INTERNATIONAL STANDARD

ISO 8636-2

Second edition
2007-12-15

Machine tools — Test conditions for bridge-type milling machines — Testing of the accuracy —

Part 2: Travelling bridge (gantry-type) machines

Machines-outils — Conditions d'essai des machines à fraiser à portique — Contrôle de l'exactitude —

Partie 2: Machines à portique mobile

Reference number
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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8636-2 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

This second edition cancels and replaces the first edition (ISO 8636-2:1988) which has been technically revised. Especially,

a) geometrical tests have been rearranged; the new G numbers compared to the old ones are given in the following table:

ISO 8636-2:2007	1	2(add)	3	4(add)	5	6	7	8	9	10	11	12
ISO 8636-2:1988	2	—	8	—	10	9	6	5	1	4&7	3	13

ISO 8636-2:2007	13	14	15	16(add)	17	18
ISO 8636-2:1988	12, 14, 15	16	11	—	17	18

b) information has been added in “Object” boxes for G6, G12, G13, G14 and G15. This information has been added because the machines have several milling heads and the test items are applicable to all of the milling heads;

c) tolerances on accuracy and repeatability of positioning have been changed in accordance with ISO 230-2:2006;

d) new test for geometric accuracy of axes of rotation of workholding spindles (R1) has been added.

The actual deviations of all parameters are shown as test results, but the tolerances are limited only to certain parameters.

ISO 8636 consists of the following parts, under the general title *Machine tools — Test conditions for bridge-type milling machines — Testing of the accuracy*:

— *Part 1: Fixed bridge (portal-type) machines*

— *Part 2: Travelling bridge (gantry-type) machines*

Machine tools — Test conditions for bridge-type milling machines — Testing of the accuracy —

Part 2: Travelling bridge (gantry-type) machines

1 Scope

This part of ISO 8636 specifies, with reference to ISO 230-1, ISO 230-2, and ISO 230-7, geometric tests, machining tests, and tests for checking accuracy and repeatability of positioning of numerically controlled axes for general-purpose normal accuracy bridge-type milling machines with a travelling bridge (gantry-type). This part of ISO 8636 also specifies the applicable tolerances corresponding to the above-mentioned tests.

This part of ISO 8636 is applicable to machines with travelling bridge and fixed table. It does not include single-column (open sided) machines and those with fixed bridge and moving tables.

This part of ISO 8636 deals only with the verification of the accuracy of the machine. It does not apply to the testing of the machine operation (vibration, abnormal noise, stick-slip motion of components, etc.) nor to machine characteristics (such as speeds, feeds, etc.), which should generally be checked before testing the accuracy.

This part of ISO 8636 provides the terminology used for the principal components of the machines and the designation of the axes with reference to ISO 841.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 230-2:2006, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning numerically controlled axes*

ISO 230-7:2006, *Test code for machine tools — Part 7: Geometric accuracy of axes of rotation*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
milling operation
machining operation, which consists of removing material by means of a rotary tool (milling cutter), of which there are several different types

NOTE Typical milling operations mostly involve face milling or end milling. The tools are mounted either in the spindle taper or on the spindle front face.

3.2
boring operation
operation which consists of machining the diameters of cylindrical, conical, blind or through-holes to the required size

3.3
drilling [tapping] operation
operation to produce blind or through-holes

3.4
travelling bridge (gantry-type) milling machine
milling machine with one fixed workpiece-holding table, two slideways on either side of the table, and a travelling bridge (gantry) on which the milling head(s) are mounted

NOTE 1 The slideways may or may not be independent of the table.

NOTE 2 The gantry, composed of a left-hand column and a right-hand column supported by respective column slides and made integral with a fixed top bridge, is moved along the bed slideways. The gantry supports a horizontal cross-rail, movable or fixed in the vertical plane, on which one or more milling heads are mounted with vertical or inclinable spindles.

4 Classification and description of travelling bridge (gantry-type) milling machines

4.1 Classification

These machines are classified into the following types depending upon construction:

— travelling bridge (gantry-type) milling machines with fixed cross-rail;

— travelling bridge (gantry-type) milling machines with movable cross-rail (see Figure 1).

4.2 Descriptions of principal components

The principal components of these machines are described in Figure 1.

4.2.1 Bed and table

The worktable (1) is located between two slideways that form the bed. The worktable and the slideways can be constructed in one piece. Alternatively, the assembly may be made of several pieces rigidly connected through the foundation or directly to each other.

NOTE The table can be replaced by a floorplate.

4.2.2 Columns, top bridge and cross-rail

The columns (9) and (10) are rigid parts with vertical slideways, which either slide on the bed or are fixed rigidly to column slides (7) and (8) which slide horizontally on the bed.

The top bridge (11) is a fixed part connecting the two columns near their top ends.

The cross-rail (14) is a part whose horizontal slideways are parallel to the plane of the table. In the case of machines with fixed cross-rails, the cross-rail is made integral with the columns and may be used as a top bridge. In the case of machines with movable cross-rails, the cross-rail slides vertically on the slideways of the columns (12) and (13).

One or more milling heads with vertical, horizontal or inclinable spindles are mounted on the cross-rail slideways.

4.2.3 Milling head(s)

Milling heads (16) and (20) are mounted on head saddles (15) and (21) which move on the cross-rail or column slideways.

The portion in direct contact with the cross-rail slideways is called the vertical head saddle (15).

The milling head may be mounted so that it slides on the vertical head saddle in the direction of the spindle axis; it is then called a ram. The spindle may be mounted in a quill sliding in the milling head in the direction of the spindle axis. Some parts of the head may be inclinable.

4.2.4 Cutting motion

Cutting motion is provided by the spindles and drive mechanisms of the milling heads.

4.2.5 Feed motion

The following feed movements may be provided with a constant or variable feed rate:

— horizontal movement of the movable gantry;

— vertical movement of the movable cross-rail;

— horizontal movement of the milling heads;

— vertical movement of rams, if any;

— rotational movement (tilt movements of milling heads).

NOTE 1 In general, rapid traverse is available in addition to feed movement.

NOTE 2 The vertical movement of the movable cross-rail can be either a feed movement (in which case the cross-rail is said to be movable when working) or a movement between fixed working positions (the cross-rail is then said to be movable when being positioned).

5 Terminology and designation of axes

5.1 Terminology

See Figure 1 and Table 1.

5.2 Designation of axes

See Figures 1 to 4.

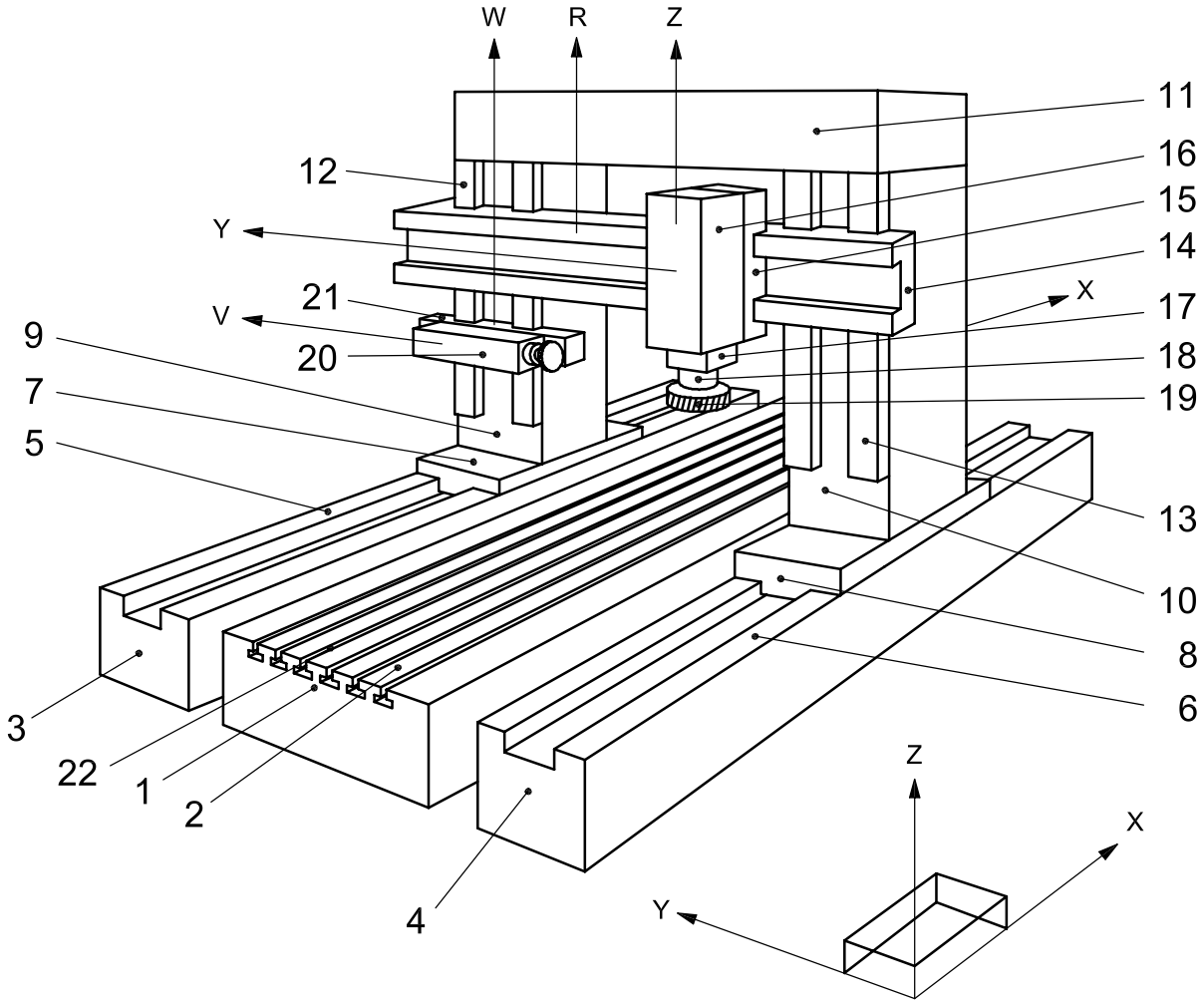


Figure 1 — Travelling bridge (gantry-type) machine with movable cross-rail (see Table 1)

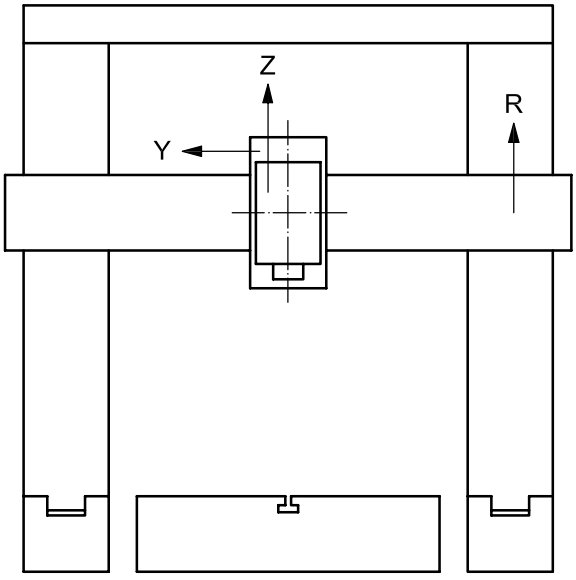


Figure 2 — Machine with one milling head

Table 1 — Terminology

Ref.	English	French	German
1	Table (or floorplate)	Table (ou taque)	Tisch (oder Bodenplatte)
2	Clamping surface	Surface de bridage	Aufspannfläche
3	Left-hand part of the bed	Banc gauche	Linker Teil des Maschinenbetts
4	Right-hand part of the bed	Banc droit	Rechter Teil des Maschinenbetts
5	Left-hand bed slideways	Glissières du banc gauche	Linke Bett-Führungsbahnen
6	Right-hand bed slideways	Glissières du banc droit	Rechte Bett-Führungsbahnen
7	Left-hand column slide	Chariot porte-montant gauche	Linker Ständerschlitten
8	Right-hand column slide	Chariot porte-montant droit	Rechter Ständerschlitten
9	Left-hand column	Montant gauche	Linker Ständer
10	Right-hand column	Montant droit	Rechter Ständer
11	Top bridge	Entretoise	Querbalken
12	Left-hand column slideways	Glissières du montant gauche	Linke Ständer-Führungsbahnen
13	Right-hand column slideways	Glissières du montant droit	Rechte Ständer-Führungsbahnen
14	Cross-rail (movable or fixed)	Traverse (mobile ou fixe)	Traverse (beweglich oder fest)
15	Vertical head saddle	Chariot porte-outils vertical	Senkrechter Spindelstockschlitten
16	Vertical milling head	Tête de fraisage verticale	Senkrechter Fräskopf
17	Quill (ram)	Fourreau (coulant)	Traghülse (Pinole)
18	Milling spindle	Broche porte-fraise	Frässpindel
19	Tool (milling cutter)	Outil (fraise)	Werkzeug (Fräser)
20	Horizontal milling head	Tête de fraisage horizontale	Waagerechter Fräskopf
21	Horizontal head saddle	Chariot porte-outils horizontal	Waagerechter Spindelstockschlitten
22	Reference T-slot	Rainure à T de référence	Referenz T-Nut

