INTERNATIONAL STANDARD

ISO 8636-1

Second edition
2000-02-15

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

Part 1: Fixed bridge (portal-type) machines

Machines-outils — Conditions d'essai des machines à fraiser à portique — Contrôle de la précision —

Partie 1: Machines à portique fixe

Reference number
ISO 8636-1:2000(E)

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Printed in Switzerland

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Foreword

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

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

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

Attention is drawn to the possibility that some of the elements of this part of ISO 8636 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 8636-1 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 8636-1:1987) of which it constitutes a technical revision. Especially,

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

ISO 8636-1:1999	6	7	8	9	10	11	12	13	14	15	16
ISO 8636-1:1987	9	6	5	1	4&7	3	14	13&15	16	12	11

b) the following extra modifications:

   addition of notes in “Object” boxes for G6, G12, G13, G14 and G15; these notes have 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 according to ISO 230-2:1997.

   The actual deviations of all parameters shall be 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 (Gartry-type) machines*

Annex A of this part of ISO 8636 is for information only.

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

Part 1:
Fixed bridge (portal-type) machines

1 Scope

This part of ISO 8636 specifies, with reference to ISO 230-1 and ISO 230-2, 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 fixed bridge (portal 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 moving tables and fixed double columns. It does not include single-column (open sided) machines and those with fixed tables and moving columns.

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 machine and the designation of the axes with reference to ISO 841[1].

NOTE In addition to terms used in the three official ISO languages (English, French and Russian), annex A of this part of ISO 8636 gives the equivalent terms in the German and Italian languages; these are published under the responsibility of the member bodies for Germany (DIN) and Italy (UNI). However, only the terms given in the official languages can be considered as ISO terms.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 8636. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 8636 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 230-2:1997, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning of numerically controlled axes.*

3 Definitions and descriptions

For the purposes of this part of ISO 8636, the following definitions apply.

3.1 Definitions of the machining processes that can be carried out

3.1.1
milling operation
machining operation which consists of removing material by means of a rotary tool called a “milling cutter” of which there are several different types

NOTE The 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.

3.1.2
boring operation
operation which consists of machining the diameters of cylindrical, conical, blind or through holes, to the required size

3.1.3
drilling and tapping operations
operations which consist of drilling and/or tapping blind or through holes

3.2 Definition and classification of fixed bridge-type milling machines

3.2.1 Definition

3.2.1.1
fixed bridge-type (portal-type) milling machine
double-column machine with one or more vertical spindle heads mounted on the cross-rail, above a table which has a longitudinal traverse (X-axis) only

NOTE Additional horizontal spindle heads may be mounted on the columns. The horizontal spindle axes may have a tilting capability.

3.2.2 Classification

These machines are classified into two types depending upon their construction:

— bridge-type milling machines with a variable height cross-rail and a bridge or tie-piece between the columns;

— bridge-type milling machines with a fixed height cross-rail which may replace the bridge or tie-piece.

3.3 Descriptions of principal components

The principal components of these machines are described below. The number indicated in brackets is shown and explained in 4.1.

3.3.1 Bed and table

The bed (1) is the fixed base of the machine which may be constructed of several parts. It supports the table (3) which moves parallel to the major axis of the bed.

3.3.2 Column, cross-rail and bridge or tie-piece

The columns (4) and (5) provide the vertical frame of the machine and are fixed on either side of the bed.

The columns may be fitted with vertical slideways to accommodate side milling head(s) (9) with other horizontal or tilting spindle axis.

The tie-piece (10) is a fixed piece connecting both columns at or near the top.

The cross-rail (7) has its major axis parallel to the table plane and is fitted with slideways on which one or more milling heads (8), with vertical or inclinable spindles, can move.

The variable height cross-rail may be moved up and down the vertical slideways (6) on the columns.

In the case of machines with a fixed height cross-rail, the latter is also fastened to the columns and may replace the tie-piece.

3.3.3 Milling head(s)

These heads include the spindle and drive mechanism and the means for their mounting on the cross-rail or column. In some cases, the spindle may be mounted in a ram or quill (12) with a feed motion for drilling or boring operations.

3.3.4 Cutting motion

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

3.3.5 Feed motion

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

— horizontal movement of the table;

— horizontal movement of the milling heads on the cross-rail or vertical movement of the side heads;

— vertical movement of spindle rams or quills (if any).

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

NOTE 2 The vertical movement of the cross-rail (if any) is usually a positioning movement.

4 Terminology and designation of axes

4.1 Terminology

See Figure 1 and Table 1.

