

3.11 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 10791-1;

c) type H for “horizontal spindle type”;

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

EXAMPLE

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

Machining centre ISO 10791-1 type H02

3.12 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.

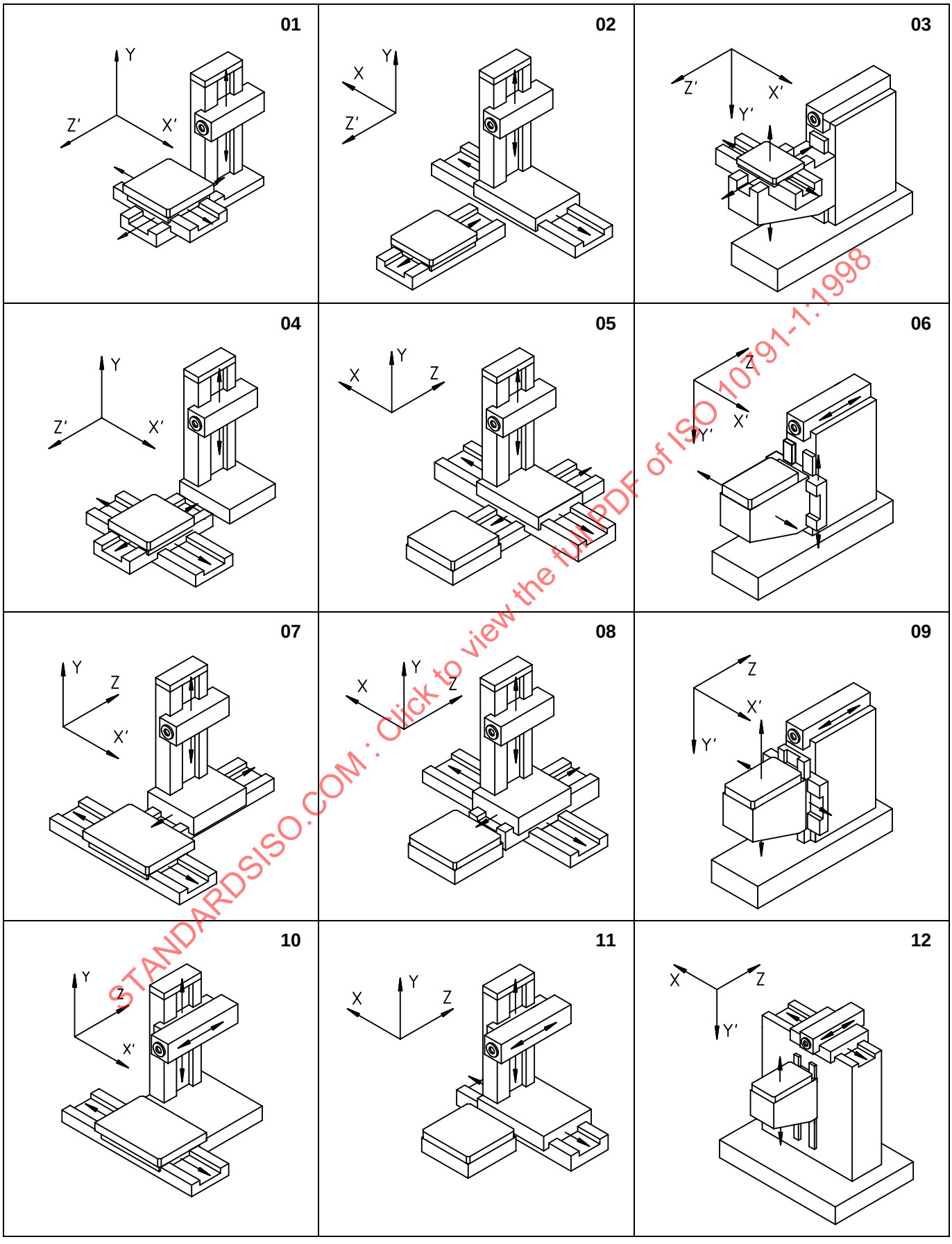


Figure 1

Table 1 — Classification of configurations of horizontal-spindle 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	

4 Geometric tests

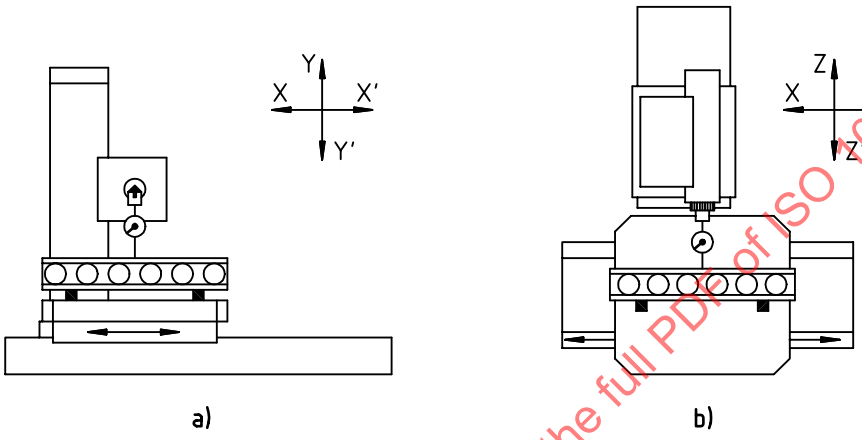
4.1 Straightness of linear motions

Object **G1**

Checking of straightness of the X-axis motion:

a) in the vertical XY plane (EYX);
b) in the horizontal ZX plane (EZX).

Diagram



Tolerance

For a) and b)

$X \leqslant 500$	0,010
$500 < X \leqslant 800$	0,015
$800 < X \leqslant 1\,250$	0,020
$1\,250 < X \leqslant 2\,000$	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 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.

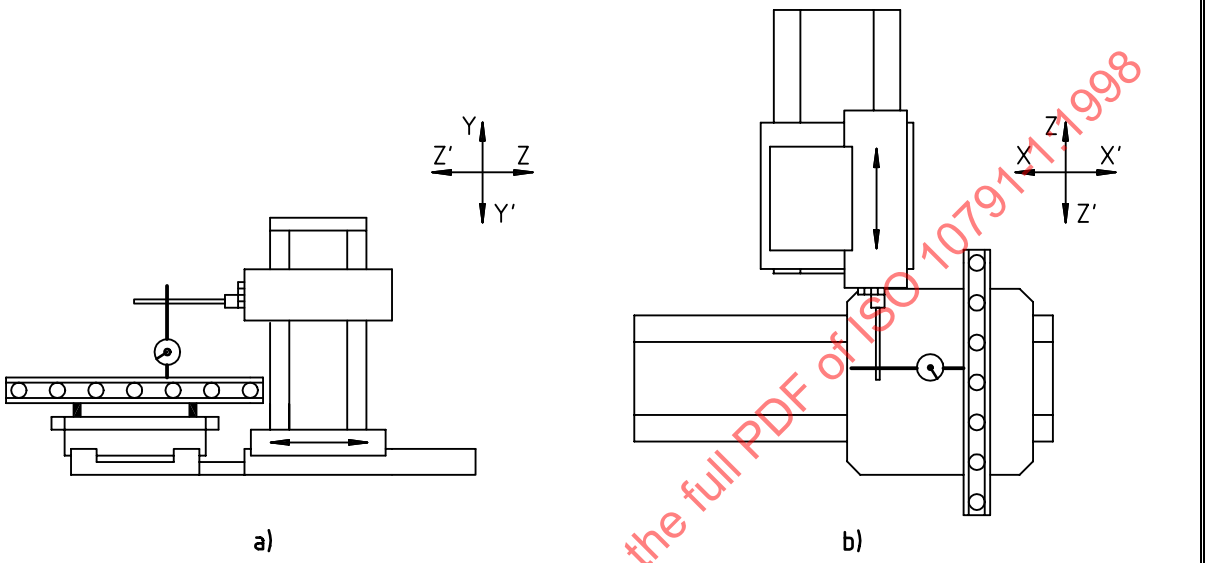
Object **G2**

Checking of straightness of the Z-axis motion:

a) in the vertical YZ plane (EYZ);

b) in the horizontal ZX plane (EXZ).

Diagram



Tolerance

For a) and b)

$Z \leqslant 500$	0,010
$500 < Z \leqslant 800$	0,015
$800 < Z \leqslant 1\,250$	0,020
$1\,250 < Z \leqslant 2\,000$	0,025

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

Measured deviation
for Z = ...