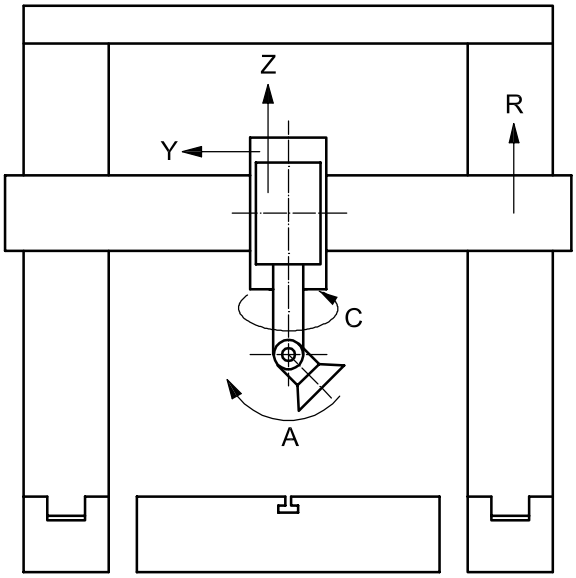


Figure 3 — Machine with one milling head swivelling on axes C and A

6 Preliminary remarks

6.1 Measuring units

In this part of ISO 8636, 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 primarily expressed in ratios (e.g. 0,00x/1 000), but in some cases microradians (µrad) or arcseconds (″) may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind:

0,010/1 000 = 10 µrad ≈ 2″

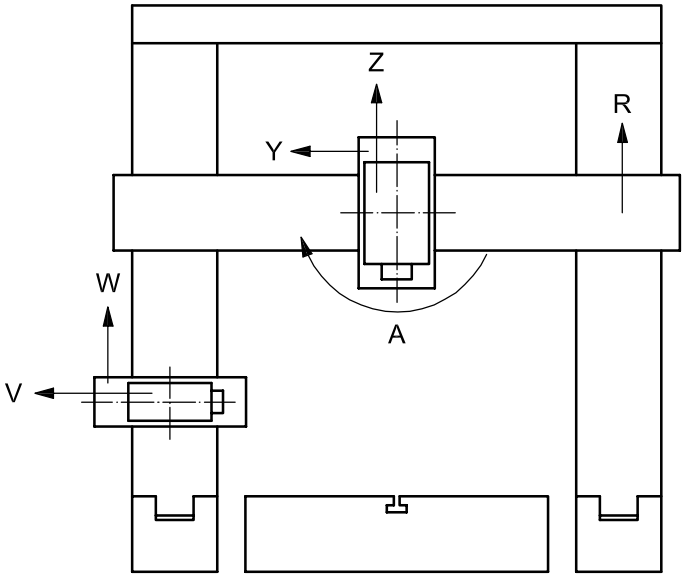
6.2 Reference to ISO 230-1, ISO 230-2, and ISO 230-7

To apply this part of ISO 8636, 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.

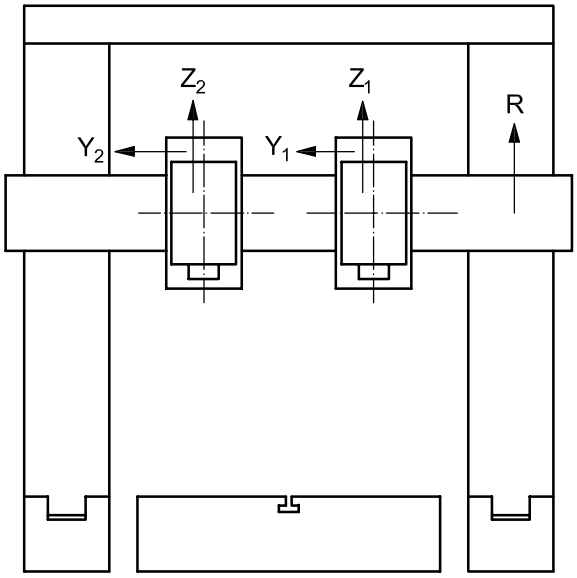
In the “Observations” box of the tests described in the following clauses, the instructions are preceded by a reference to the corresponding clause in ISO 230-1, ISO 230-2 or ISO 230-7 in cases where the test concerned is in compliance with the specifications of one of those parts of ISO 230.

6.3 Temperature conditions

The temperature conditions throughout the tests shall be specified by agreement between the supplier/manufacturer and user.



a) One swivelling (A-axis) milling head mounted on the cross-rail and one horizontal milling head mounted on the right- or left-hand column



b) Two vertical milling heads mounted on the cross-rail

Figure 4 — Machine with two milling heads (two examples)

6.4 Testing sequence

The sequence in which the tests are presented in this part of ISO 8636 in no way defines the practical order of testing. In order to facilitate the mounting of instruments or gauging, tests may be performed in any order.

6.5 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 8636. If the tests are required for acceptance purposes, it is the responsibility of 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. Mere reference to this part of ISO 8636 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.

6.6 Measuring instruments

The measuring instruments indicated in the tests described in the following clauses are examples only. Other instruments measuring the same quantities and having no larger measurement uncertainty may be used.

6.7 Minimum tolerance

When establishing the tolerance for a measuring length different from that given in this part of ISO 8636 (see 2.311 of ISO 230-1:1996), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

6.8 Machining tests

Machining tests shall be made with finishing cuts only. Roughing cuts shall be avoided since they are liable to generate appreciable cutting forces.

6.9 Positioning tests

Positioning tests for numerically controlled machines shall refer to ISO 230-2. Tolerances in this part of ISO 8636 are given only for some parameters. The presentation of the test results shall be in compliance with ISO 230-2.

7 Geometric tests

Tolerances are limited to the machines of table size up to 3 000 mm × 10 000 mm. For machines greater than this length or width, the tolerance shall be agreed upon between the supplier/manufacturer and user.

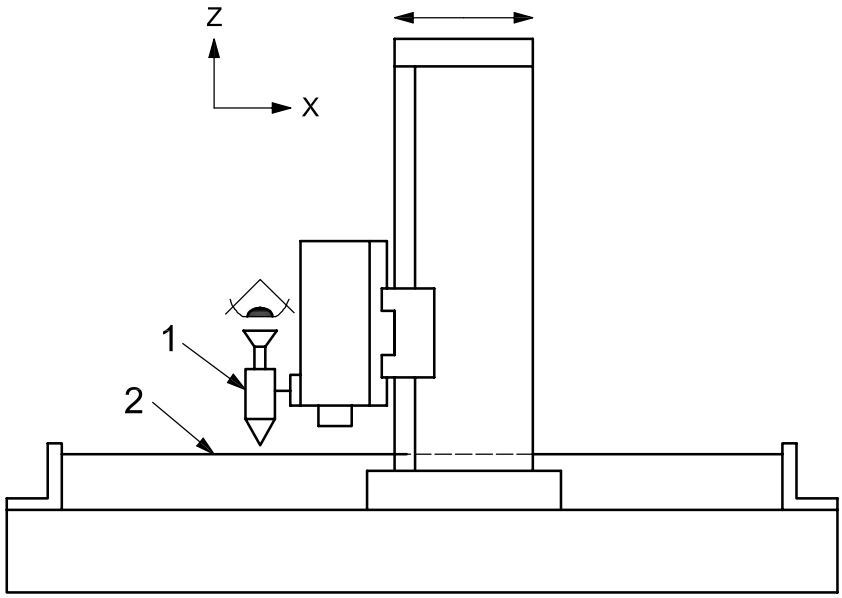
Place the gantry at mid-stroke, with milling head at mid-position on cross-rail (or in symmetrical positions if several heads are available).

7.1 Axes of motion

Object **G1**

Checking of straightness of movement of the column (X-axis) in the horizontal X-Y plane (EYX).

Diagram



Key

1 microscope

2 taut wire

Tolerance	**Measured deviation**
0,02 for measuring length up to 2 000 Add 0,01 to the preceding tolerance for each 1 000 increase in length beyond 2 000 Maximum tolerance: 0,10 Local tolerance: 0,01 for any measuring length of 1 000	

Measuring instruments

Microscope/CCD camera and taut wire or other methods.

Observations and references to ISO 230-1:1996, 5.232.12, 5.232.13 and 5.232.14

When using microscope/CCD camera and taut wire, the microscope/CCD camera shall be mounted on the head, and the taut wire shall be fixed to each end of the table parallel to X-axis movement of the column (readings of the microscope/CCD camera at both ends of the movement should be the same. In this case, the maximum difference of the readings gives the straightness deviation).

Traverse the column in the X-direction and record the readings.

Object **G2**

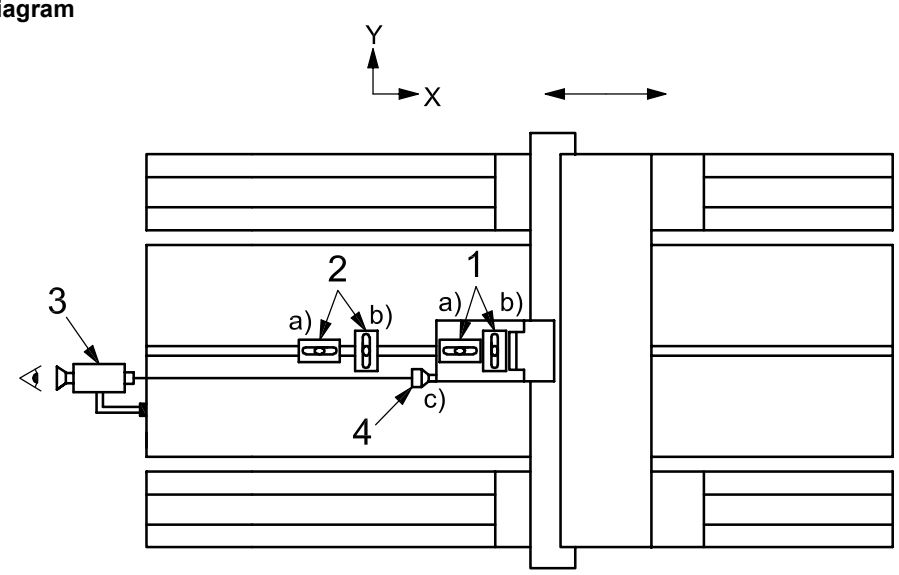
Checking of angular deviations of the movement of the column (X-axis):

a) in the vertical Z-X plane (EBX: pitch);

b) in the vertical Y-Z plane (EAX: roll);

c) in the horizontal X-Y plane (ECX: yaw).

Diagram



Key

1 measuring level
2 reference level
3 autocollimator
4 mirror

Tolerance

	a) and c)	b)
$X \leqslant 4\,000$	0,04/1 000	0,02/1 000

a) and c)

Add 0,01/1 000 to the preceding tolerance for each 1 000 increase in length larger than 4 000

b)

Add 0,005/1 000 to the preceding tolerance for each 1 000 increase in length larger than 4 000

Measured deviation

Measuring instruments

a) Precision level or optical angular deviation measuring instruments

b) Precision level

c) Autocollimator or other optical angular deviation measuring instruments

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

The level or instrument shall be placed on the movable component:

a) (EBX: pitch) in the X-axis direction, set vertically;

b) (EAX: roll) in the Y-axis direction, set vertically;

c) (ECX: yaw) in the X-axis direction, set the autocollimator horizontally.

If X-axis motion causes angular deviation of both the spindle head and work-holding table, differential measurements of the two angular movements shall be taken.

Measurements shall be carried out at a minimum of five positions equally spaced along the travel, in both directions of movement.

The difference between the maximum and minimum readings shall not exceed the tolerance.