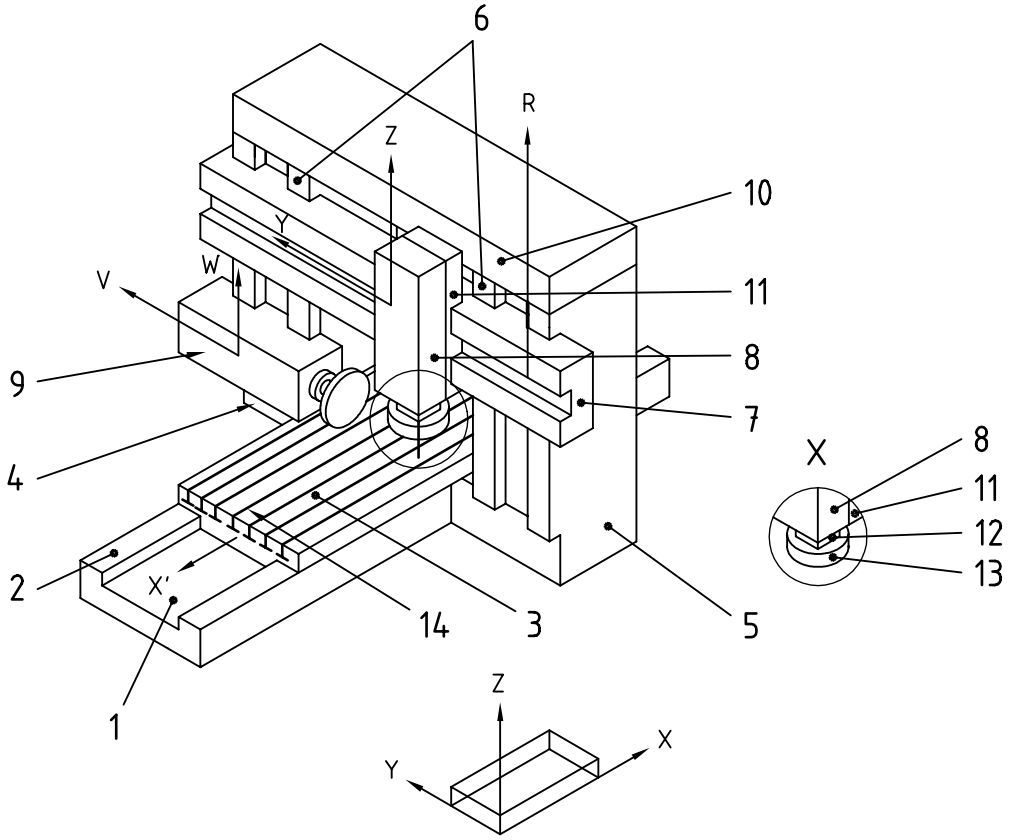


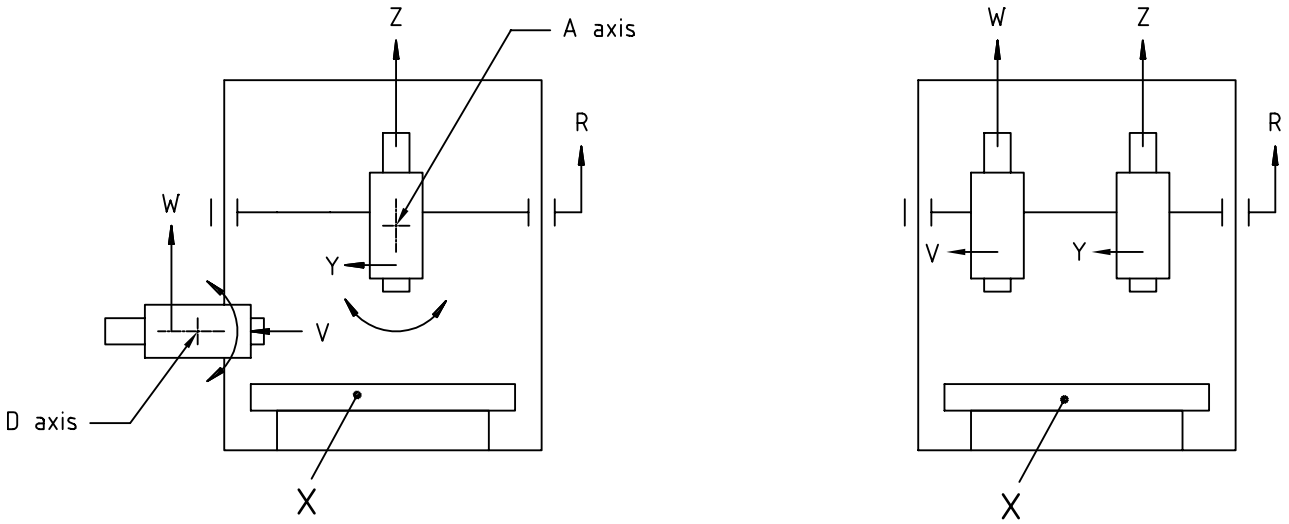
Figure 1 — Fixed bridge- (portal-) type milling machine with variable height cross-rail