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 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1

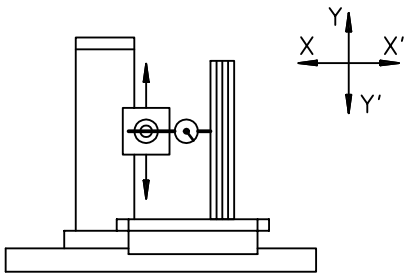
For all machine configurations, either the straightedge, the taut wire or the straightness reflector shall be placed on the table. If the spindle can be locked, either the dial gauge, the microscope or the interferometer may be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine.

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

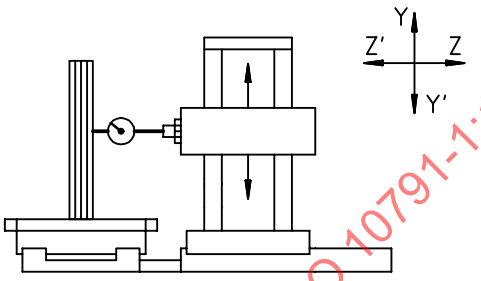
Object **G3**

Checking of straightness of the Y-axis motion:
a) in the vertical XY plane (EXY);
b) in the vertical YZ plane (EZY).

Diagram



a)



b)

Tolerance

For a) and b)

$Y \leqslant 500$	0,010
$500 < Y \leqslant 800$	0,015
$800 < Y \leqslant 1\,250$	0,020
$1\,250 < Y \leqslant 2\,000$	0,025

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

Measured deviation
for Y = ...

a)

b)

Measuring instruments

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

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

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.

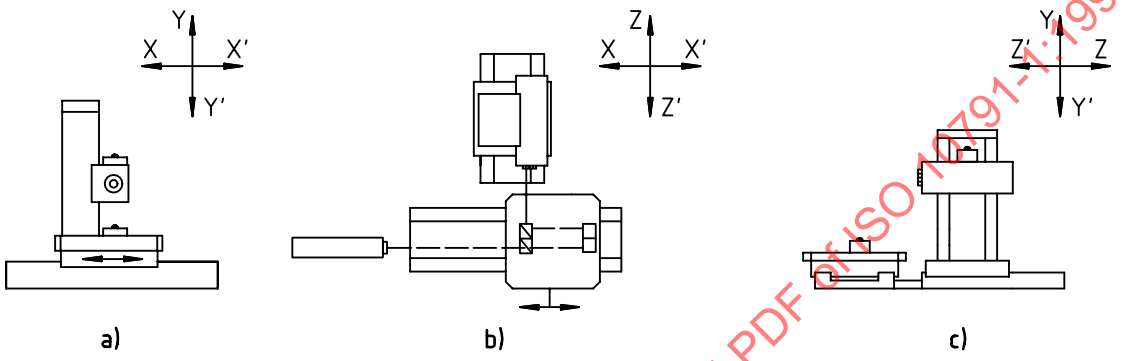
4.2 Angular deviations of linear motions

Object **G4**

Checking of angular deviations of the X-axis motion:

a) in the vertical XY plane perpendicular to the spindle-axis (pitch ECX);
b) in the horizontal ZX plane (yaw EBX);
c) in the vertical YZ plane parallel to the spindle axis (roll EAX).

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 ECX) Precision level or optical angular-deviation measuring instruments
b) (yaw EBX) Optical angular-deviation measuring instruments
c) (roll EAX) Precision level

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

The instrument shall be placed on the movable component:

a) (pitch ECX) longitudinally;
b) (yaw EBX) horizontally;
c) (roll EAX) transversely.

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.

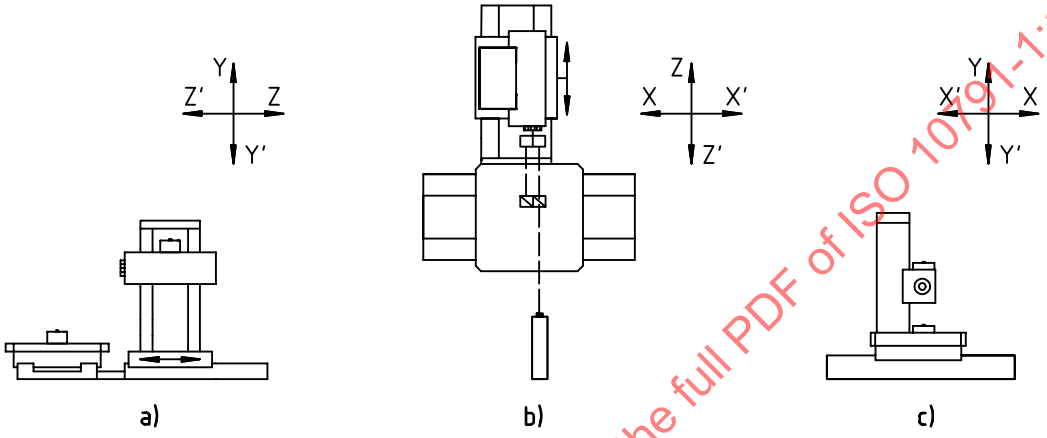
Measurements shall be taken at least at five positions equally spaced along the travel in both directions of movement at every position. The difference between the maximum and the minimum readings shall not exceed the tolerance.

Object **G5**

Checking of angular deviations of the Z-axis motion:

a) in the vertical YZ plane parallel to the spindle axis (pitch EAZ);
b) in the horizontal ZX plane (yaw EBZ);
c) in the vertical XY plane perpendicular to the spindle axis (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) (pitch EAZ)	Precision level or optical angular-deviation measuring instruments
b) (yaw EBZ)	Optical angular-deviation measuring instruments
c) (roll ECZ)	Precision level

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

The instrument shall be placed on the movable component:

a) (pitch EAZ)	longitudinally;
b) (yaw EBZ)	horizontally;
c) (roll ECZ)	transversely.

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.

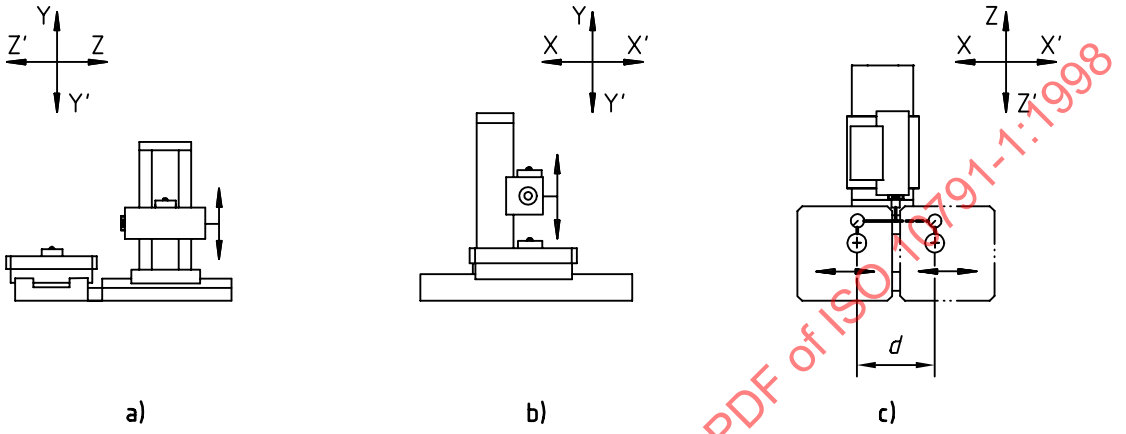
Measurements shall be taken at least at five positions equally spaced along the travel in both directions of movement at every position. The difference between the maximum and the minimum readings shall not exceed the tolerance.

Object **G6**

Checking of angular deviations of the Y-axis motion:

a) in the vertical YZ plane parallel to the spindle axis (EAY);
b) in the vertical XY plane perpendicular to the spindle axis (ECY);
c) in the horizontal ZX plane (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) and b)	Precision level or optical angular-deviation measuring instruments
c) (roll EBY)	Cylindrical square, precision level and dial gauge, or precision cube and dial gauges

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

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.

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

a) (pitch, EAZ) longitudinally;
b) (yaw, EBZ) horizontally.

When Y-axis motion causes an angular movement of both spindle head and workholding table, differential measurements of the two angular movements shall be made and this shall be stated. In this case, when using precision levels for measurement, the reference level shall be located on the non-moving component (spindle head or workholding table) of the machine.