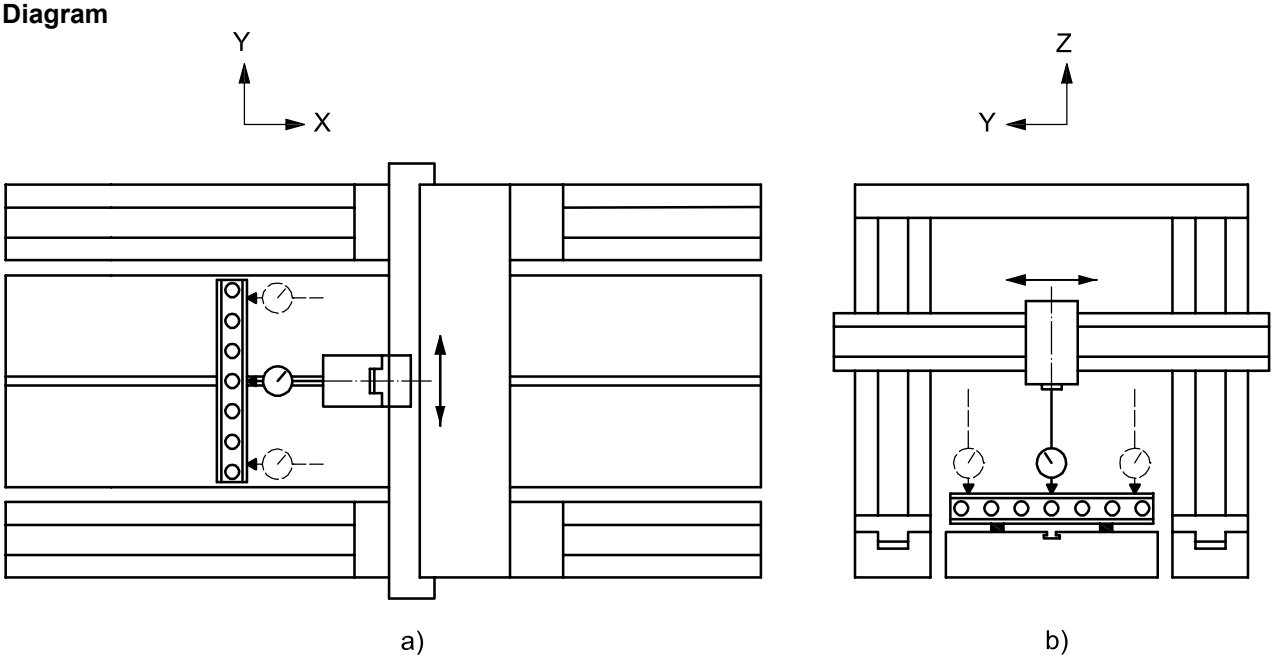
Object **G3**

Checking of straightness of the horizontal movement of the milling head (Y-axis):

a) in the horizontal X-Y plane (EXY);

a) in the vertical Y-Z plane (EZY).

Diagram



a) b)

Tolerance	**Measured deviation**
0,02 for measuring length up to 1 000 Add 0,01 to the preceding tolerance for each 1 000 increase in length beyond 1 000 Maximum tolerance: 0,04 Local tolerance: 0,01 for any measuring length of 500	

Measuring instruments

Straightedge, linear displacement sensor/support and gauge blocks or optical methods or microscope and taut wire (for measurement in horizontal plane only)

Observations and references to ISO 230-1:1996, 5.232.11, 5.232.12 and 5.232.13

Fix the cross-rail in the mid-height and move the column in mid-travel.

Place a straightedge on the table, parallel to the Y-axis movement of the milling head, for a) horizontally and for b) vertically (reading of the linear displacement sensor touching the straightedge at both ends of the movement should be the same value and, in this case, the maximum difference of the readings gives the straightness deviation).

Attach a linear displacement sensor to the milling head. The linear displacement sensor stylus shall be normal to the reference face of the straightedge.

Traverse the milling head in the Y-direction through the measuring length and record the readings. (The measuring length is normally the length between two columns (not the full length of cross-rail). In other cases, this shall be agreed upon between the supplier/manufacturer and user).

Object **G4**

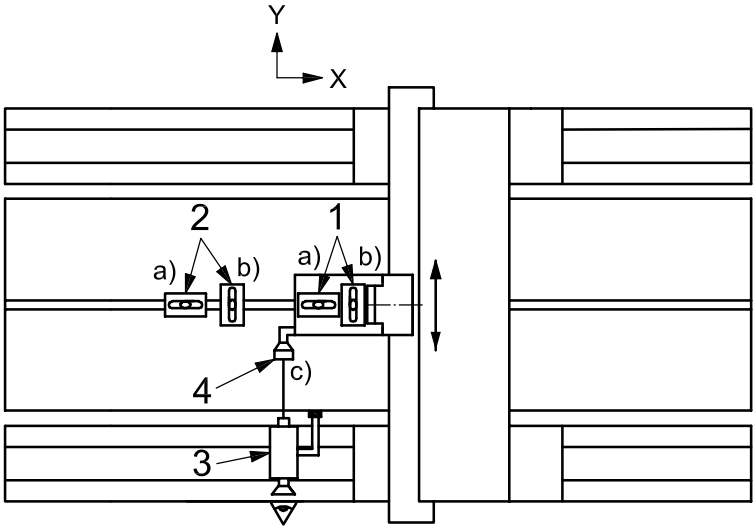
Checking of angular deviations of the horizontal movement of the milling head (Y-axis):

a) in the vertical Y-Z plane (EAY: pitch);

b) in the vertical Z-X plane (EBY: roll);

c) in the horizontal X-Y plane (ECY: yaw).

Diagram



Key

1 measuring level

2 reference level

3 autocollimator

4 mirror

Tolerance	**Measured deviation**
For a), b) and c): 0,04/1 000 Local tolerance: 0,02/1 000 for any measuring length of 300	

Measuring instruments

a) Precision level or optical angular deviation measuring instruments

b) Precision level

c) Autocollimator or other optical angular deviation measuring instruments

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

The level or instrument shall be placed on the movable component:

a) (EAY: pitch) in the Y-axis direction, set vertically;

b) (EBY: roll) in the X-axis direction, set vertically;

c) (ECY: yaw) in the Y-axis direction, set autocollimator horizontally.

When Y-axis motion causes angular deviation of both the spindle head and work-holding table, differential measurements of the two angular movements shall be taken.

When differential measurement is applied, the reference level should be placed on the work-holding table, and the column shall be in the middle of its travel range.

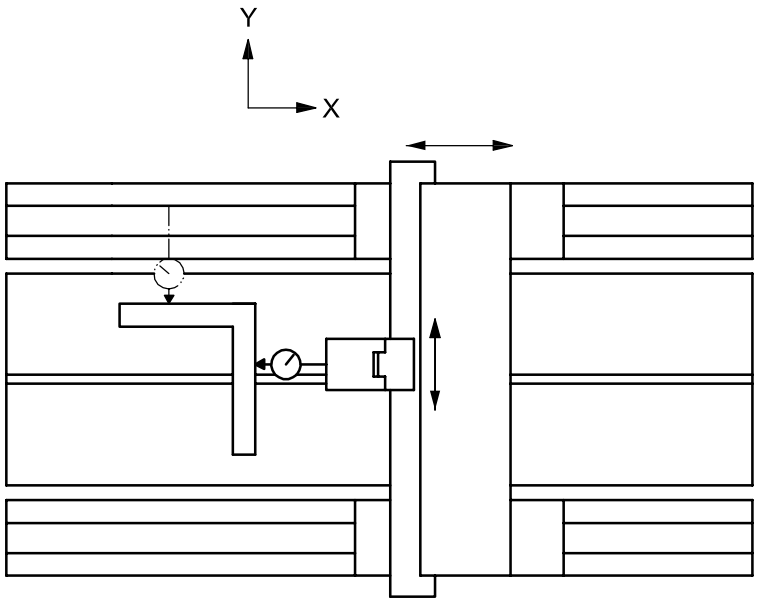
Measurements shall be carried out at a minimum of five positions equally spaced along the travel, in both directions of movement.

The difference between the maximum and the minimum readings shall not exceed the tolerance.

Object **G5**

Checking of squareness of milling carriage transverse displacement on cross-rail (Y-axis) to column displacement (X-axis) in a horizontal plane.

Diagram



Tolerance	**Measured deviation**
0,02 for a measuring length of 1 000	

Measuring instruments

Square and linear displacement sensor

Observations and references to ISO 230-1:1996, **5.522.4**

Place column in mid-position, orient one arm of square parallel to column displacement (X-axis).

Fix linear displacement sensor support and linear displacement sensor on milling head.

Place linear displacement sensor stylus against the other arm of the square. Move milling head along cross-rail and read indication.

Rotate square 180°, repeat checks in the same order and calculate the average value of the deviations determined.

For large machines, repeat the operation in two extreme column positions.

Object **G6**

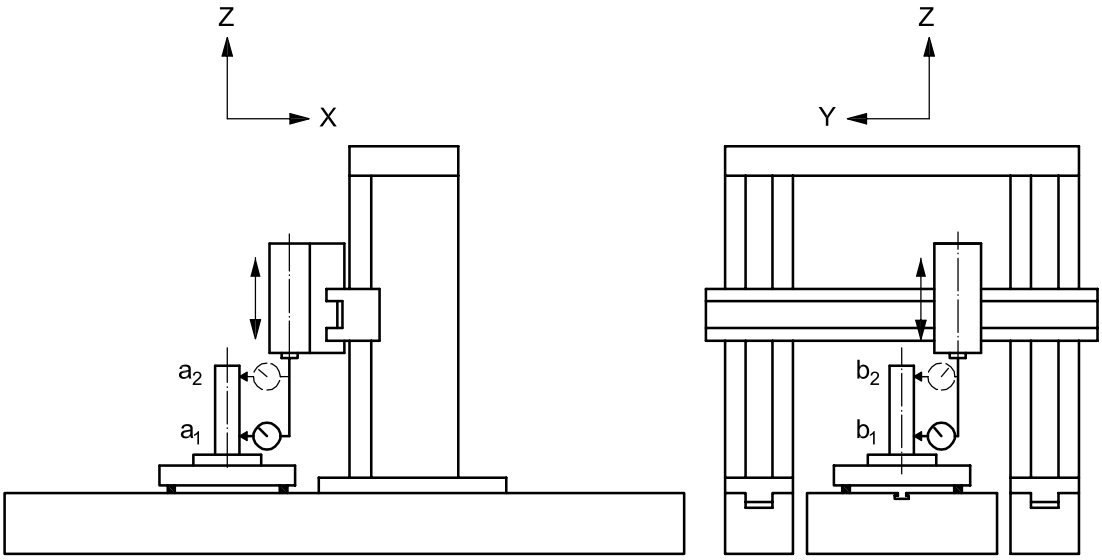
Checking of squareness of milling head vertical displacement (Z-axis) to:

a) X-axis;

b) Y-axis.

NOTE This test is also applicable to additional vertical milling heads on the cross-rail.

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b): 0,02 for a measuring length of 300	

Measuring instruments

Cylindrical square, surface plate, adjustable blocks and linear displacement sensor

Observations and references to ISO 230-1:1996, **5.522.4**

Place bridge, cross-rail and milling head at mid-stroke.

Fix linear displacement sensor on milling head. Lock cross-rail on column, where possible.

Place cylindrical square on a surface plate oriented parallel to the X- and Y-directions motion defined by the bridge longitudinal displacement and the milling head transverse displacement; then place linear displacement sensor stylus in the longitudinal plane at point a_1 on the cylindrical square. Move Z-axis to point a_2 and record the sensor reading.

Rotate cylindrical square 180° and repeat the measurement in the same order.

Calculate the average value of the deviations determined.

Then carry out measurement in the transverse (Y-Z) plane at points b_1 and b_2.

For large machines, checking may be carried out at the mid-position and in two extreme positions of the milling head on the cross-rail.