Table 1 — Terminology

Ref.	English	French	Russian
1	Bed	Banc	Станина
2	Slideway, bed	Glissière du banc	Направляющая станины
3	Table (clamping surface)	Table (surface de bridage)	Стол (рабочая поверхностъ)
4	Left-hand column	Montant gauche	Левая стойка
5	Right-hand column	Montant droit	Правая стойка
6	Slideway, right-hand and left-hand column	Glissière des montants droit et gauche	Направляющая левой и правой стоек
7	Cross-rail (movable, fixed)	Traverse (mobile, fixe)	Траверса (подвижная, неподвижная)
8	Vertical milling head	Tête de fraisage verticale	Головка вертикально-фрезерная
9	Horizontal milling head	Tête de fraisage horizontale	Головка горизонтально-фрезерная
10	Tie-piece	Entretoise	Поперечная балка
11	Bottom slide (saddle)	Cuirasse	Каретка суппорта
12	Quill (ram)	Coulisseau (fourreau)	Ползун (втулка)
13	Tool (milling cutter)	Outil (fraise)	Инструмент (фреза)
14	Reference T-slot	Rainure de référence	Базовый паз

4.2 Designation of axes

See Figures 2 to 5.



a) One spindle milling head tilting on the A-axis, placed on the cross-rail, and one spindle milling head tilting on the D-axis, placed on the right- or left- hand column

b) Two milling heads on the cross-rail

Figure 2 — Type 1: Machines with two milling heads

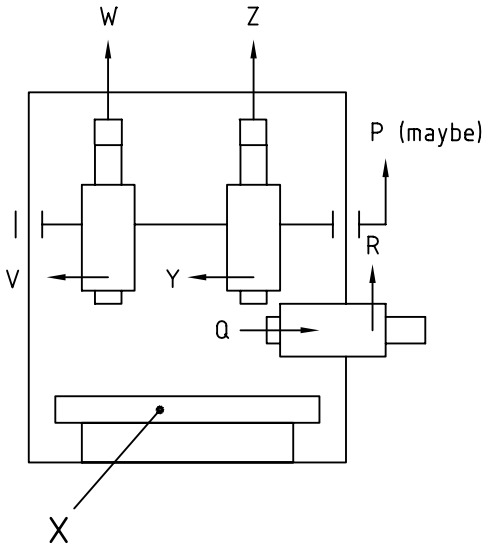


Figure 3 — Type 2: Machine with three milling heads

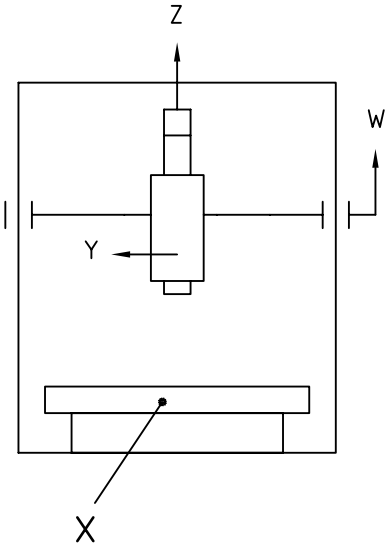


Figure 4 — Type 3: Machine with one milling head on the cross-rail

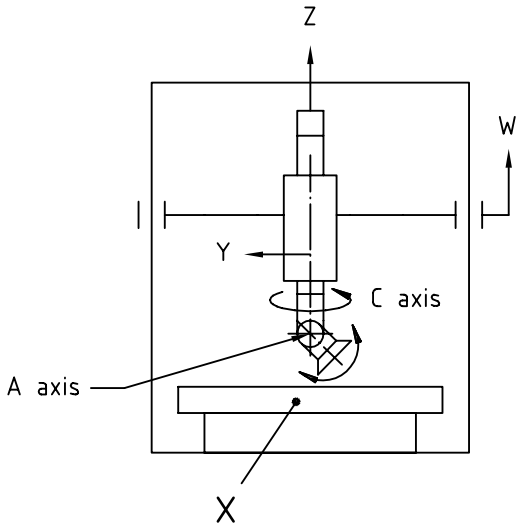


Figure 5 — Type 4: Machine with one milling head on the cross-rail swivelling on axes C and A

5 Preliminary remarks

5.1 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 or arcseconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind:

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

5.2 Reference to ISO 230-1

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 in cases where the test concerned is in compliance with the specifications of ISO 230-1.

5.3 Temperature conditions

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

5.4 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 make the mounting of instruments or gauging easier, tests may be performed in any order.

5.5 Tests to be performed

When testing a machine, it is not always necessary nor possible to carry out all the tests described in this part of ISO 8636. 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 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.

5.6 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 at least the same accuracy may be used.

5.7 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.

5.8 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.

5.9 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.