For c) (roll, ECZ), place a cylindrical square on the table, approximately parallel to the Y-axis, and set the stylus of a dial gauge mounted on a special arm against the square. Note the readings and mark the corresponding heights on the square. Move the 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, then 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

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

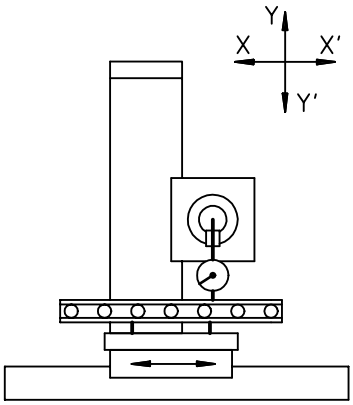
shall not exceed the tolerance, "d" being the distance between the two positions of the dial gauge.

4.3 Squareness between linear motions

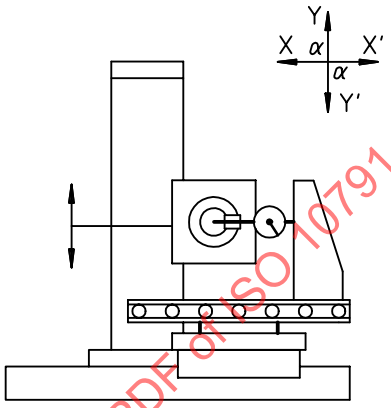
Object **G7**

Checking of squareness between 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 or surface plate, square and dial gauge

Observations and references to ISO 230-1 5.522.4

In Step 1), the straightedge or the surface plate shall be set parallel to the X-axis.

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

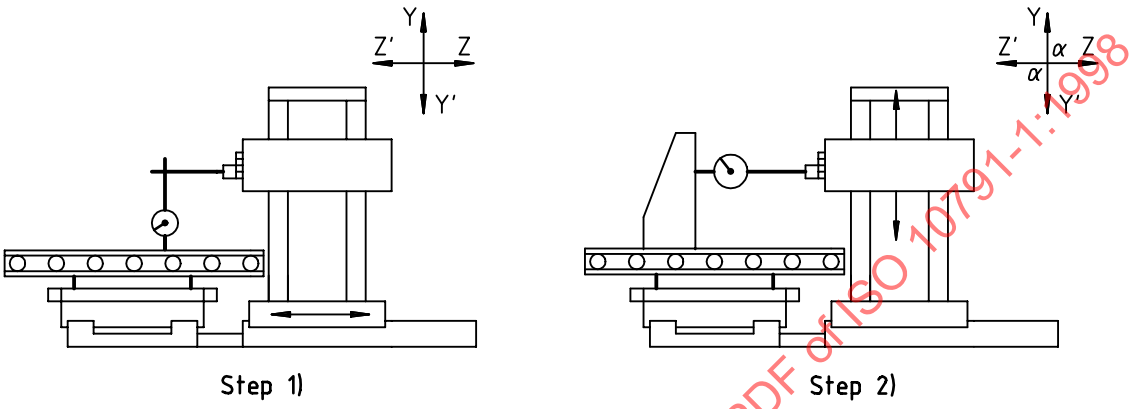
If the spindle can be locked, the dial gauge may be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **G8**

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

Diagram



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 5.522.4

In Step 1), the straightedge or the surface plate shall be set parallel to the Z-axis.

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

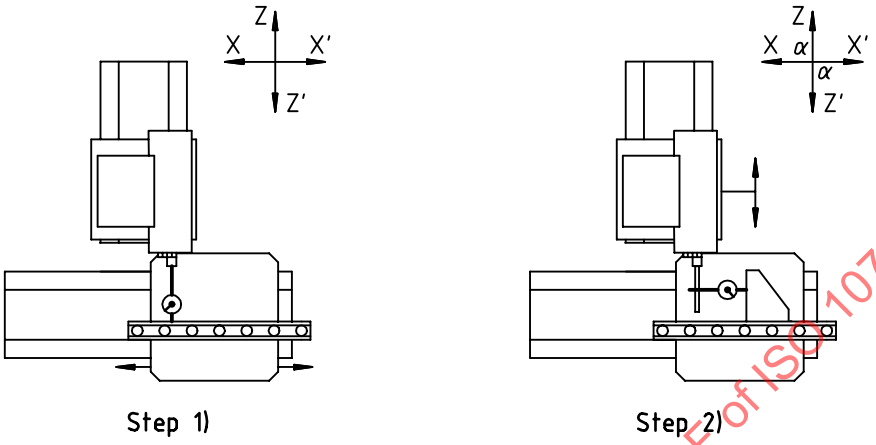
If the spindle can be locked, the dial gauge may be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **G9**

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

Diagram



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 5.522.4

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

In Step 2), the Z (or X)-axis shall then be checked by means of a square placed on the table with one side against the straightedge.

This test can also be performed without the straightedge, aligning one arm of the square along one axis and checking the second axis on the other arm of the square.

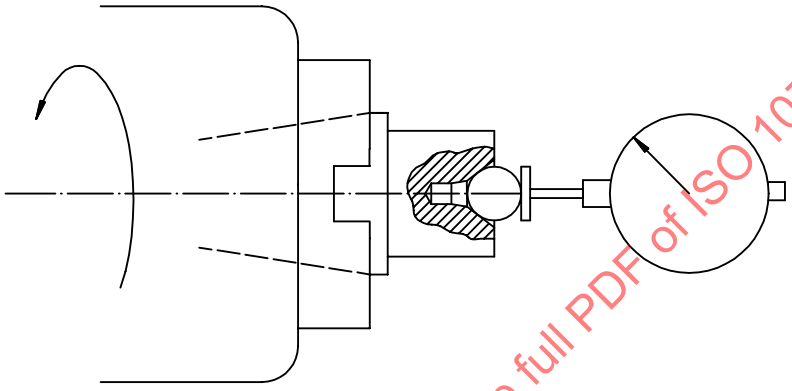
If the spindle can be locked, the dial gauge may be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

4.4 Spindle

Object	**G10**
Checking of periodic axial slip of the spindle.	

Diagram



Tolerance	**Measured deviation**
0,005	

Measuring instruments

Dial gauge

Observations and references to ISO 230-1 5.621.1 and 5.622.2

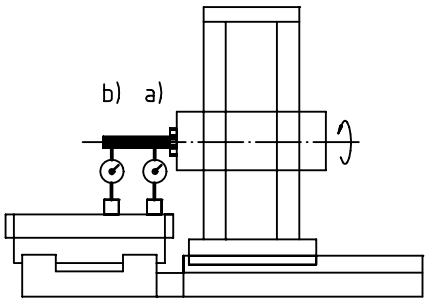
This test shall be performed on all working spindles of the machine.

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**
For the integral spindle: a) 0,007 b) 0,015 For spindles of accessory heads: a) 0,01 b) 0,02	a) b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.611.4 and 5.612.3

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

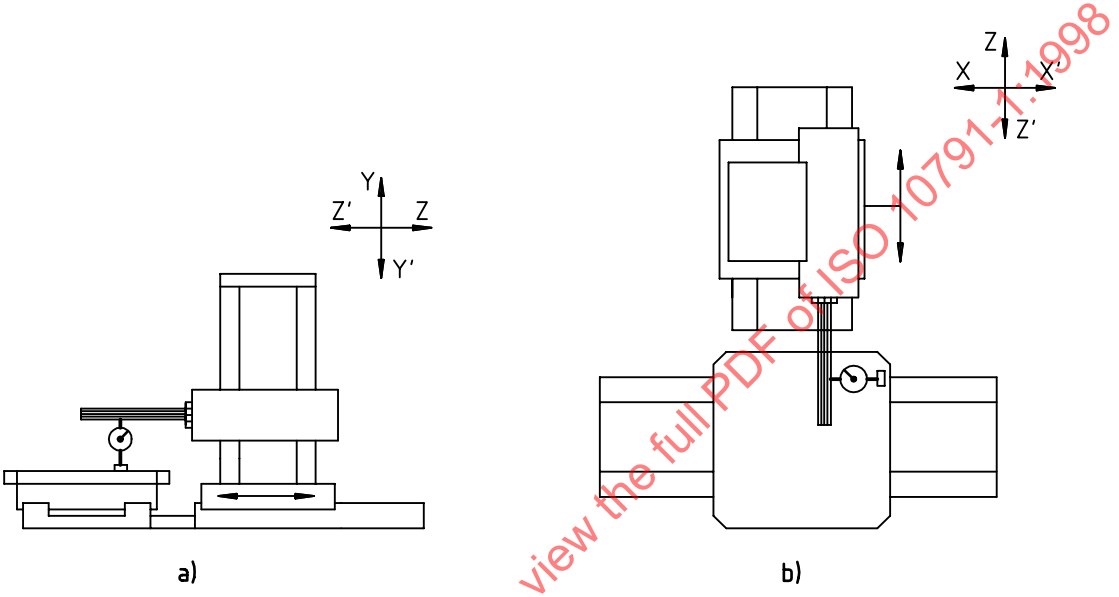
This test shall be carried out through at least two revolutions, in accordance with the note in 5.611.4 of ISO 230-1:1996.