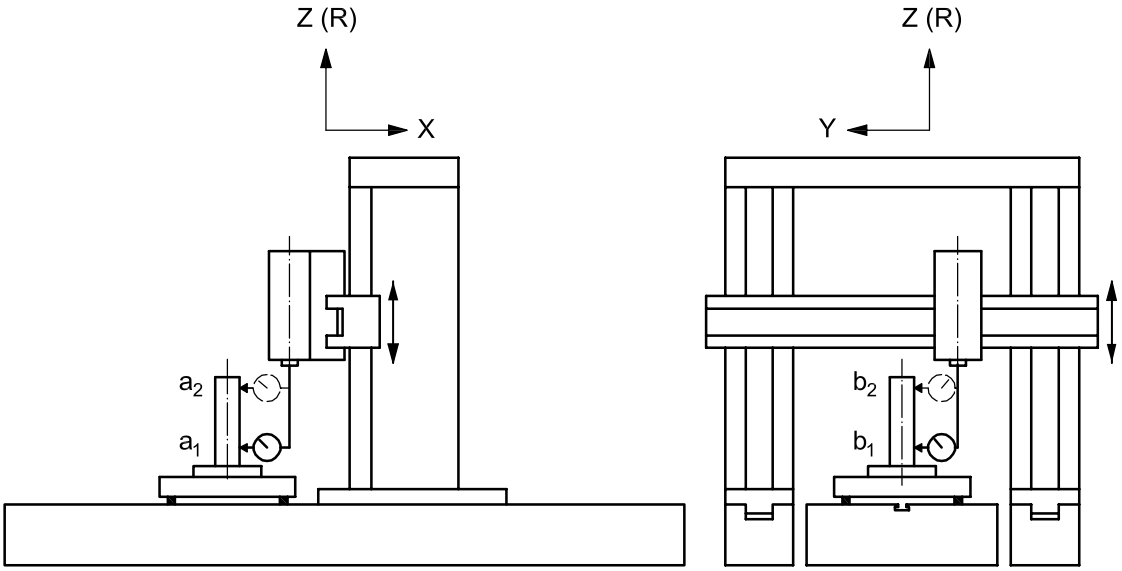
Object **G7**

Checking of squareness of movable cross-rail vertical displacement (R-axis) to:

a) X-axis;

b) Y-axis.

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b): 0,02 for a measuring length of 300	

Measuring instruments

Cylindrical square, surface plate, adjustable blocks and linear displacement sensor

Observations and references to ISO 230-1:1996, 5.522.4

Place bridge, cross-rail and milling head at mid-stroke.

Fix dial-gauge support and linear displacement sensor on milling head. Lock milling head on cross-rail, where possible.

Place cylindrical square on a surface plate oriented parallel to the X- and Y-directions motion defined by the bridge longitudinal displacement and the milling head transverse displacement; then place linear displacement sensor stylus in the longitudinal plane at point a_1 on the cylindrical square. Move cross-rail to point a_2 and read indication.

Rotate cylindrical square 180° and repeat the checking in the same order.

Calculate the average value of the deviations determined.

Then check in the transverse plane at points b_1 and b_2.

For large machines, checking may be carried out at the mid-position and in two extreme positions of the milling head on the cross-rail.

Object **G8**

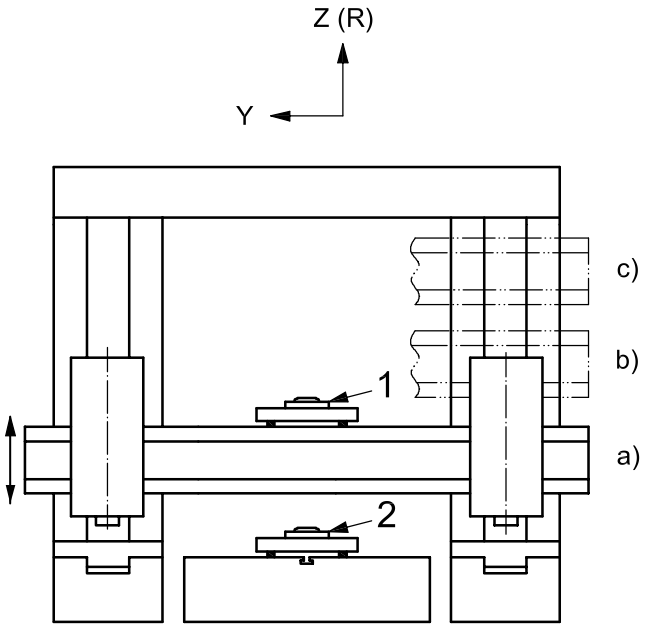
Checking of slope variation of the cross-rail in its R-axis movement in the vertical Y-Z plane:

a) in the lower position;

b) in the mid-position;

c) in the higher position.

Diagram



Key

1 measuring level

2 reference level

Tolerance	**Measured deviation**
0,02/1 000	

Measuring instruments

Precision level

Observations and references to ISO 230-1:1996, 5.232.21

Place the level at the mid-position of the cross-rail on an adequate face and read the indication in the quoted positions.

When R-axis motion causes angular deviation of both the cross-rail and the work-holding table, differential measurements of the two angular movements shall be taken.

When differential measurement is applied, the reference level shall be placed on the work-holding table.

Place milling heads symmetrically relative to the work-holding table.

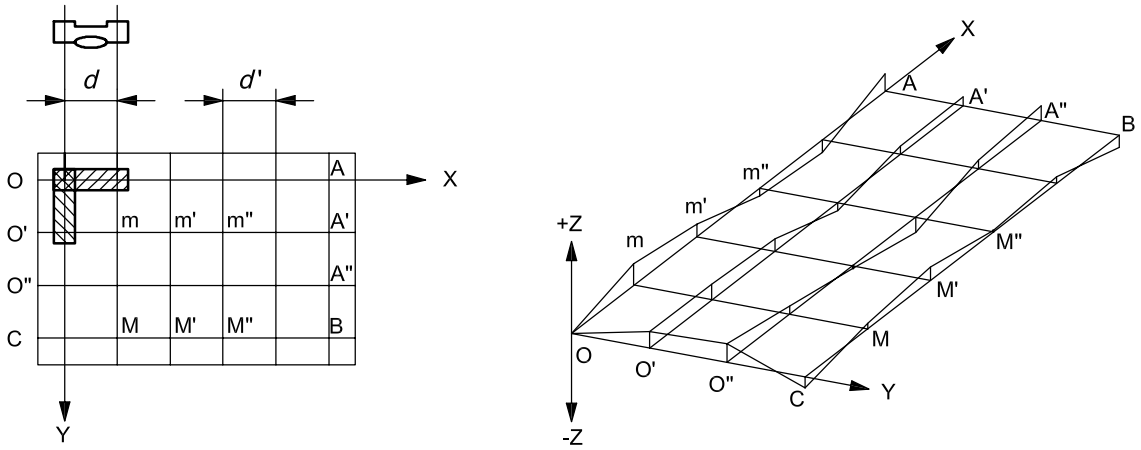
For machines with only one milling head, it shall be placed in a central position.

Lock the cross-rail at each position, where possible.

7.2 Table

Object	**G9**
Checking of flatness of the table surface.	

Diagram



Tolerance	**Measured deviation**
For X ⩽ 3 000 and Y⩽ 2 000: 0,030 For each additional increment of 1 000 in X: add 0,010 For each additional increment of 1 000 in Y: add 0,010 Local tolerance for 1 000 × 1 000: 0,020	

Measuring instruments

Precision levels and support with contact points 500 mm apart or optical or other equipment

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

Bridge at mid-travel (mid-position).

Place the precision level with support on the surface of the table and displace it in directions O-X and O-Y in steps corresponding to the length of support (500) in the direction concerned, and record readings.

Test method G10 is also useful for the checking of flatness if finish-machining of table is not carried out after assembly.

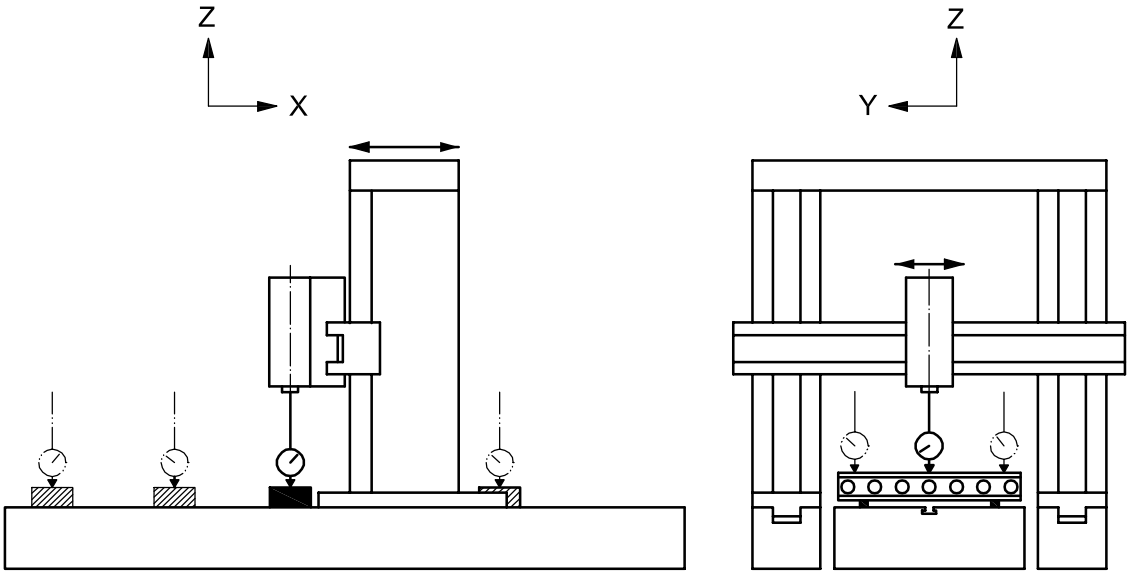
Object **G10**

Checking of parallelism of the table surface to:

a) the movement of the column (X-axis);

b) the movement of the milling head (Y-axis).

Diagram



a) b)

Tolerance[1]		**Measured deviation**
a) $X \leqslant 10\,000$: 0,05	b) $Y \leqslant 1\,000$: 0,03	
Local tolerance: 0,02 for any measuring length of 1 000	For each additional increment of 1 000: add 0,02	
	Max. tolerance: 0,06	
	Local tolerance: 0,03 for any measuring length of 1 000	

1) The above tolerances are specified assuming that finish-machining of the table is not carried out after assembly. If this is not the case, the tolerances shall be agreed upon between the supplier/manufacturer and user.

Measuring instruments

Linear displacement sensor, straightedge and gauge blocks

Observations and references to ISO 230-1:1996, 5.422.21 and 5.422.22

Attach a linear displacement sensor to the milling spindle or to the head near the spindle. The linear displacement sensor shall be normal to the table surface and touching it directly or touching a gauge block located on the table surface.

a) The milling head is at mid-travel. Traverse the column in the X-direction and record the maximum difference of the readings.

Repeat the test in two other positions of the milling head, symmetrical to the previous position, and record the maximum difference of the readings in the same way.

The largest of the maximum differences gives the parallelism deviation of the X-axis.

b) Cross-rail is locked, where possible. Move the milling head in the Y-direction and record the maximum differences of the readings.

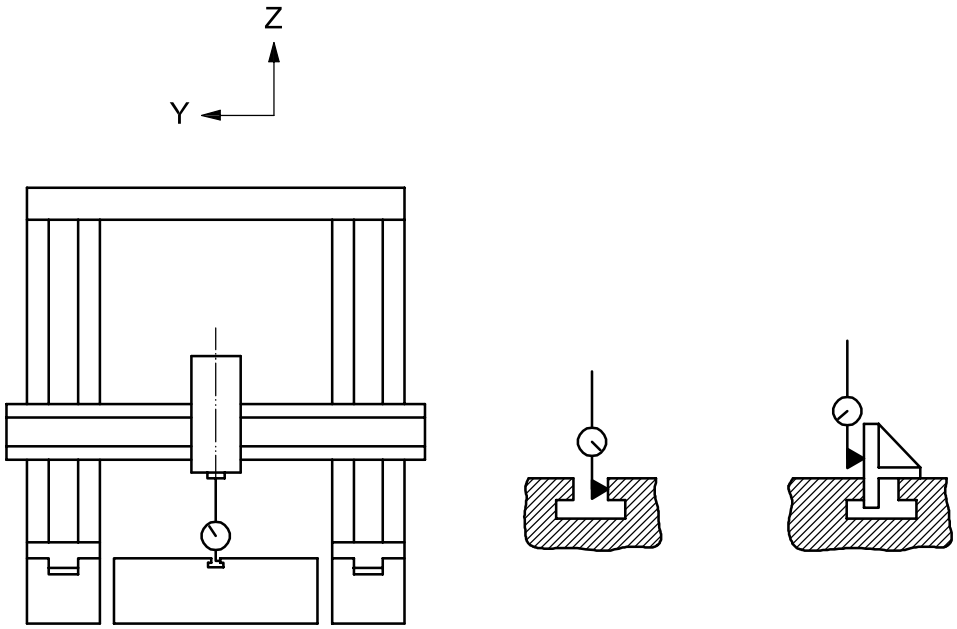
Repeat the test in two other positions symmetrical to the previous position and record the maximum differences of the reading in the same way.

The largest of the maximum differences gives the parallelism deviation of the Y-axis.

Object **G11**

Checking of the parallelism of median or reference T-slot to the movement of the column (X-axis).