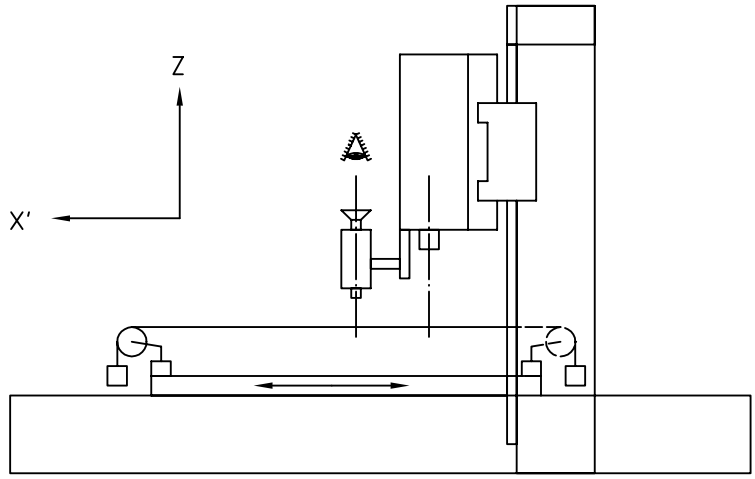
6 Geometric tests

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

6.1 Coordinate axes of motion

Object	**G1**
Checking of straightness of movement of the table (X-axis) in the horizontal XY-plane (EYX).	

Diagram



Tolerance	**Measured deviation**
0,02 for a 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 and taut wire or other optical methods

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

When using microscope and taut wire, the microscope shall be mounted on the head, and the taut wire shall be fixed to each end of the table parallel [1)] to X-axis movement of the table.

Traverse the table in the X-direction and note the readings.

When using optical methods, the target shall be set on the spindle nose or on the head near the spindle.

The reticle is set on the table parallel to X-axis movement of the table and aligned with the target horizontally.

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

1) Parallel means: Readings of the telescope or reticle at both ends of the movement are the same. In this case, the maximum difference of the readings gives the straightness deviation.

Object **G2**

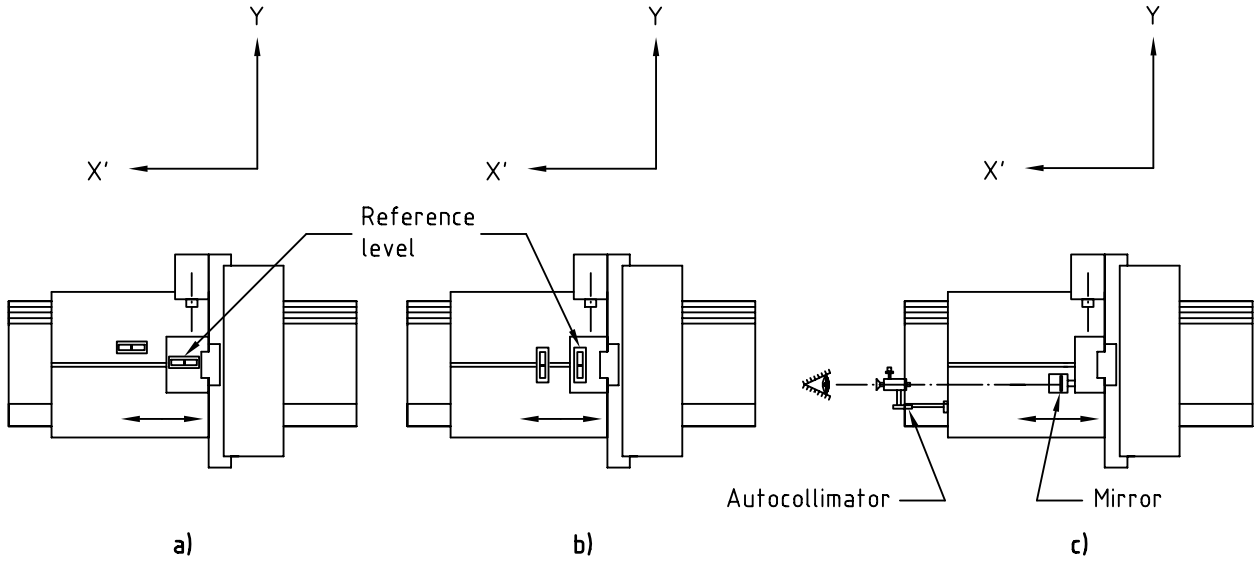
Checking of angular deviations of the movement of the table (X-axis):

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

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

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

Diagram



Tolerance

	a) and c)	b)
$X \leqslant 4\,000$	0,04/1 000	0,02/1 000
$X > 4\,000$	0,06/1 000	0,02/1 000

Local tolerance: 0,02/1 000 for any measuring length of 1 000

Measured deviation

X = . . .

a)

b)

c)

Measuring instruments

a) Precision level or optical angular deviation measuring instruments

b) Precision level

c) 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.

When 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.

When differential measurement is applied, the reference level should be placed on the spindle head, and the spindle head 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 reading shall not exceed the tolerance.

For tests a) and b), the instrument shall be placed at the two ends and possibly in the middle of the table. The instrument located at one end of the table explores the characteristics of half of the bed.

The instrument located in the middle of the table reveals different deviations from the ones located at both ends of the table.