Object **G12**

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

a) in the vertical YZ plane;
b) in the horizontal ZX plane.

Diagram



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

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

Z-axis in centre of the travel.

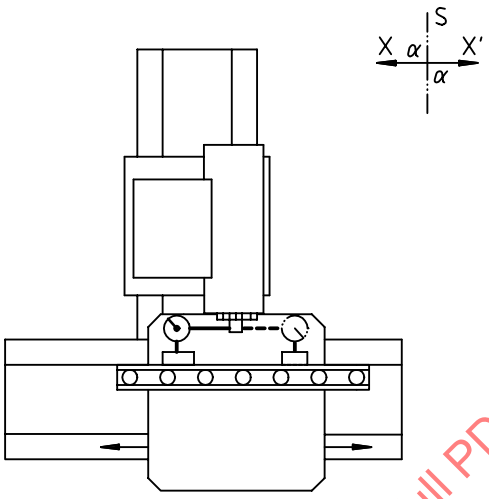
For a), Y-axis to be locked, if possible.

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

Object **G13**

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

Diagram



Tolerance	**Measured deviation**
0,015/300 Where 300 is the distance between the two measuring points touched.	

Measuring instruments

Straightedge, special arm and dial gauge

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

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

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

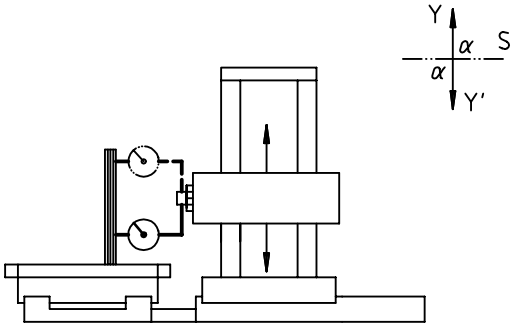
This squareness deviation can also be derived from tests G9 and G12 b).

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **G14**

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

Diagram



Tolerance	**Measured deviation**
0,015/300 Where 300 is the distance between the two measuring points touched.	

Measuring instruments

Square, special arm and dial gauge

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

X and Z-axes to be locked, if possible.

The measurement side of the square should be set parallel to the Y-axis, or the lack of parallelism shall be considered in the measurement.

This squareness deviation can also be derived from tests G8 and G12 a).

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

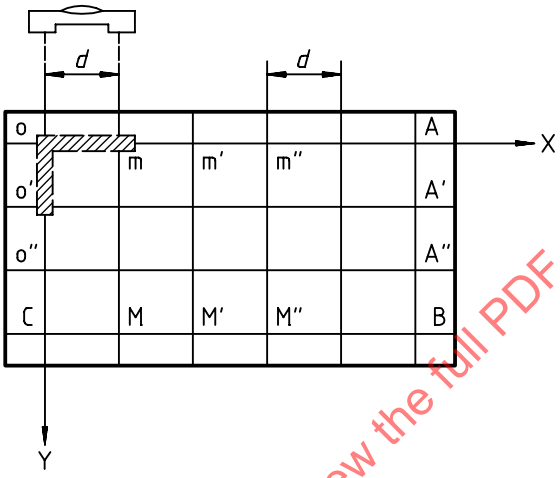
4.5 Table or pallet

Object **G15**

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

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 shorter side of the table or pallet.

The surface shall not be convex.

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

Measured deviation

for L = ...

Measuring instruments

Precision level or straightedge and slip gauges and dial gauge or optical methods

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

X and Z-axes are to be in centre of travel.

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

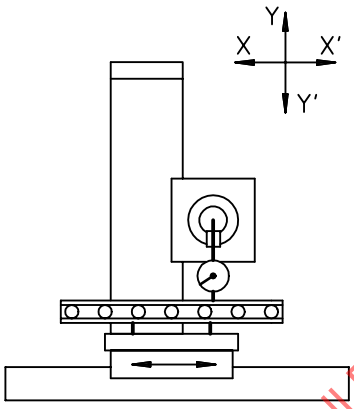
Object **G16**

Checking of parallelism between the table[1)] surface, in the four rotary positions at 90° from each other, and the X-axis motion.

_____

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

Diagram



Tolerance		**Measured deviation**
$X \leqslant 500$	0,020	for X = ...
$500 < X \leqslant 800$	0,025	
$800 < X \leqslant 1\,250$	0,030	
$1\,250 < X \leqslant 2\,000$	0,040	

Measuring instruments

Straightedge, gauge blocks and dial gauge

Observations and references to ISO 230-1 5.422.1 and 5.422.2

Y-axis to be locked, if possible.

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

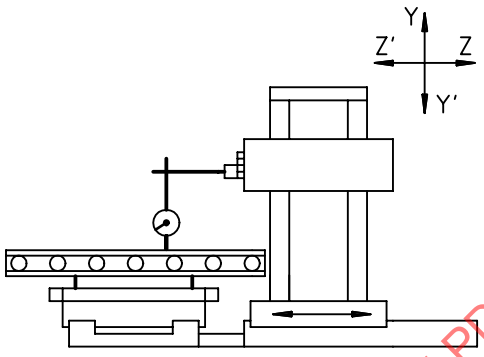
If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.

Object **G17**

Checking of parallelism between the table[1)] surface, in the four rotary positions at 90° from each other, and the Z-axis motion.

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

Diagram



Tolerance		**Measured deviation**
$Z \leqslant 500$	0,020	for Z = ...
$500 < Z \leqslant 800$	0,025	
$800 < Z \leqslant 1\,250$	0,030	
$1\,250 < Z \leqslant 2\,000$	0,040	

Measuring instruments

Straightedge, gauge blocks and dial gauge

Observations and references to ISO 230-1 5.422.1 and 5.422.2

Y-axis to be locked, if possible.

The stylus of the dial gauge is to be placed approximately at the working position of the tool. The measurement 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.

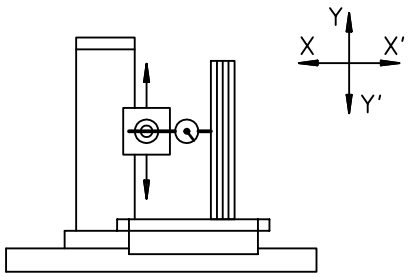
Object **G18**

Checking of squareness between the table[1)] surface and the Y-axis motion, in the four rotary positions at 90° from each other:

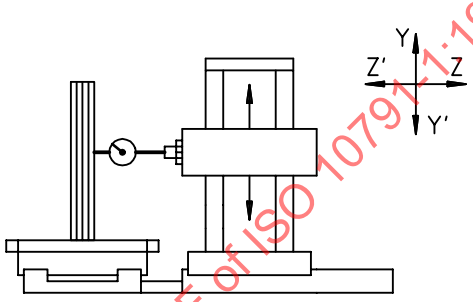
a) in the vertical XY plane perpendicular to the spindle axis;
b) in the vertical YZ plane parallel to the spindle axis

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

Diagram



a)



b)

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

Measuring instruments

Surface plate, square or cylindrical square and dial gauge

Observations and references to ISO 230-1 5.522.2

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

The square or cylindrical square should be in the centre of the table.

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.

This squareness deviation can also be derived:

for a), from tests G7 and G16;
for b), from tests G8 and G17.