Diagram



Tolerance	**Measured deviation**
0,03 for a measuring length up to 2 000 Add 0,01 to the preceding tolerance for each 1 000 increase in length Maximum tolerance: 0,1 Local tolerance: 0,02 for any measuring length of 1 000	

Measuring instruments

Linear displacement sensor, cross-square

Observations and references to ISO 230-1:1996, 5.422.21

Attach a linear displacement sensor to the milling spindle or to the head near the spindle. Place the gauge stylus in contact with the measuring face of the reference T-slot or use a piece of suitable shape.

Move the cross-rail and record the linear displacement sensor indicator variation.

7.3 Milling head

Object **G12**

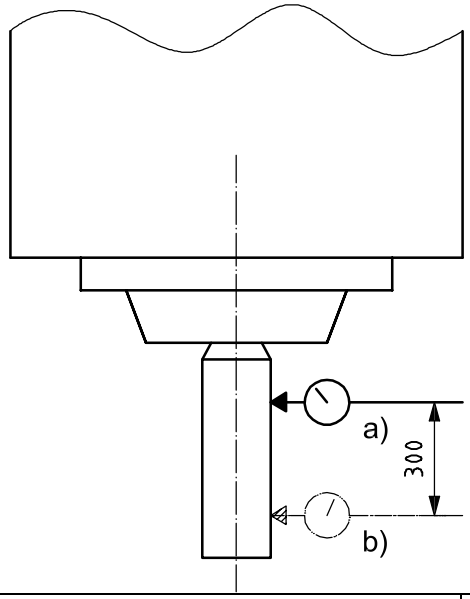
Checking of run-out of internal taper of the milling spindle:

a) close to the spindle nose;

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

Carry out these tests for each milling spindle of the machine.

Diagram



Tolerance				**Measured deviation**
$D \leqslant 200$	a)	0,010	b) 0,020	
$D > 200$	a)	0,015	b) 0,030	

where D is the external diameter of the spindle-nose face

Measuring instruments

Linear displacement sensor and test mandrel

Observations and references to ISO 230-1:1996, 5.612.3

Attach a linear displacement sensor to a fixed part of the machine and insert the test mandrel in the spindle.

Place the linear displacement sensor stylus as close as possible to position a), rotate the spindle and record the indication.

Repeat the same operation at position b) at a distance of 300 mm from position a).

NOTE An alternative test (testing error motions of the axis of rotation) is presented in R1.

Object **G13**

Checking of the milling spindle for:

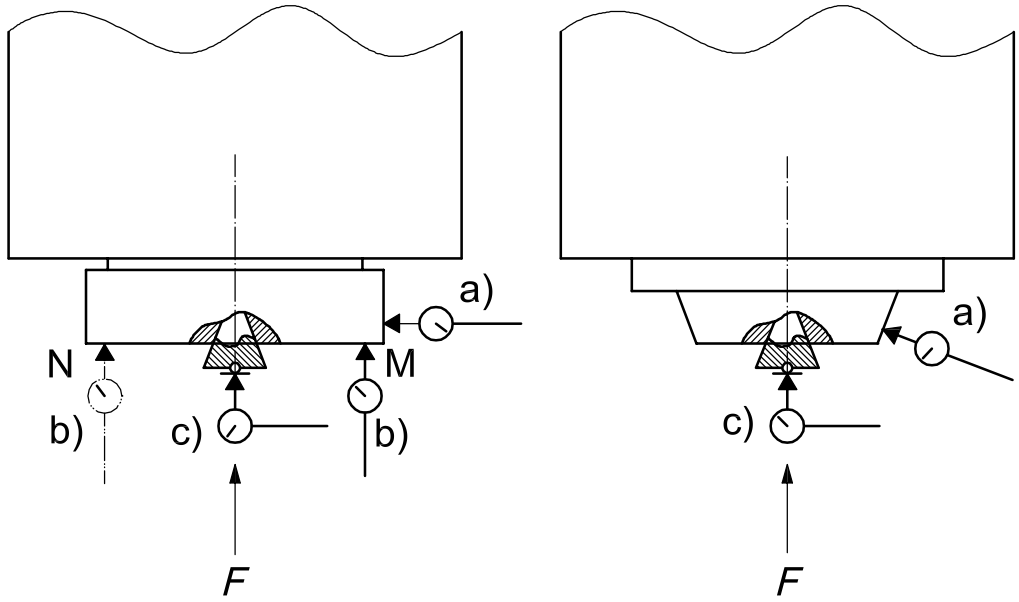
a) run-out of external surface-nose face;

b) camming of spindle-nose face (including periodic axial slip);

c) periodic axial slip.

Carry out these tests for each milling spindle of the machine in the vertical or horizontal position.

Diagram



Tolerance			**Measured deviation**
	$D \leqslant 200$	$D > 200$	
a)	0,010	0,015	
b)	0,015	0,020	
c)	0,005	0,010	

where D is the external diameter of the spindle-nose face

Measuring instruments

Linear displacement sensor

Observations and references to ISO 230-1:1996

Attach a linear displacement sensor support and a linear displacement sensor to a fixed part of the machine.

a) 5.612.2

Place the linear displacement sensor stylus normal to the generating line, rotate the milling spindle and record the indication.

b) 5.63.2

Place the linear displacement sensor stylus as close as possible to the outside edge of the flat face at position M, rotate the milling spindle and record the indication.

Repeat the same operation at position N after moving the linear displacement sensor.

Determine the average value.

c) 5.622.1 and **5.622.2**

Insert a steel ball in the spindle centre (by auxiliary means if necessary).

Position the linear displacement sensor stylus to contact the steel ball, rotate the spindle and record the indication.

The value and the direction of the force to be applied shall be specified by the supplier/manufacturer.

When axially preloaded bearings are used, there is no need to apply the force F.

NOTE An alternative test (testing error motions of the axis of rotation) is presented in R1.

Object **G14**

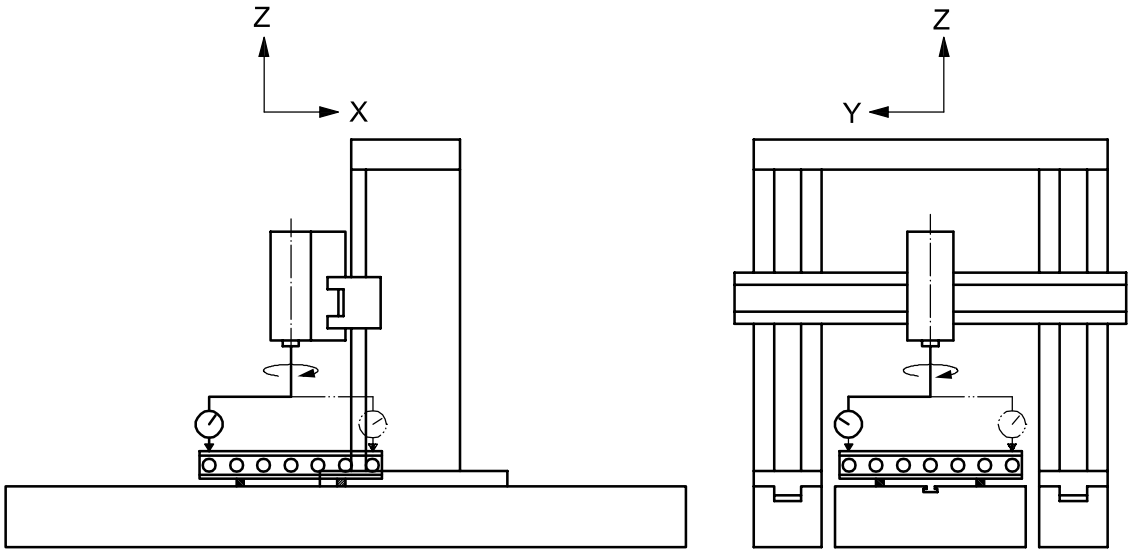
Checking of squareness of the vertical milling spindle axis of rotation to:

a) X-axis;

b) Y-axis.

NOTE This test is also applicable to additional vertical milling heads on the cross-rail.

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b): 0,03/500 (distance between the two measuring points touched).	

Measuring instruments

Linear displacement sensor/support arm and straightedge or surface plate

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

Place a straightedge at the centre of the table parallel to the X-axis movement of the cross-rail in the vertical plane.

Cross-rail at mid-height and locked, vertical milling head at mid-travel and locked, where possible. Quill or ram 1/3 travel from the head.

Attach the supporting arm with linear displacement sensor to the milling spindle and adjust the stylus of the linear displacement sensor to touch the straightedge, and record the indication. Then rotate the spindle by 180° and record the new indication. Record the difference between the two readings over the distance between the two measurement points.

Repeat the above measurement with straightedge set parallel to the Y-axis movement.

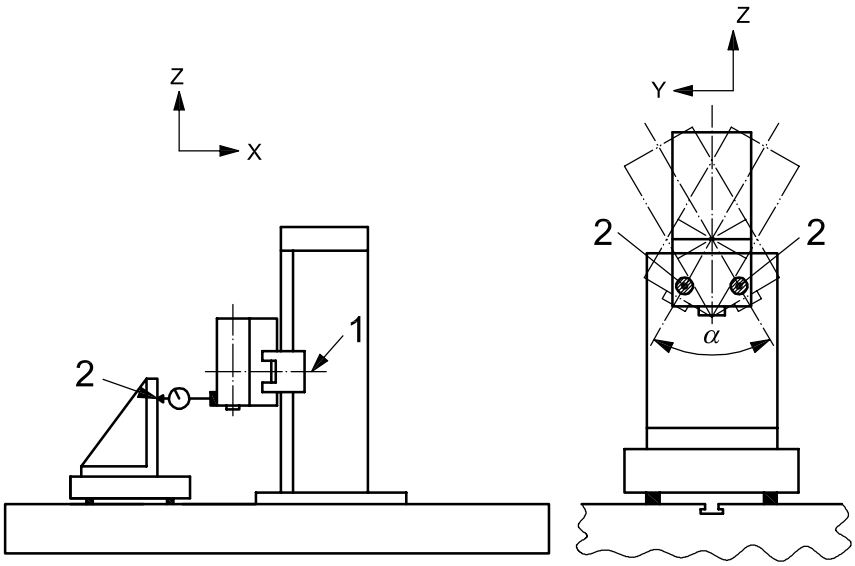
7.4 Swivelling milling head

Object **G15**

Checking of parallelism of the milling-head swivel axis to the Y-Z plane when the milling head swivels.

NOTE This test is also applicable to additional vertical milling heads on the cross-rail.

Diagram



Key

1 swivel axis

2 measuring point

Tolerance	**Measured deviation**
For linear displacement sensor placed at 100 mm from the spindle nose swivel axis 0,02 for $\alpha \leqslant 10°$ 0,03 for $10° < \alpha \leqslant 20°$ 0,04 for $\alpha > 20°$	

Measuring instruments

Square, surface plate, adjustable blocks and linear displacement sensor

Observations and references to ISO 230-1:1996, 5.422.22

Place a surface plate on the table and adjust its top surface parallel to both X- and Y-axes movements.

Position the flat square on it so that its vertical surface is parallel to the Y-axis movement.

Cross-rail fixed at mid-height, milling-head saddle fixed at mid-travel.

Attach a linear displacement sensor to the milling head so that the stylus of a linear displacement sensor is 100 mm from the spindle nose.

Apply the stylus of the linear displacement sensor to the flat-square face in the X-direction; rotate the milling head and record readings.

7.5 Horizontal milling head (side milling head)

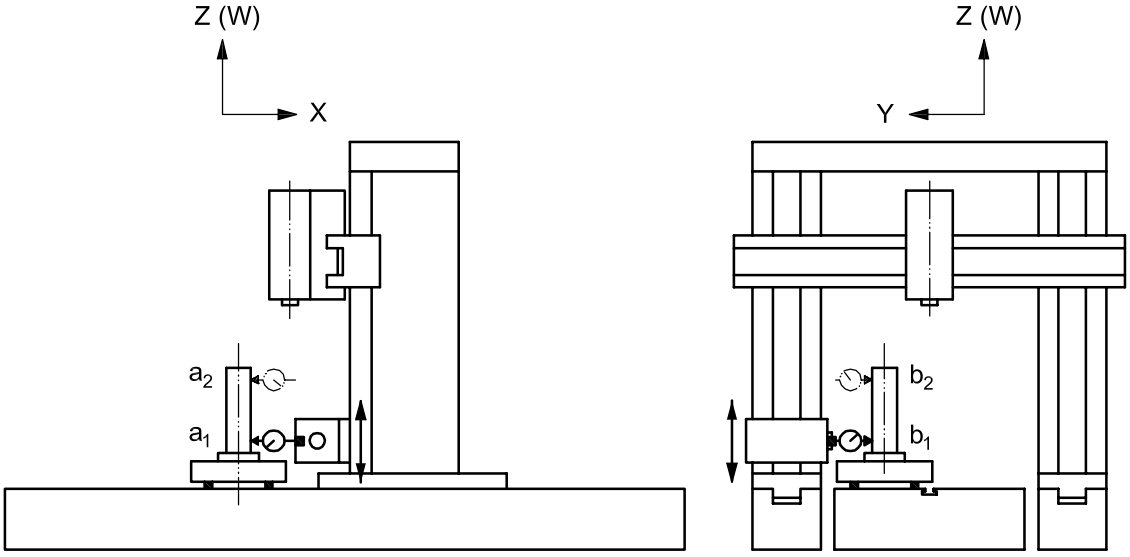
Object **G16**

Checking of squareness between the vertical movement of the side milling head (W-axis) on a column and the:

a) X-axis;

b) Y-axis.