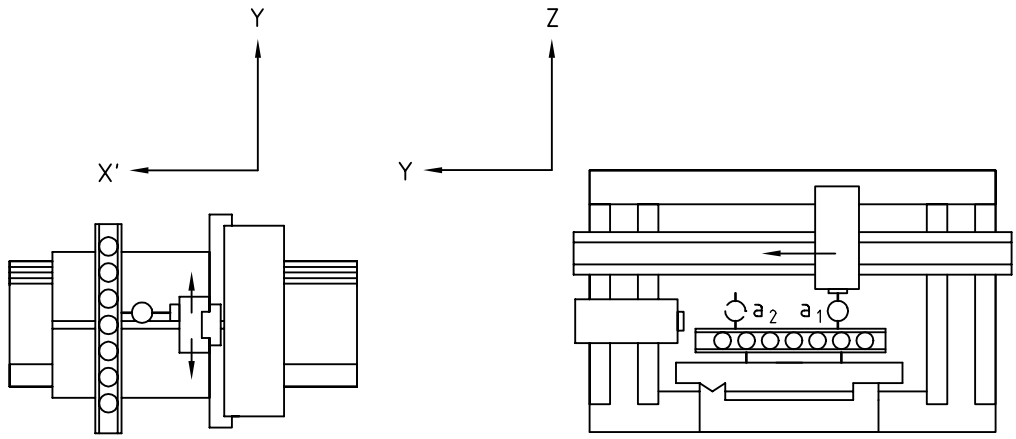
Object **G3**

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

a) in the horizontal XY-plane (EXY);

b) in the vertical YZ-plane (EZY).

Diagram



a) b)

Tolerance	**Measured deviation**
For a) and b)	a)
0,02 for a measuring length up to 1 000	b)
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, dial gauge/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 table in mid-travel.

Place a straightedge on the table, parallel[1)] to the Y-axis movement of the milling head; for a) horizontally and for b) vertically.

Attach a dial gauge to the milling head. The dial gauge stylus shall be normal to the reference face of the straightedge.

Traverse the milling head in the Y-direction through the measuring length[2)] and record the readings.

---

1) Parallel means: Readings of the dial gauge touching the straightedge at both ends of the movement are the same value and, in this case, the maximum difference of the readings gives the straightness deviation.

2) 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**

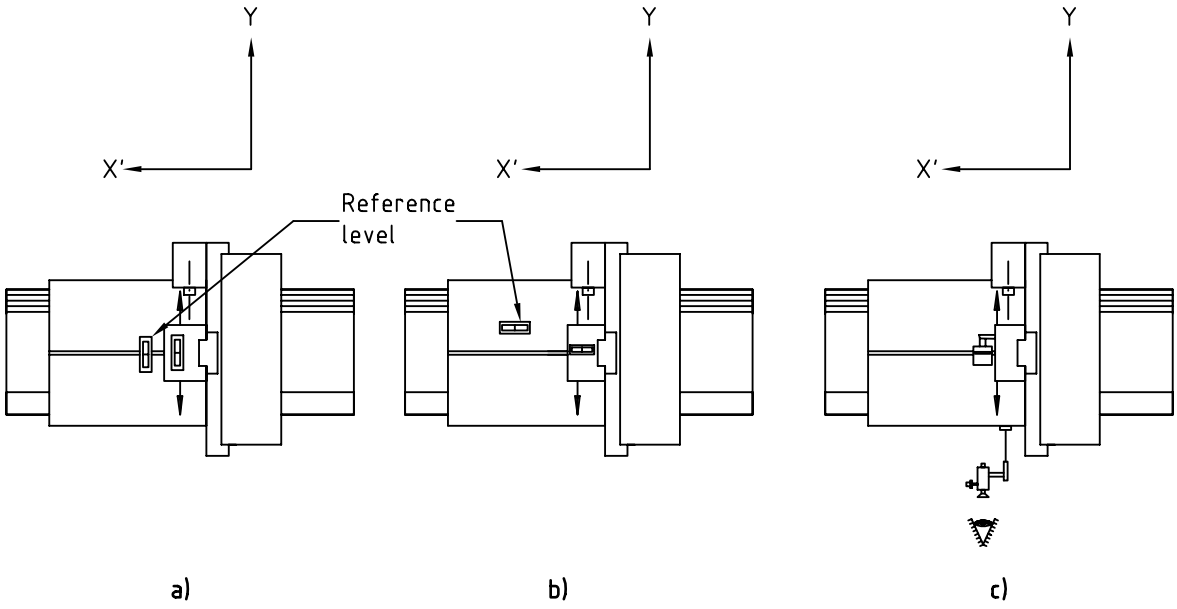
Checking of angular deviations of the horizontal movement of the milling head (Y-axis):

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

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

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

Diagram



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

Measuring instruments

a) Precision level or optical angular deviation measuring instruments

b) Precision level

c) 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.