Object **G19**

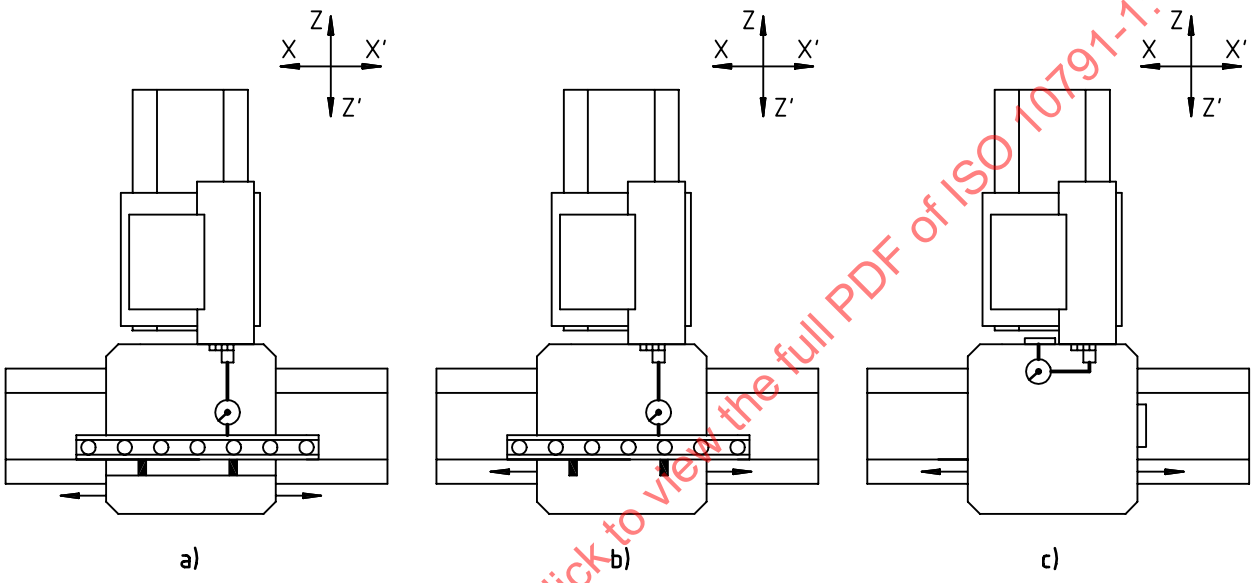
Checking of parallelism between

a) the longitudinal median or reference T-slot, or
b) the centre line of the alignment holes (if longitudinal), or
c) the longitudinal edge locator

of the table[1)] in the 0° position and the X-axis motion.

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

Diagram



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

Measuring instruments

Dial gauge and, if necessary, straightedge and master pins

Observations and references to ISO 230-1 5.422.1 and 5.422.2

Z-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.

Object **G20**

Checking of parallelism between

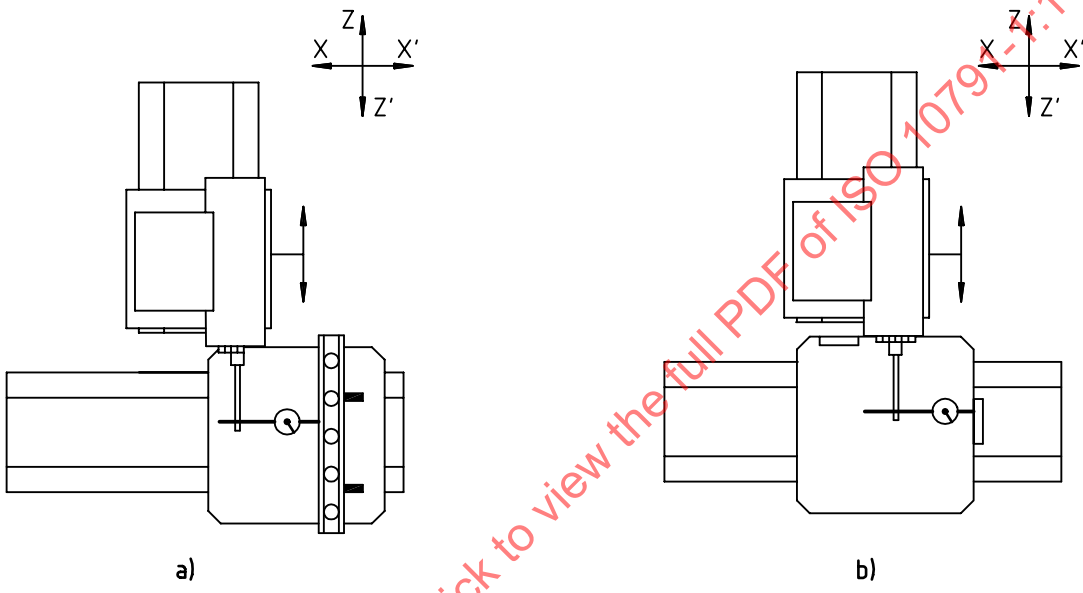
a) the centre line of the alignment holes (if transverse), or
b) the transverse edge locator

of the table[1)] in the 0° position and the Z-axis motion.

_____

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

Diagram



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

Measuring instruments

Dial gauge and, if necessary, straightedge and master pins

Observations and references to ISO 230-1 5.422.1 and 5.422.2

Z-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.

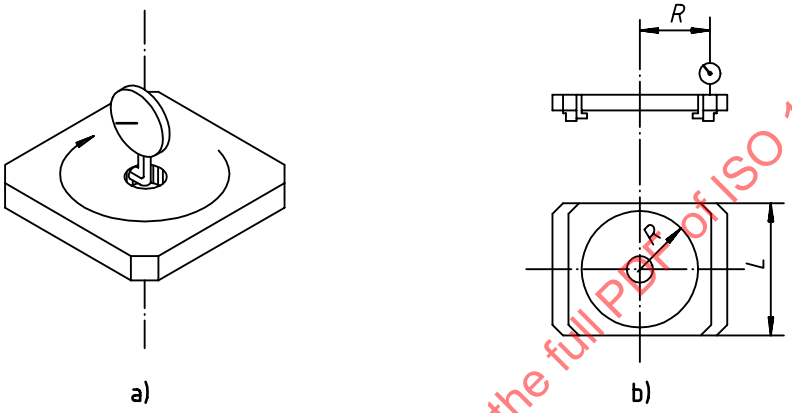
Object **G21**

Checking of

a) run-out of the centre hole of the table[1)] (when the centre hole is used for locating purposes);
b) camming of the table[1)] surface[2)].

1) Build-in rotary table or one representative pallet clamped in position.
2) For indexing tables, check at least four positions at 90° from each other.

Diagram



Tolérance

a) 0,025

b)

$L \leqslant$	500	0,030
$500 < L \leqslant$	800	0,040
$800 < L \leqslant$	1 250	0,050
$1\,250 < L \leqslant$	2 000	0,060

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

Measured deviation

a)

b) for L = ...

Measuring instruments

a) Dial gauge

b) Gauge blocks and dial gauge

Observations and references to ISO 230-1

a) 5.612.3
X and Z-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
Y-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.

Object **G22**

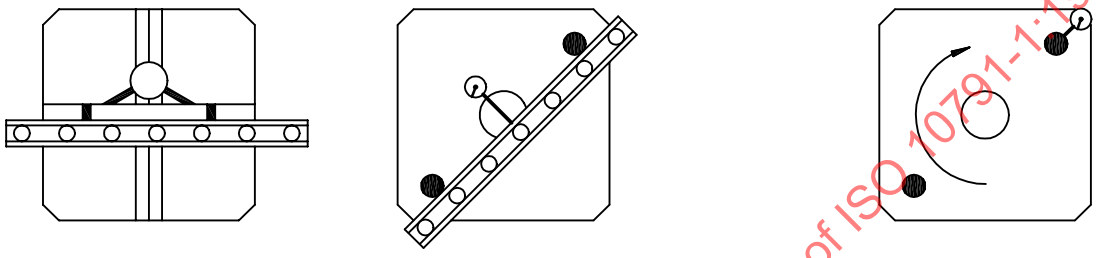
Checking of

a) intersection of the centre line 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 table[1)].

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

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b) 0,030	a) b)

Measuring instruments

a) Straightedge, gauge blocks or master pins and dial gauge

b) Master pins and dial gauge

Observations and references to ISO 230-1

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.

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.

These tests shall be performed on all workholding tables, rotating around vertical or horizontal axes, changing the nomenclature of the axes accordingly.