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b): 0,03 for measuring length of 500	

Measuring instruments

Cylindrical square, surface plate, adjustable blocks and linear displacement sensor

Observations and references to ISO 230-1:1996, 5.522.4

Place column and vertical milling head at mid-stroke.

Fix linear displacement sensor support and linear displacement sensor on side milling head.

Place cylindrical square on a surface plate oriented parallel to the reference plane defined by the column longitudinal displacement (X-axis) and the vertical milling head transverse displacement (Y-axis); then place linear displacement sensor stylus in the longitudinal plane at point a_1 on the cylindrical square. Move side milling head to point a_2 and read indication.

Rotate cylindrical square 180°and repeat the checking in the same order.

Calculate the average value of the deviations determined.

Then carry out checking in the transverse plane at points b_1 and b_2.

If the spindle can be locked, the linear displacement sensor may be mounted on it. If the spindle cannot be locked, the linear displacement sensor shall be placed on a fixed part of the machine.

Object **G17**

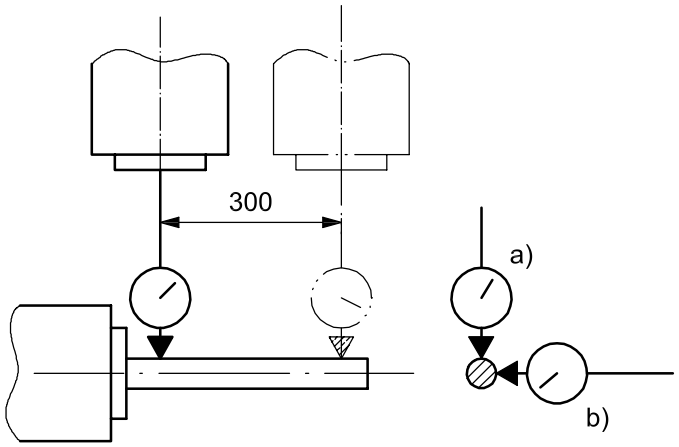
Checking of parallelism of the horizontal milling spindle axis to the Y-axis:

a) in the vertical Y-Z plane;

b) in the horizontal X-Y plane.

NOTE Applicable only for the milling head with a horizontal spindle axis. This check does not apply to removable milling heads.

Diagram



Tolerance	**Measured deviation**
For a) and b): 0,03 for measuring length of 300	

Measuring instruments

Test mandrel and linear displacement sensor

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

Attach a linear displacement sensor to the vertical milling head and adjust the stylus of the linear displacement sensor to touch the test mandrel mounted on the horizontal milling spindle, a) vertically, b) horizontally, as near as possible to the spindle nose.

Horizontal milling head is locked in low-position. Cross-rail is locked in mid-position, where possible.

Move the vertical milling head (Y-axis) for the measuring length and record the indications.

Record the maximum difference of linear displacement sensor readings.

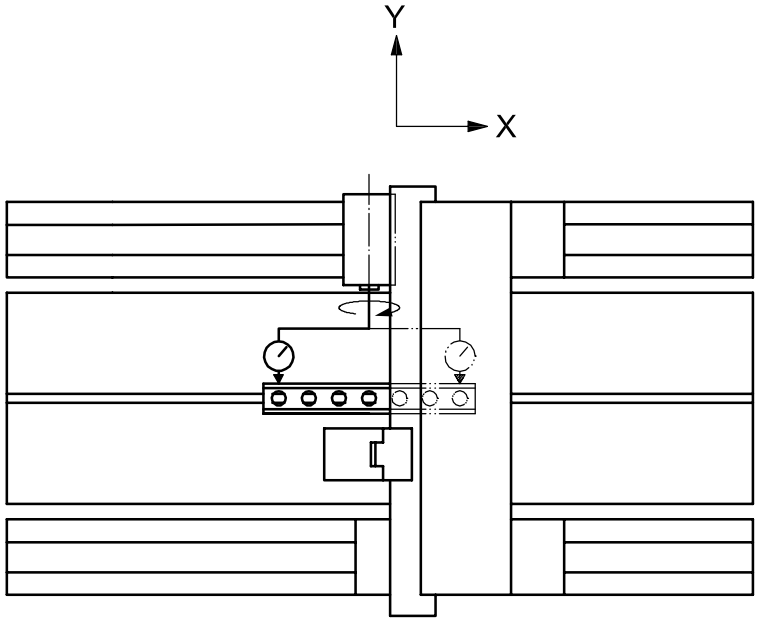
Tests shall be carried out at the mean position of the spindle rotation for both a) and b).

Object **G18**

Checking of squareness between the axis of rotation of the horizontal milling spindle and the movement of the column (X-axis).

NOTE Applicable only for the milling head with a horizontal spindle axis. This check does not apply to removable milling heads.

Diagram



Tolerance	**Measured deviation**
0,03/500[1)]	

[1)] Distance between the two measuring points touched.

Measuring instruments

Straightedge, linear displacement sensor and support arm

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

Place a straightedge at the centre of the table parallel to the X-axis movement of the column in the horizontal plane. The column is locked at mid-travel, where possible.

Horizontal milling head at low-position and locked, where possible. Quill or ram 1/3 travel from the horizontal milling head.

Attach the support arm with linear displacement sensor to the horizontal milling spindle and adjust the stylus of the linear displacement sensor to touch the straightedge and record the indication. Then rotate the spindle by 180° and record the new indication. Record the difference between the two readings over the distance between the two measurement points.

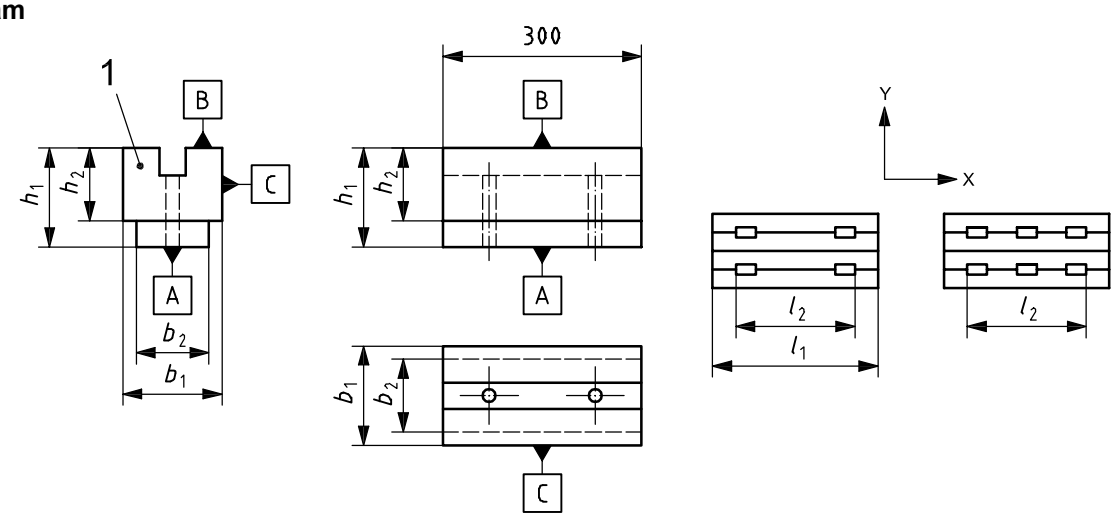
8 Machining tests

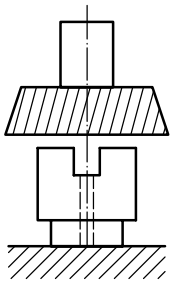
8.1 Flatness of test pieces by slab milling

Object **M1**

Milling of four test pieces (face B) along X-axis for table length of up to 2 000 mm.
For a table length in excess of 2 000 mm, six (or eight) test pieces as shown in the diagram may be used.

Diagram





Key

1 test piece
l_1 is the length of the table
l_2 is the distance between extreme faces of test pieces mounted in successive order
$b_1 = h_1 = 150$
$b_2 = h_2 = 110$
$l_1 - l_2 = 600$; or $l_1 - l_2$ is defined by agreement between user and manufacturer

Test conditions

Machining shall be carried out with an insert cutter mounted on a vertical milling spindle.

All other test conditions (quality and dimensions of tools, cutting speed, feed rate and depth of cut of the tool, material of test pieces) shall be specified by the supplier/manufacturer.

All test pieces shall have the same hardness.

Tolerance	**Measured deviation**
a) Flatness of face B of each test piece: 0,015	
b) Height h_1 of blocks shall be constant for one test piece or for:	
$l_2 \leqslant 2\,000$ 0,03	
$2\,000 < l_2 \leqslant 5\,000$ 0,05	
$5\,000 < l_2 \leqslant 10\,000$ 0,08	

Measuring instruments

Straightedge and gauge blocks or linear displacement sensor and surface plate, micrometer

Observations and references to ISO 230-1:1996, 3.1, 3.22, 4.1, 4.2, 5.321 and 5.412.2

Before starting the test:

— ensure that faces A are flat;

— orient block(s) parallel to the movement of the table (X-axis).

With milling cutter mounted on milling spindle, the following tolerances are recommended:

a) run-out $\leqslant$ 0,02;
b) camming $\leqslant$ 0,03.

8.2 Milling of lateral face

Object **M2**

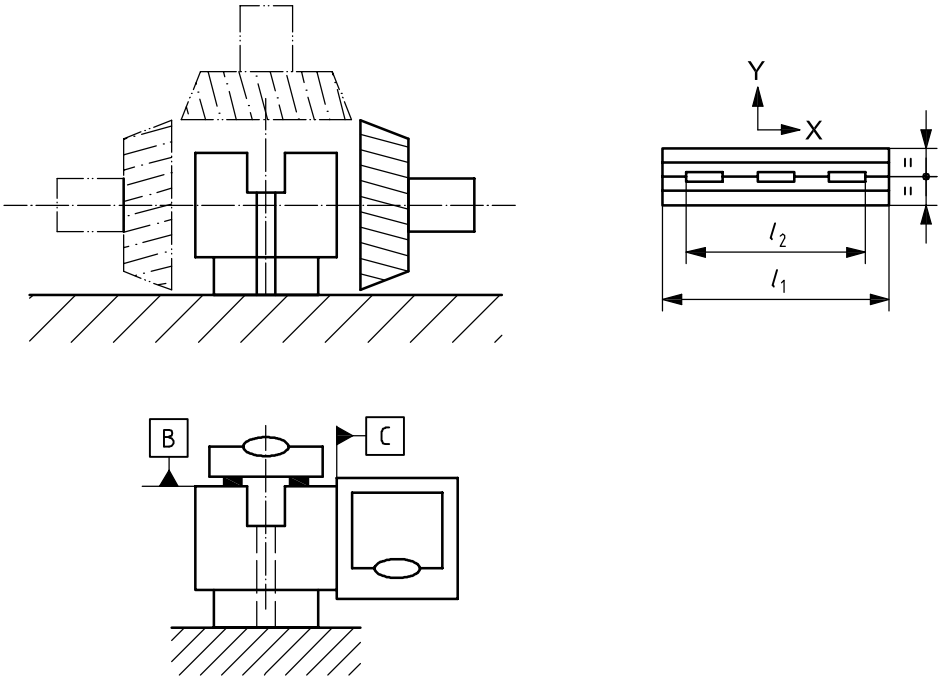
Milling of one of the lateral faces of two or three test pieces placed on the table along the X-axis.

One face perpendicular to face B can be machined with the tool (milling head) guided on the right- or left-hand column.

Test to be carried out if the machine is fitted with the required spindles.

M2 is a follow-on test after M1.

Diagram



l_1 is the length of the table

l_2 is the distance between extreme faces of test pieces mounted in successive order

$l_1 - l_2 = 600$; or $l_1 - l_2$ is defined by agreement between user and manufacturer

Nominal dimensions of test piece are the same as for test M1

Test conditions

All other test conditions (quality and dimensions of tools, cutting speed, feed rate and depth of cut of the tool, material of test pieces) shall be specified by the supplier/manufacturer.