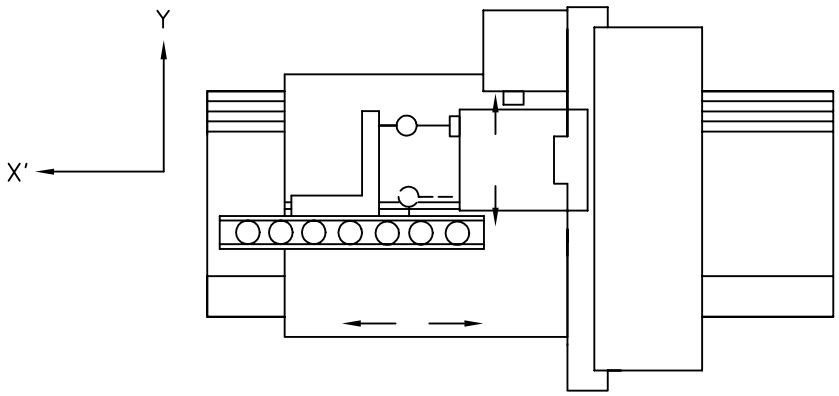
When differential measurement is applied, the reference level should be placed on the work-holding table, and the table shall be in the middle of its travel range.

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 reading shall not exceed the tolerance.

Object	**G5**
Checking of squareness between the movement of the table (X-axis) and the horizontal movement of the milling head (Y-axis).	

Diagram



Tolerance	**Measured deviation**
0,03 for a measuring length of 1 000 up to a table width of 3 000 NOTE In the case of a table width beyond 3 000 mm, the tolerance is subject to agreement between the supplier/manufacturer and user.	

Measuring instruments

Straightedge, square and dial gauge

Observations and references to ISO 230-1:1996 5.522.4

Lock the cross-rail in mid-travel.

Attach a dial gauge to the milling head. Align a straightedge parallel[1)] to the table movement (X-axis) in the horizontal plane.

Press one edge of the square against the straightedge and set the dial gauge against the other edge of the square. Move the milling head by the measuring length[2)] and read indications at a minimum of five equally spaced positions. Record the maximum difference of the readings.

For more precise measurement, rotate the square by 180° and repeat the checking in the same order.

Calculate the average value at each measuring position, and record the maximum difference.

If the table width exceeds 2 000 mm, tests shall be repeated at different positions across the table width.

---

1) Parallel means: Readings of the dial gauge touching the straightedge at both ends of the movement are the same value and, in this case, the maximum difference of the readings gives the straightness deviation.

2) The measuring length is normally the length between two columns (not the full length of cross-rail). In other cases, it shall be agreed upon between the supplier/manufacturer and user.

Object	**G6**

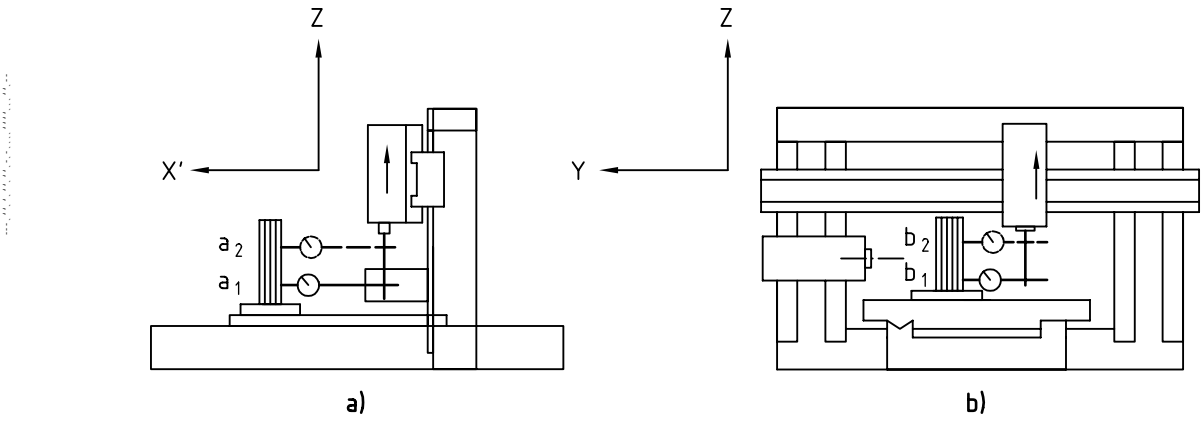
Checking of squareness between the vertical movement of the milling head (Z-axis) and

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

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

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

Diagram



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

Measuring instruments

Cylindrical square, surface plate, adjustable blocks and dial gauge

Observations and references to ISO 230-1:1996 5.522.4

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

Attach a dial gauge to the milling spindle when the spindle can be locked, otherwise to the milling head near the spindle and lock the milling head saddle (Y-axis) to the cross-rail.

Apply the stylus of the dial gauge to the cylindrical square in the X-direction and move the head through the measuring length a_1 a_2 and record the maximum difference of dial gauge readings.

For more precise measurement, rotate the cylindrical square by 180^o and repeat the checking in the same order. Calculate the average value at each measuring position and record the maximum difference.

Check subsequently in the Y-direction over the measuring length b_1 b_2.

For a large machine, the check may be made in the mid-position and in two extreme positions of the cross-rail.