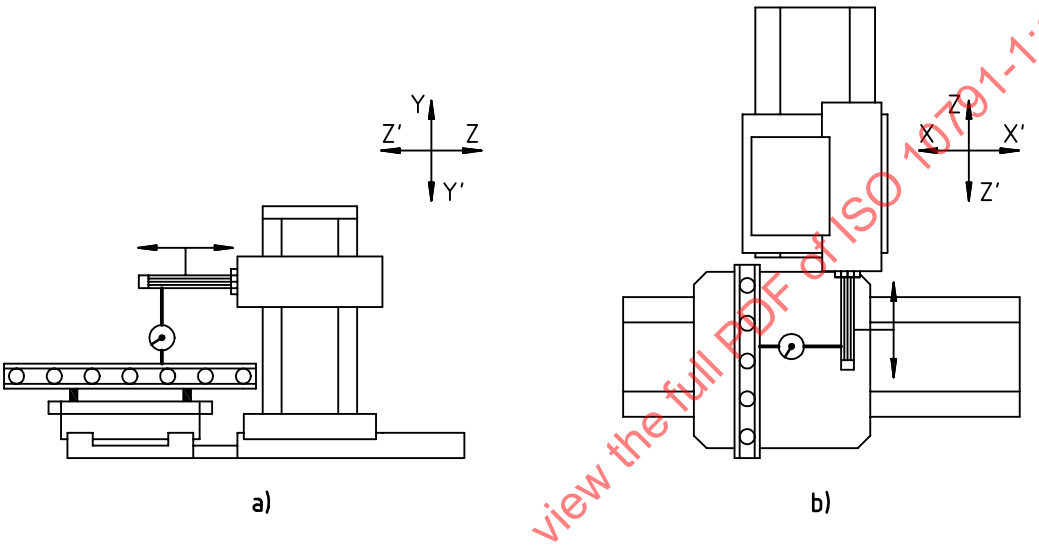
4.6 Supplementary axes parallel to the Z-axis

Object **G23**

Checking of straightness of the axial movement of the spindle:

a) in the vertical YZ plane;
b) in the horizontal ZX plane.

Diagram



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

Measuring instruments

Straightedge and dial gauge

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

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

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

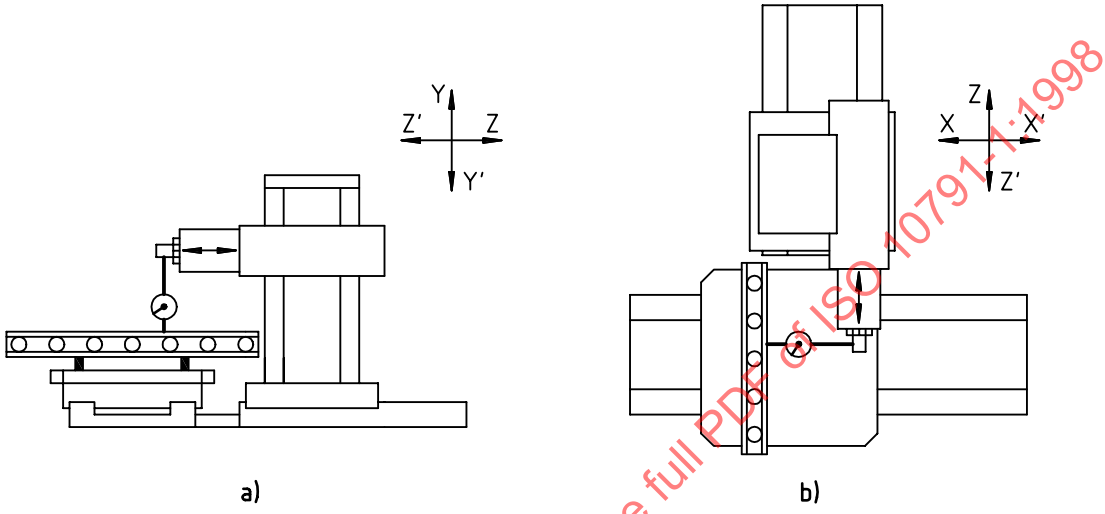
It should be noted that, for a), the deviation includes the normal deflection of the spindle.

Object **G24**

Checking of the straightness of the ram movement:

a) in the vertical YZ plane;
b) in the horizontal ZX plane.

Diagram



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

Measuring instruments

Straightedge and dial gauge

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

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

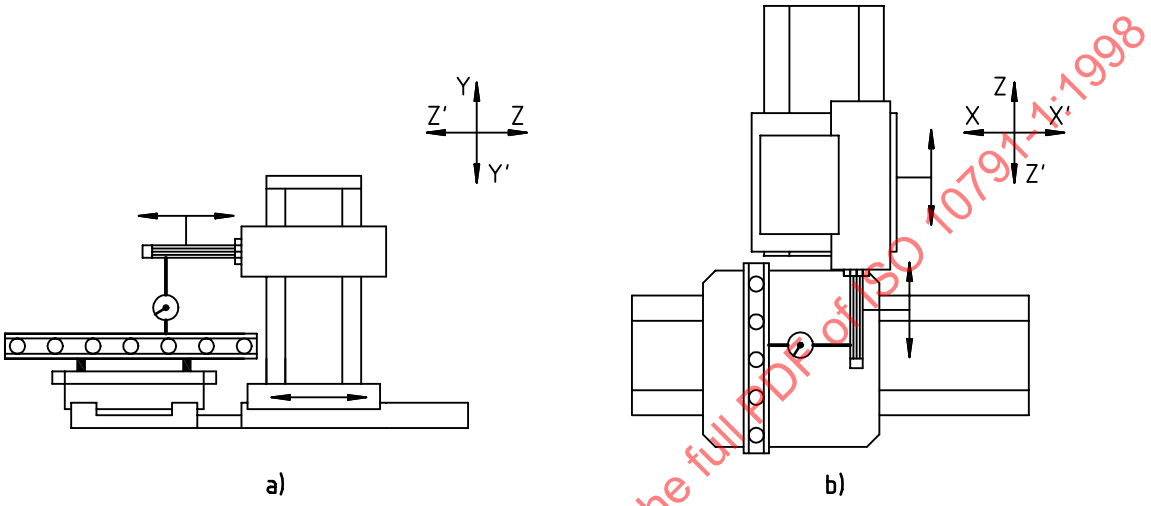
b) X-axis to be locked, if possible.

Object **G25**

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

a) in the vertical YZ plane;
b) in the horizontal ZX plane.

Diagram



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

Measuring instruments

Straightedge and dial gauge or gauge block 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.

It should be noted that, for a), the deviation includes the normal deflection of the spindle.

If the two movements can be operated together, move the two parts by the same amount so that the stylus always touches the straightedge or the gauge block in the same point.

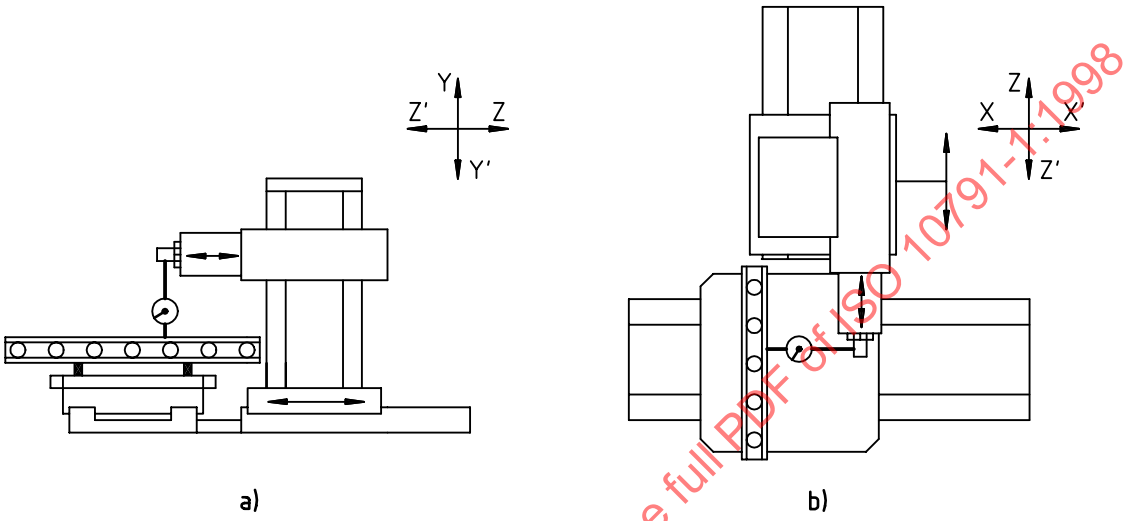
If this is not possible, the straightedge should be set parallel to the Z-axis, or the lack of parallelism shall be considered in the measurement.

Object **G26**

Checking of parallelism between the ram movement and the Z-axis motion:

a) in the vertical YZ plane;
b) in the horizontal ZX plane.

Diagram



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

Measuring instruments

Straightedge and dial gauge or gauge block 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 movements can be operated together, move the two parts by the same amount so that the stylus always touches the straightedge or the gauge block in the same point.

If this is not possible, the straightedge should be set parallel to the Z-axis, or the lack of parallelism shall be considered in the measurement.