All test pieces shall have the same hardness.

Tolerance	**Measured deviation**
Squareness between side face C and face B Squareness deviations of all test pieces: within 0,02 for a measuring length of 300	

Measuring instruments

Precision level

Observations and references to ISO 230-1:1996, 3.1, 3.22, 4.1, 4.2, 5.321 and 5.412.2

Orient block(s) parallel to X-axis.

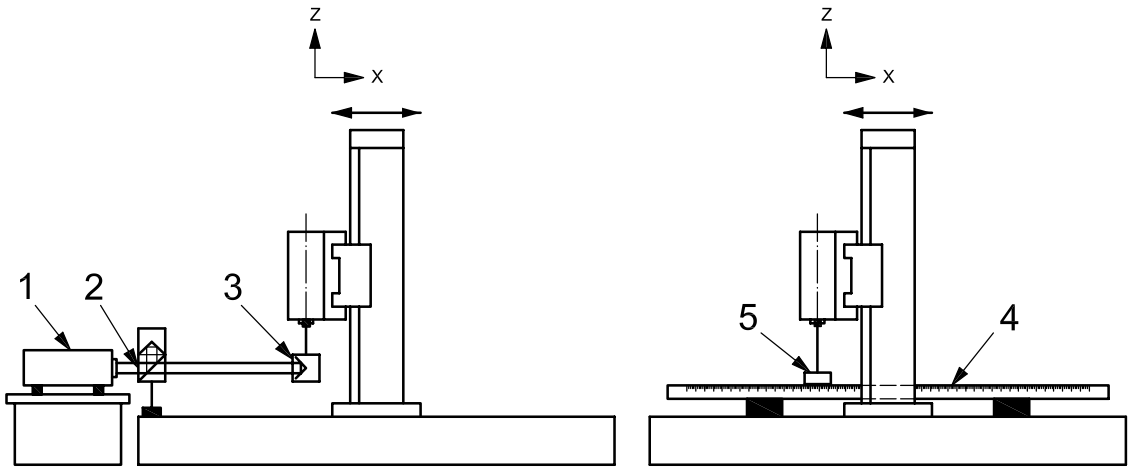
9 Accuracy and repeatability of positioning of numerically controlled axes

9.1 Linear axes

Object **P1**

Checking of accuracy and repeatability of the X-axis movement of the column.

Diagram



Key

1	laser head	4	scale
2	interferometer	5	scale reader
3	reflector		

Tolérance	**Measured length**			**(Measured deviation)**
	$\leqslant$ 500	$\leqslant$ 1 000	$\leqslant$ 2 000	
Axes up to 2 000 mm				
Bidirectional accuracy of positioning, A	0,020	0,025	0,032	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	0,008	0,010	0,013	
Reversal value of the axis, B	0,010	0,013	0,016	
Bidirectional systematic deviation of positioning, E	0,016	0,020	0,025	
Range of the mean bidirectional positional deviation of the axis, M	0,010	0,013	0,016	
Axes exceeding 2 000 mm				
Bidirectional systematic deviation, E	0,025 + 0,005 for each additional 1 000			
Range of the mean bidirectional positioning deviation of the axis, M	0,016 + 0,003 for each additional 1 000			
Reversal value of the axis, B	0,016 + 0,003 for each additional 1 000			

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

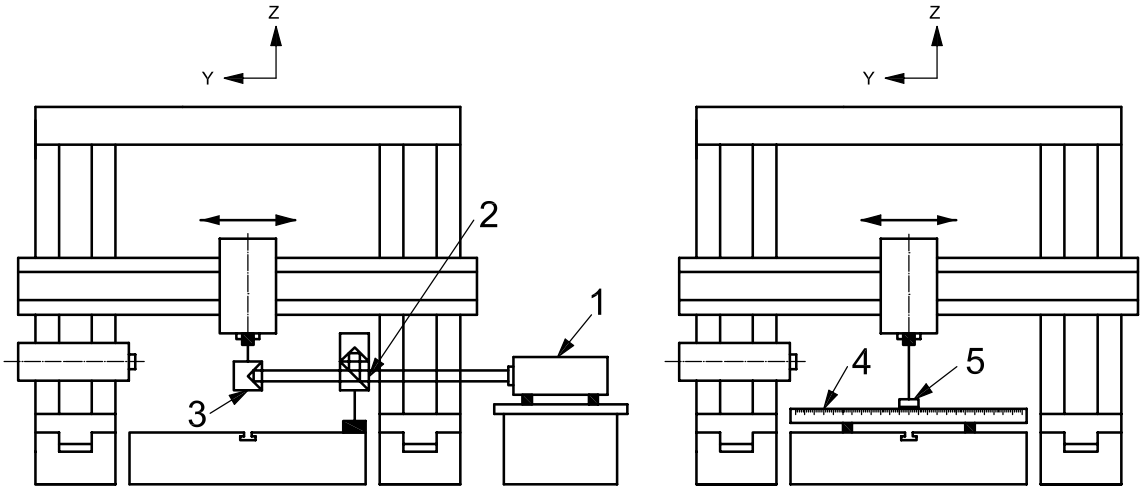
Relative measurement between the tool position and work-piece position is desired. If a linear scale is used, it shall be set on the table parallel to the X-axis, the scale reader being on the tool position. If laser equipment is used, the reflector shall be set on the vertical milling head (tool position) and the interferometer on the table.

Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to.

Object **P2**

Checking of accuracy and repeatability of the Y-axis movement of the vertical milling-head saddle.

Diagram



Key

1	laser head	4	scale
2	interferometer	5	scale reader
3	reflector		

Tolerance	Measured length			(Measured deviation)
	⩽ 500	⩽ 1 000	⩽ 2 000	
Axes up to 2 000 mm				
Bidirectional accuracy of positioning, A	0,020	0,025	0,032	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	0,008	0,010	0,013	
Reversal value of the axis, B	0,010	0,013	0,016	
Bidirectional systematic deviation of positioning, E	0,016	0,020	0,025	
Range of the mean bidirectional positional deviation of the axis, M	0,010	0,013	0,016	
Axes exceeding 2 000 mm				
Bidirectional systematic deviation, E	0,025 + 0,005 for each additional 1 000			
Range of the mean bidirectional positional deviation of the axis, M	0,016 + 0,003 for each additional 1 000			
Reversal value of the axis, B	0,016 + 0,003 for each additional 1 000			

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

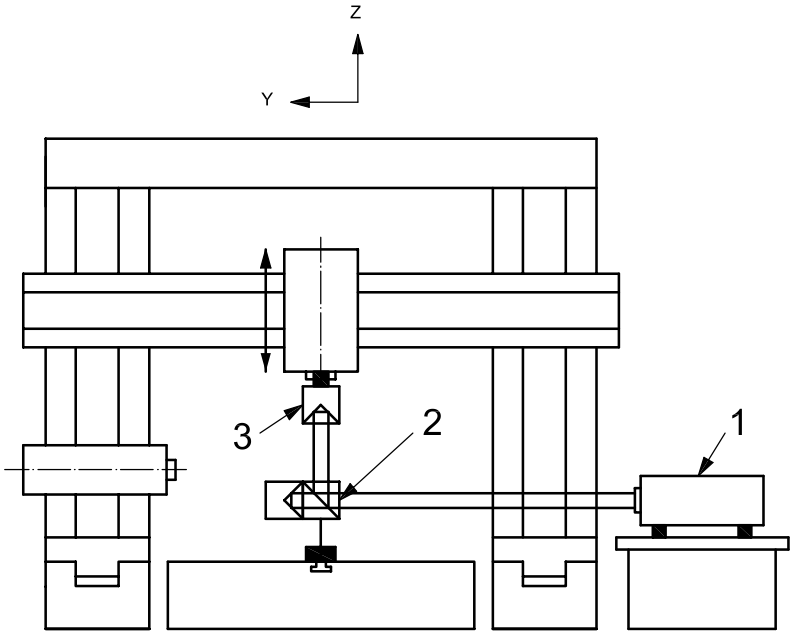
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Y-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the vertical milling head and the interferometer on the table or on its extension.

Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to. The starting point of measurement shall be stated.

Object **P3**

Checking of accuracy and repeatability of the Z-axis movement of the vertical milling head or quill.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance	Measured length		(Measured deviation)
	⩽ 500	⩽ 1 000	
Axes up to 2 000 mm			
Bidirectional accuracy of positioning, A	0,020	0,025	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	0,008	0,010	
Reversal value of the axis, B	0,010	0,013	
Bidirectional systematic deviation of positioning, E	0,016	0,020	
Range of the mean bidirectional positioning deviation of the axis, M	0,010	0,013	

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

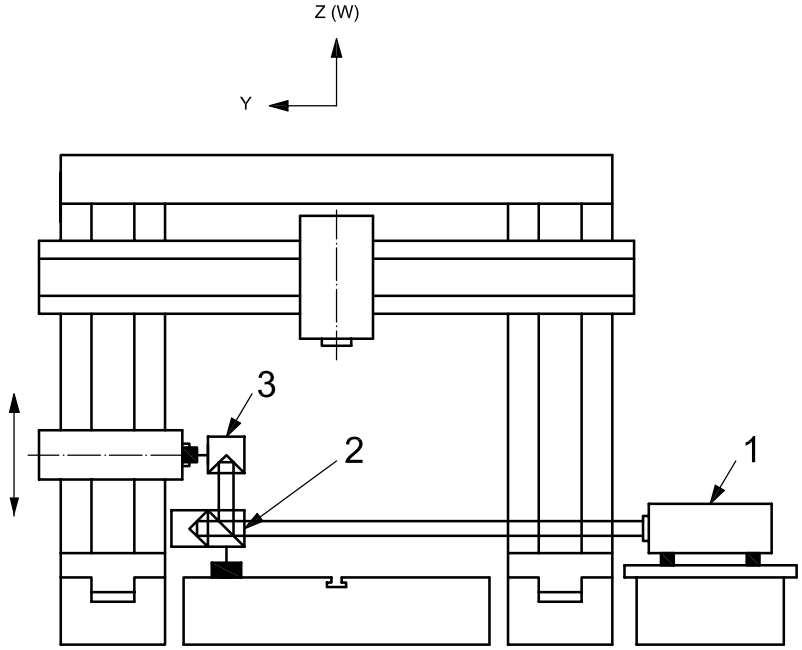
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Z-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the vertical milling head and the interferometer on the table.

Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to.

Object **P4**

Checking of accuracy and repeatability of the W-axis movement of the horizontal milling head.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance	Measured length			(Measured deviation)
	⩽ 500	⩽ 1 000	⩽ 2 000	
Axes up to 2 000 mm				
Bidirectional accuracy of positioning, A	0,020	0,025	0,032	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	0,008	0,010	0,013	
Reversal value of the axis, B	0,010	0,013	0,016	
Bidirectional systematic deviation of positioning, E	0,016	0,020	0,025	
Range of the mean bidirectional positional deviation of the axis, M	0,010	0,013	0,016	
Axes exceeding 2 000 mm				
Bidirectional systematic deviation, E	0,025 + 0,005 for each additional 1 000			
Range of the mean bidirectional positional deviation of the axis, M	0,016 + 0,003 for each additional 1 000			
Reversal value of the axis, B	0,016 + 0,003 for each additional 1 000			

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

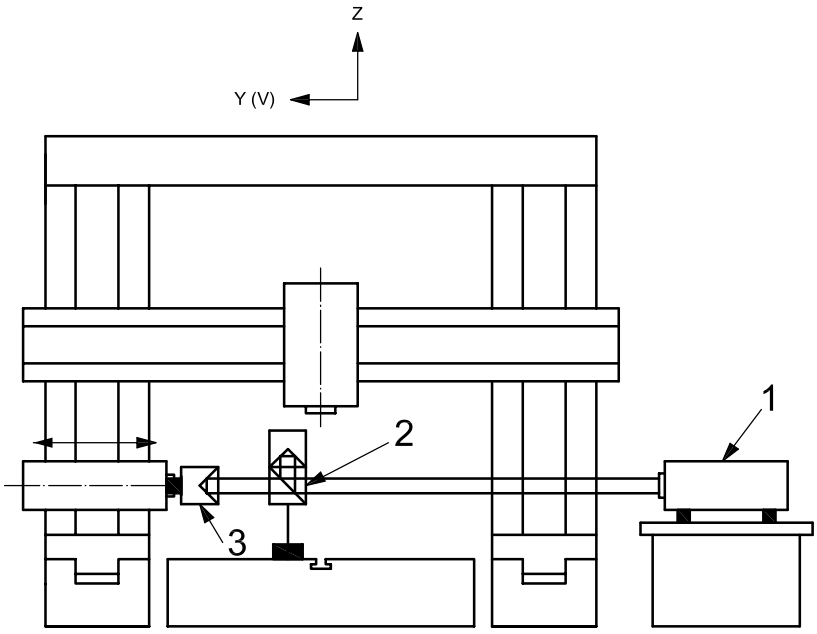
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Z-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the horizontal milling head and the interferometer on the table.

Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to. The starting point of measurement shall be stated.

Object **P5**

Checking of accuracy and repeatability of the V-axis movement of the horizontal milling head or quill.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance	Measured length		(Measured deviation)
	⩽ 500	⩽ 1 000	
Axes up to 2 000 mm			
Bidirectional accuracy of positioning, A	0,020	0,025	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	0,008	0,010	
Reversal value of the axis, B	0,010	0,013	
Bidirectional systematic deviation of positioning, E	0,016	0,020	
Range of the mean bidirectional positional deviation of the axis, M	0,010	0,013	

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

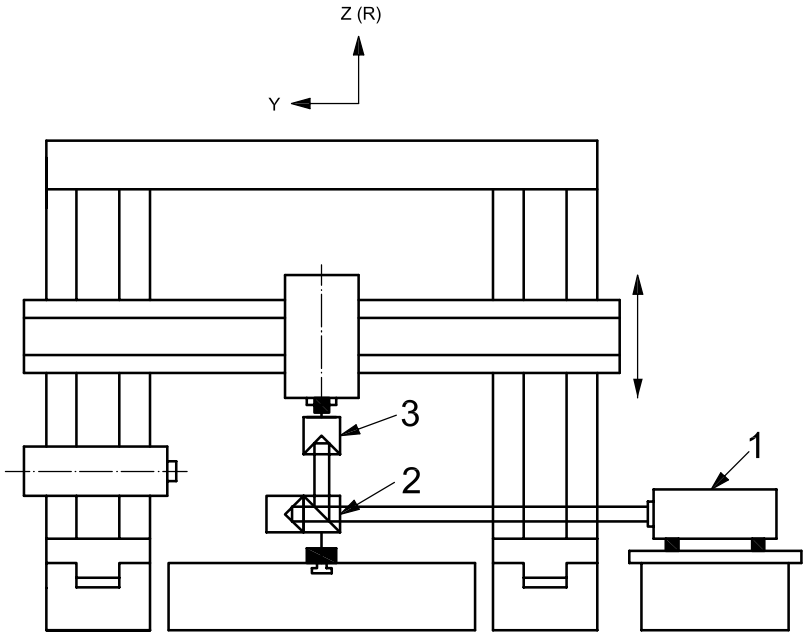
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Y-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the horizontal milling head and the interferometer on the table.

Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to.

Object **P6**

Checking of accuracy and repeatability of the R-axis movement of the cross-rail when numerically controlled.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance	Measured length			(Measured deviation)
	⩽ 500	⩽ 1 000	⩽ 2 000	
Axes up to 2 000 mm				
Bidirectional accuracy of positioning, A	0,020	0,025	0,032	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	0,008	0,010	0,013	
Reversal value of the axis, B	0,010	0,013	0,016	
Bidirectional systematic deviation of positioning, E	0,016	0,020	0,025	
Range of the mean bidirectional positioning deviation of the axis, M	0,010	0,013	0,016	
Axes exceeding 2 000 mm				
Bidirectional systematic deviation, E	0,025 + 0,005 for each additional 1 000			
Range of the mean bidirectional positional deviation of the axis, M	0,016 + 0,003 for each additional 1 000			
Reversal value of the axis, B	0,016 + 0,003 for each additional 1 000			

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Z-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the vertical milling head and the interferometer on the table.

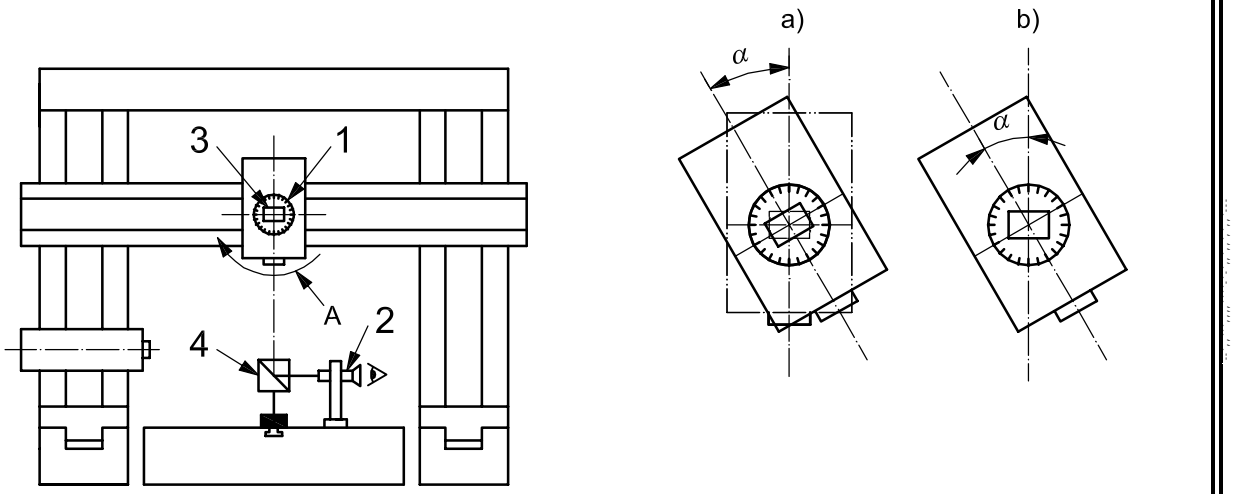
Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to.

9.2 Rotary axes

Object **P7**

Checking of accuracy and repeatability of the A-axis movement of the vertical milling head.

Diagram



Key

1 master index table
2 autocollimator
3 mirror
4 beam bender

Tolerance (in arc seconds)	**Measured angle**		**(Measured deviation)**
	⩽ 90°	⩽ 180°	
Bidirectional accuracy of positioning, A	12	16	
Unidirectional repeatability of positioning, $R\uparrow$ or $R\downarrow$	5	6	
Bidirectional systematic deviation of positioning, E	10	13	
Reversal value of the axis, B	6	8	

Measuring instruments

Polygon with autocollimator or master index table with mirror and autocollimator or master index table with angle interferometer

Observations and references to ISO 230-2

When a master index table is used, set it on the swivelling head so that its rotation axis is parallel and near to the rotation axis of the head. Rotate the head by an indexable angle [a)] and then rotate back the index table [b)] so that the mirror comes back to its original position, and check the angular deviation.

Concerning the test conditions, test programme and presentation of results, ISO 230-2:2006, Clauses 3, 4 and 7 shall be referred to.

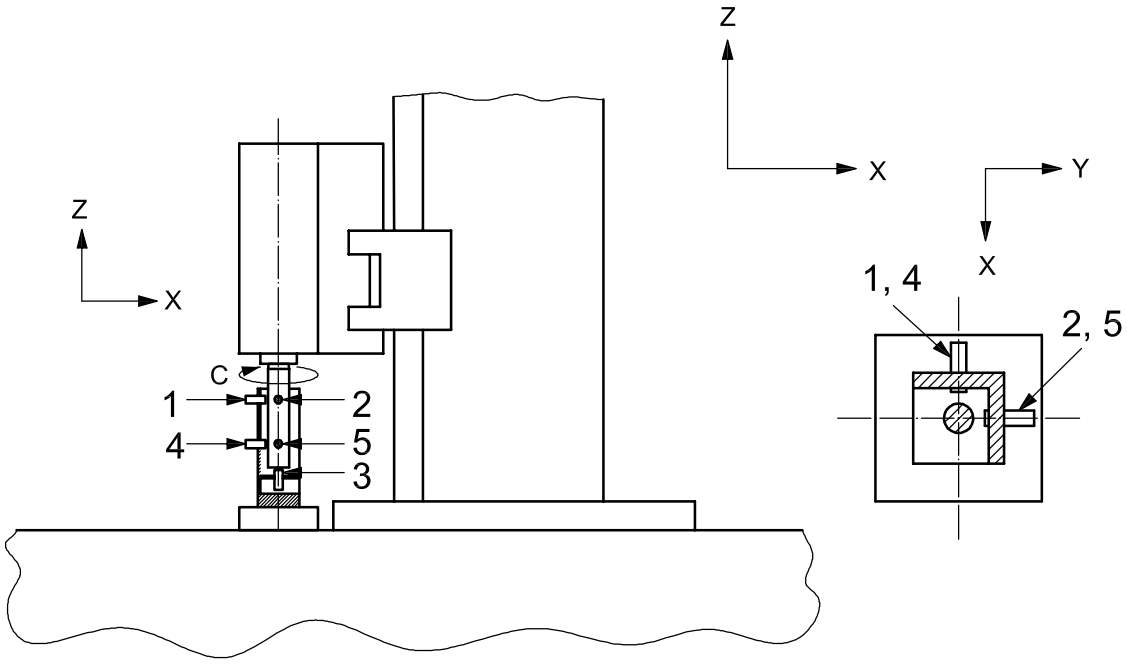
10 Geometric accuracy of axes of rotation of toolholding spindles

Object **R1**

Axis of rotation error motion for toolholding spindle (C1):

a) radial error motion (ERC);
b) axial error motion (EZC);
c) tilt error motion (ETC).

Diagram



Key

1 to 5 linear displacement sensors (probes). (See Observations)

Tolerance	at percentage of maximum speed			**Measured deviation**
	10 %	50 %	100 %	
a) total radial error motion value ERC	0,010	0,014	0,020	
b) total axial error motion value EZC	0,010	0,014	0,020	
c) total tilt error motion value ETC	0,040/1 000	0,060/1 000	0,080/1 000	

If the minimum speed is larger than 10 % of the maximum speed, then the spindle should be operated at minimum speed.

Measuring instruments

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

Observations and references to ISO 230-7:2006

This test is a spindle test with rotating sensitive direction (5.4 of ISO 230-7:2006).

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

Total error motion is defined in 3.2.4 of ISO 230-7:2006; total error motion value is defined in F.3.4 of ISO 230-7:2006. Measurements shall be carried out as follows:

a) total radial error motion value ERC (using probes 1 and 2)

Radial error motion measurement is described in 5.4.2 of ISO 230-7:2006. The radial error motion shall be measured as close as possible to the spindle nose (sensors 1 and 2 in the diagram of this test).

For the radial error motion ERC, a total error motion polar plot (3.3.1 of ISO 230-7:2006) with a least squares circle (LSC) centre (3.4.3 of ISO 230-7:2006) shall be provided.

b) total axial error motion value EZC (using probe 3)

Axial error motion measurement is described in 5.4.4 of ISO 230-7:2006.

For the axial error motion EZC, a total error motion polar plot (3.3.1 of ISO 230-7:2006) with a polar chart (PC) centre (3.4.1 of ISO 230-7:2006) shall be provided.

c) total tilt error motion values ETC (using probes 1,2,4,5)

Tilt error motion measurement is described in 5.4.3 of ISO 230-7:2006. The tilt error motion can also be checked with just two non-contacting probes (see 5.4.2.1 and 5.4.2.2 of ISO 230-7:2006).

For the tilt error motion ETC, a total error motion polar plot (3.3.1 of ISO 230-7:2006) with a PC centre (3.4.1 of ISO 230-7:2006) shall be provided.

For these tests the following parameters shall be stated:

- radial, axial or face locations at which the measurements are made;
- identification of all artifacts, targets and fixtures used;
- location of the measurement set-up;
- position of any linear or rotary positioning stages that are connected to the device under test;
- direction angle of the sensitive direction, e.g. axial, radial or intermediate angles as appropriate;
- presentation of the measurement result, for example error motion value, polar plot, time-based plot, frequency content plot;
- rotational speed of the spindle (zero for static error motion);
- time duration, expressed in seconds or number of spindle rotations;
- appropriate warm-up or break-in procedure;
- frequency response of the instrumentation, expressed in hertz or cycles per revolution, including roll-off characteristics of any electronic filters. In the case of digital instrumentation, state the displacement resolution and sampling rate;
- structural loop, including the position and orientation of sensors relative to the spindle housing from which the error motion is reported, specified objects with respect to which the spindle axes and the reference coordinate axes are located, and the elements connecting these objects;
- time and date of measurement;
- type and calibration status of all measurement instrumentation;
- other operating conditions which may influence the measurement, such as ambient temperature.

Bibliography

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

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