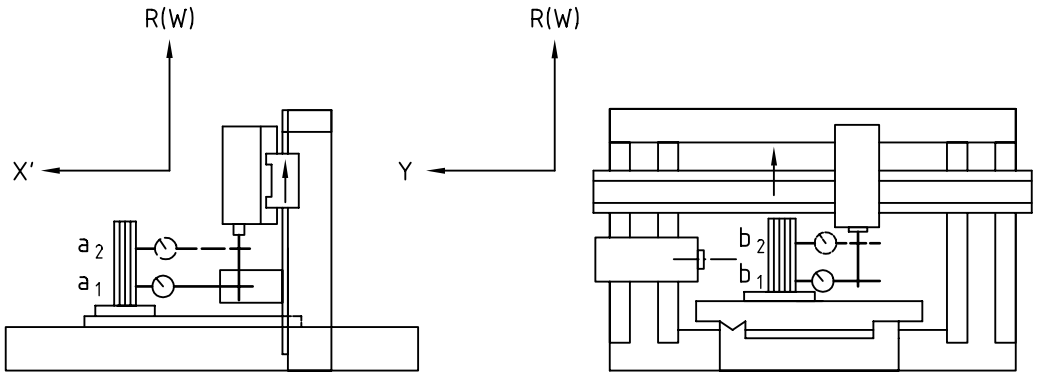
Object	**G7**

Checking of squareness between the vertical movement of the cross-rail (W- or R- axis) and

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

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

Diagram



Tolerance	**Measured deviation**
For a) and b)	a)
0,02 for a measuring length of 500	b)

Measuring instruments

Dial gauge, cylindrical square, surface plate and adjustable blocks

Observations and references to ISO 230-1:1996 5.522.4

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

Attach a dial gauge to the milling spindle when the spindle can be locked, otherwise to the milling head near the spindle and lock the milling head (Y-axis) to the cross-rail.

Apply the stylus of the dial gauge to the cylindrical square in the X-direction and move the cross-rail through the measuring length a_1 a_2 and record the maximum difference of dial gauge readings.

For more precise measurement, rotate the cylindrical square by 180^o and repeat the checking in the same order. Calculate the average value at each measuring positions and record the maximum difference.

Check subsequently in the Y-direction over the measuring length b_1 b_2.

For a large machine, the check may be made in the mid-position and in two extreme positions of the cross-rail.

Object	**G8**

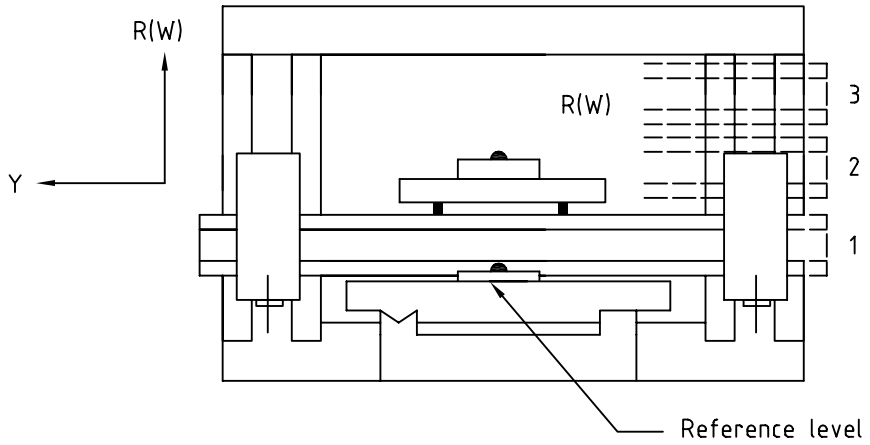
Checking of slope variation of the cross-rail in its W- or R-axis movement in the vertical YZ-plane:

a) in the lower position;

b) in the mid-position;

c) in the higher position.

Diagram



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 postions.

When W- or 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, and the table shall be in the middle of the travel range.

Place milling heads symmetrically relative to the machine table.

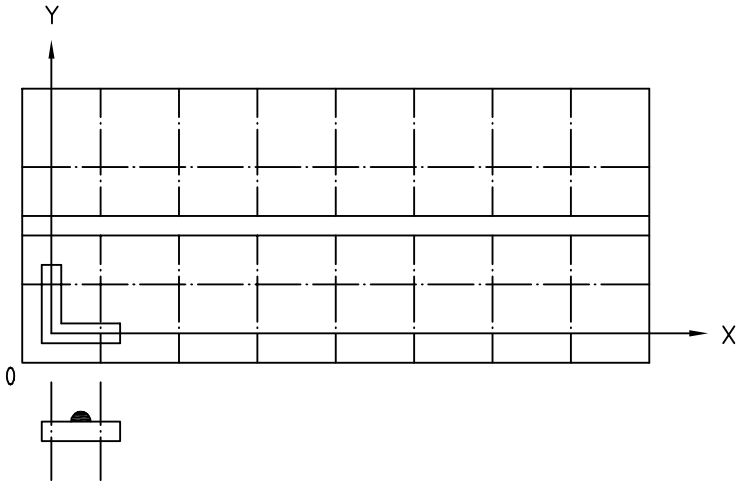
For machines with only a single milling head, it shall be placed in a central position.