Annex A
(normative)

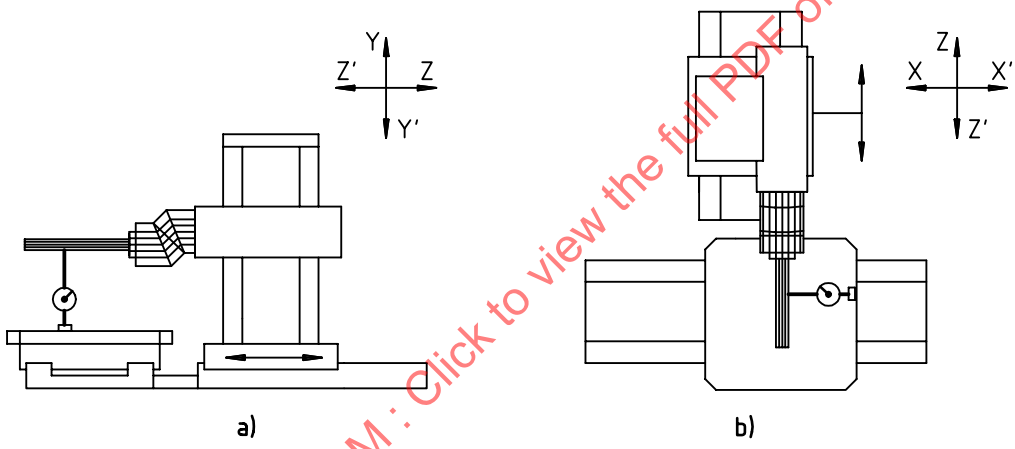
Accessory 45° split indexable heads

Object — **AG1**

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

a) in the vertical YZ plane;
b) in the horizontal ZX plane.

Diagram



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

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

X-axis should be in the centre of the direction of travel.

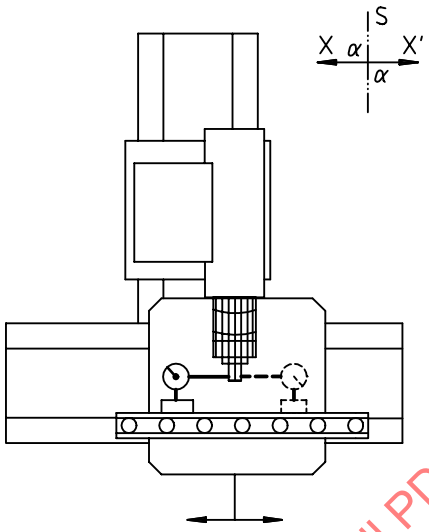
For a), Y-axis to be locked, if possible.

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

Object **AG2**

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

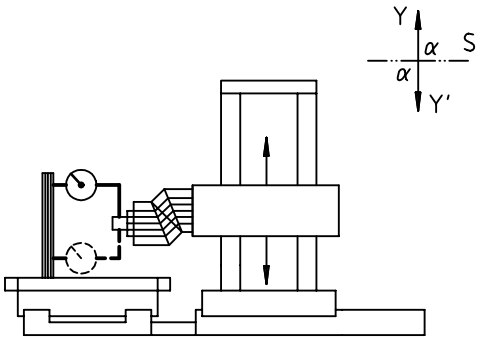
This squareness deviation can also be derived from tests G9 and AG1 b).

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **AG3**

Checking of squareness between the spindle axis in the horizontal position along the Z-direction and the Y-axis motion.

Diagram



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

Measuring instruments

Square, special arm and dial gauge

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

Z-axis to be locked, if possible.

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

This squareness deviation can also be derived from tests G8 and AG1 a).

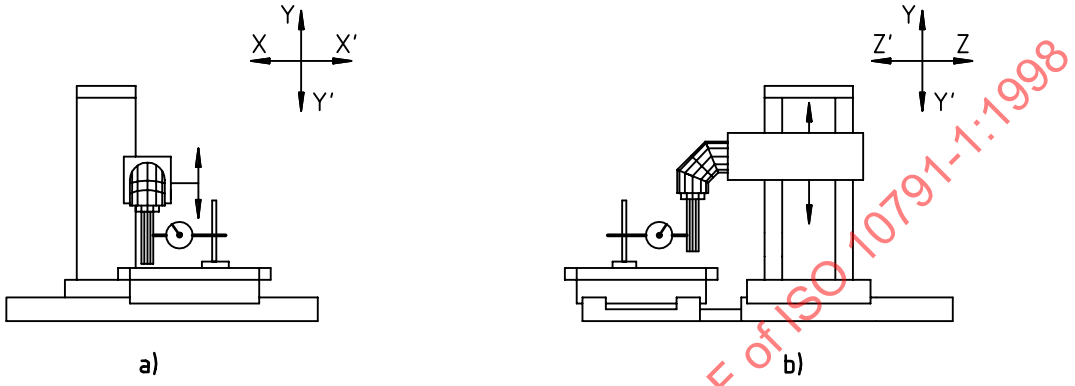
The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **AG4**

Checking of parallelism between the spindle axis in the vertical position and the Y-axis motion:

a) in the vertical XY plane;
b) in the vertical YZ plane.

Diagram



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

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

X-axis should be in the centre of the direction of travel.

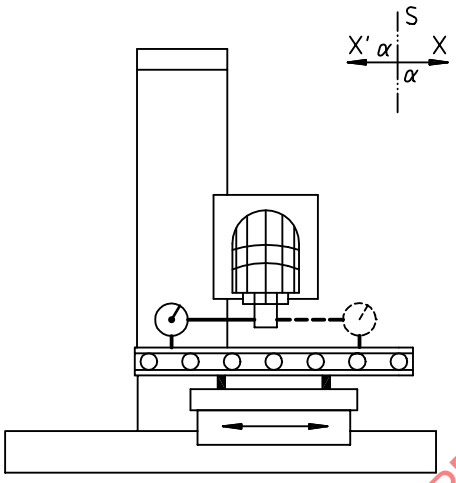
For a), X-axis to be locked, if possible.

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

Object **AG5**

Checking of squareness between the spindle axis in the vertical position and 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 5.512.1 and 5.512.42

Y-axis to be locked, if possible.

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

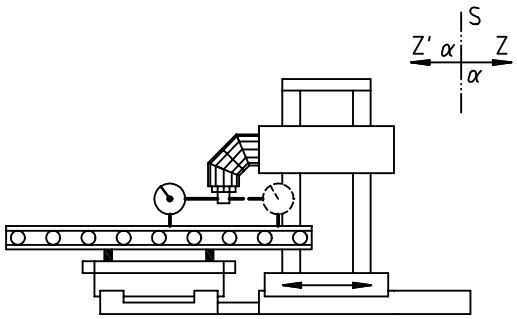
This squareness deviation can also be derived from tests G7 and AG4 a).

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **AG6**

Checking of squareness between the spindle axis in the vertical position and the Z-axis motion.

Diagram



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

Measuring instruments

Straightedge, special arm and dial gauge

Observations and references to ISO 230-1 5.512.1 and 5.512.42

Y-axis to be locked, if possible.

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

This squareness deviation can also be derived from tests G8 and AG4 b).

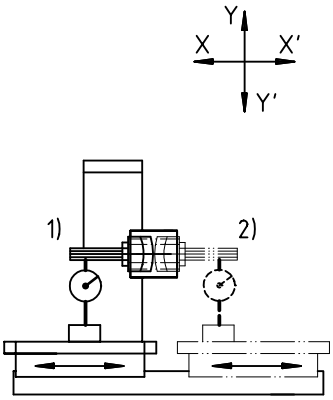
The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **AG7**

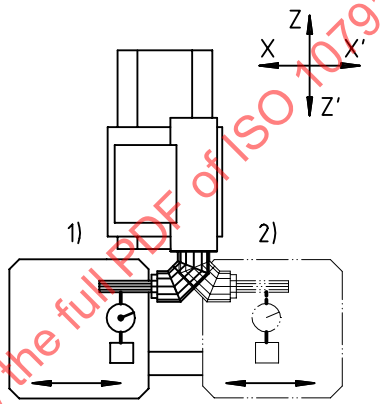
Checking of parallelism between the spindle axis in either of the two horizontal positions along the X-direction and the X-axis motion:

1) With the spindle in the left position:
   a) in the vertical XY plane;
   b) in the horizontal ZX plane.
2) With the spindle in the right position:
   a) in the vertical XY plane;
   b) in the horizontal ZX plane.

Diagram



a)



b)

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

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

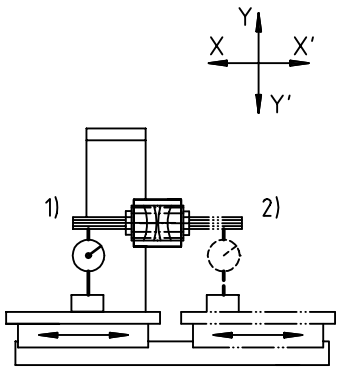
For a), Y-axis to be locked, if possible.

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

Object **AG8**

Checking of difference between the spindle heights in the two horizontal positions in the X-direction.

Diagram



Tolerance	**Measured deviation**
0,03	

Measuring instruments

Test mandrel and dial gauge

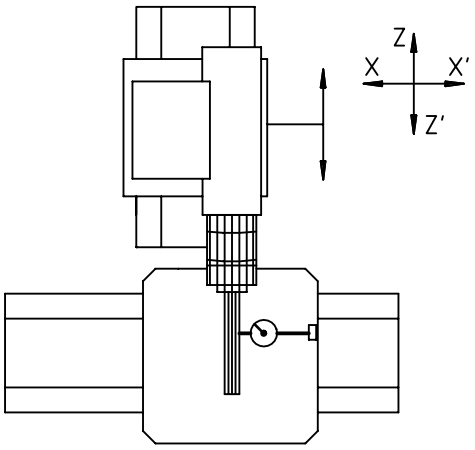
Observations and references to ISO 230-1

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.

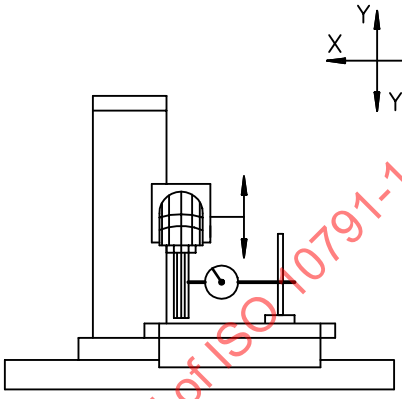
Object **AG9**

Checking that the spindle axis S and rotary axis at 45° D lie in the same plane.

Diagram



Step 1)



Step 2)

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 Z-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 in order 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-axis movements.

When the movements in step 2) have been completed, half of the reading on the dial gauge shall not exceed the tolerance.

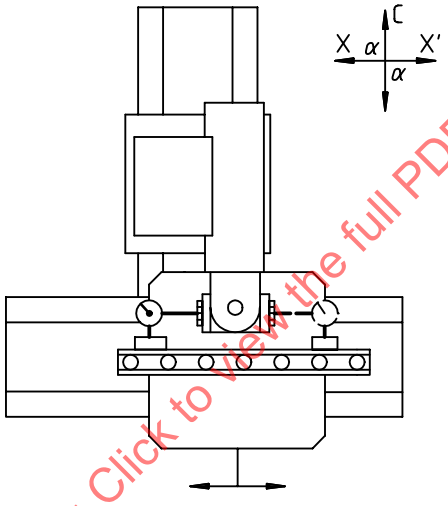
The deviation of this test can be measured by performing test AG4 a) after AG1 b), without moving the X-axis and without resetting the dial gauge.

Annex B
(normative)

Accessory swivel heads

Object	**BG1**
Checking of squareness between the C-axis of the yoke rotation and the X-axis motion.	

Diagram



Tolerance	**Measured deviation**
0,025/500	

Measuring instruments

Straightedge and dial gauge

Observations and references to ISO 230-1 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 X-axis.

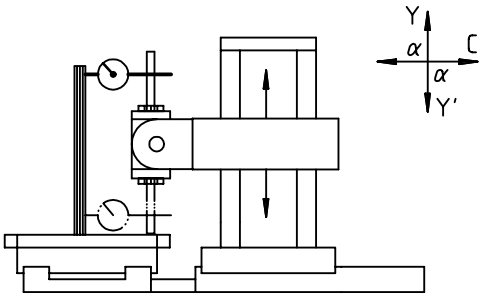
The dial gauge may be mounted either on the yoke body or on the spindle head, in this case setting the spindle perpendicular to the Z-axis.

The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object **BG2**

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

Diagram



Tolerance	**Measured deviation**
0,025/500	

Measuring instruments

Square and dial gauge

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

Z-axis to be locked, if possible.

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

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

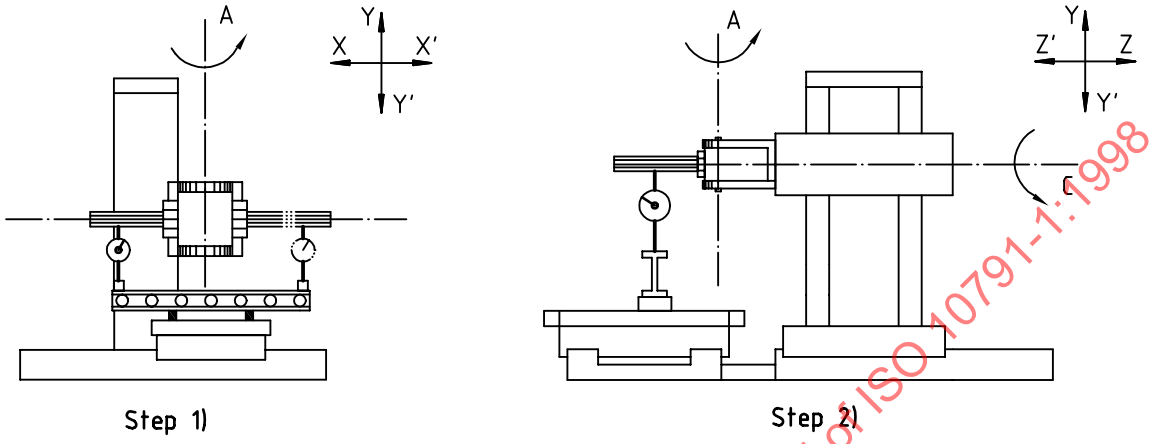
The value of angle α, being less than, equal to or greater than 90°, should be noted for information and possible corrections.

Object

BG3

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

Diagram



Tolerance	**Measured deviation**
0,035/500	

Measuring instruments

Straightedge or surface plate, test mandrel and dial gauge

Observations and references to ISO 230-1

Y-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 (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° in order to set the spindle horizontal along the Z direction (in the YZ plane) and move the Z-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 (C-axis) 180°, repeat adjustment step 1) and measurement step 2).

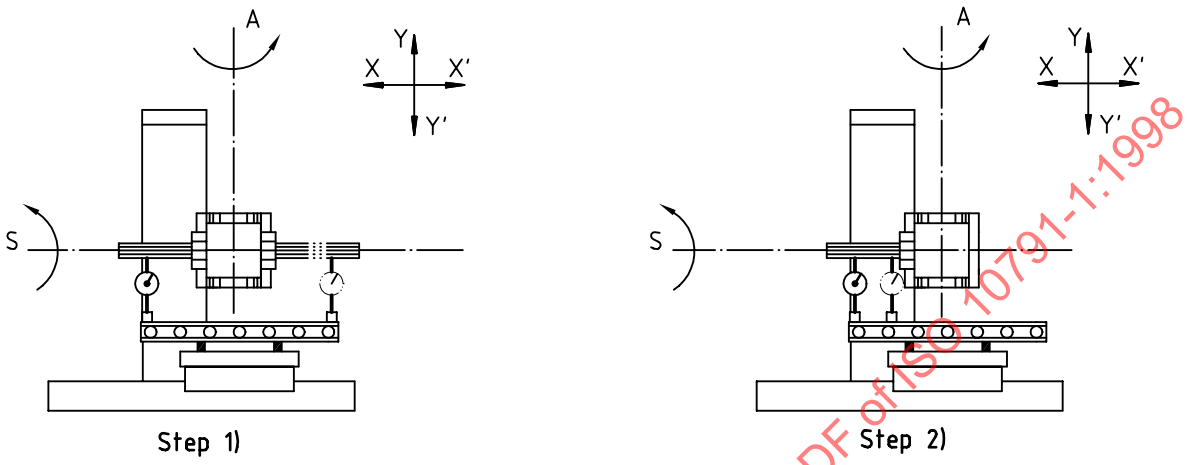
Half of the difference between the two measurements step 2); divided by the distance between the dial gauge and the A-axis of the head rotation, shall not exceed the tolerance.

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 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 BG4, is bypassed by zeroing the dial gauge during the adjustment step 1).

Object **BG4**

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

Diagram



Tolerance	**Measured deviation**
0,040 for a measuring length of 500	

Measuring instruments

Straightedge or surface plate, test mandrel and dial gauge

Observations and references to ISO 230-1

Y-axis to be locked, if possible.

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

Step 1) Use the adjustment carried out in Step 1) of the previous test (BG3).

Step 2) Measure the parallelism deviation between the spindle axis S in the vertical XY 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.