Lock the cross-rail at each position.

6.2 Table

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

Diagram



Tolerance	**Measured deviation**
For Y $\leqslant$ 3 000 and X $\leqslant$ 1 000 0,02 for a measuring length up to 1 000 Add 0,01 to the preceding tolerance for each 1 000 increase in length Maximum tolerance: 0,1	

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

Table 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 mm) in the direction concerned, and record readings.

Test method G10 is also useful for the checking of flatness.

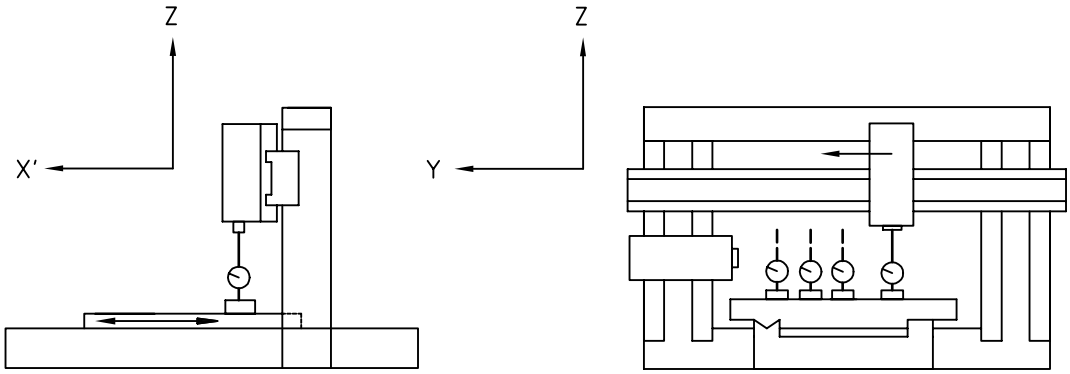
Object **G10**

Checking of parallelism of the table surface to

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

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

Diagram



Tolerance	**Measured deviation**
For a) and b)	a)
0,020 for a measuring length up to 2 000	b)
Add 0,005 to the preceding tolerance for each 1 000 increase in length	
Maximum tolerance: 0,05	

Measuring instruments

Dial gauge, straightedge and gauge blocks

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

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

a) The cross-rail is locked at mid-height. The milling head is at mid-travel. Traverse the table 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.

b) The cross-rail is locked. The table is at mid-travel. Move the milling head in the Y-direction and record the maximum difference of the readings.

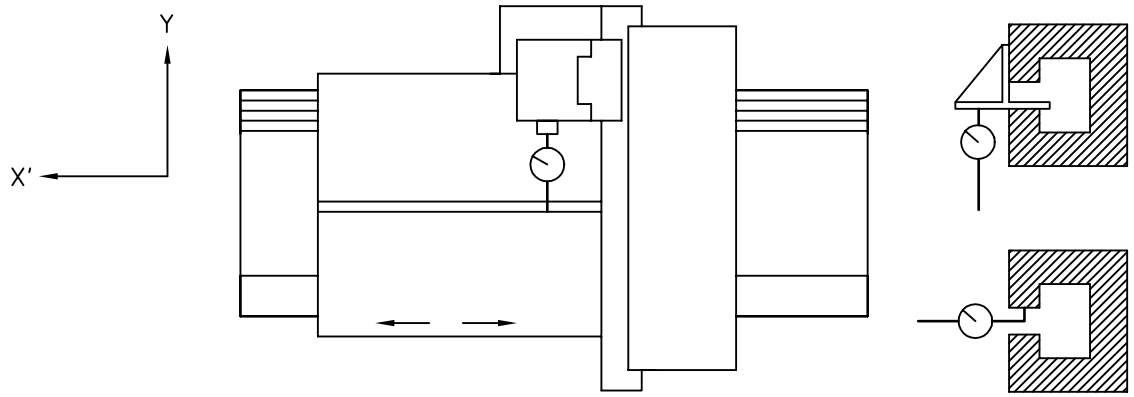
Repeat the test in two other positions symmetrical to the previous position and record the maximum differences of the reading in the same way.

The largest of the maximum differences gives the parallelism deviation.

NOTE The above tolerances are specified assuming that finished machining is carried out after assembly. If this is not the case, the tolerances shall be agreed upon between the supplier/manufacturer and user.

Object	**G11**
Checking of the parallelism of median or reference T-slot to the movement of the table (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 mm	

Measuring instruments

Dial gauge, cross-square

Observations and references to ISO 230-1:1996 5.422.21

Attach a dial gauge to a fixed part of the machine. Place the gauge stylus in contact with the measuring face of the reference T-slot or use a piece of suitable shape.

Move the table and record the dial gauge indicator variation.

6.3 Milling spindle

Object **G12**

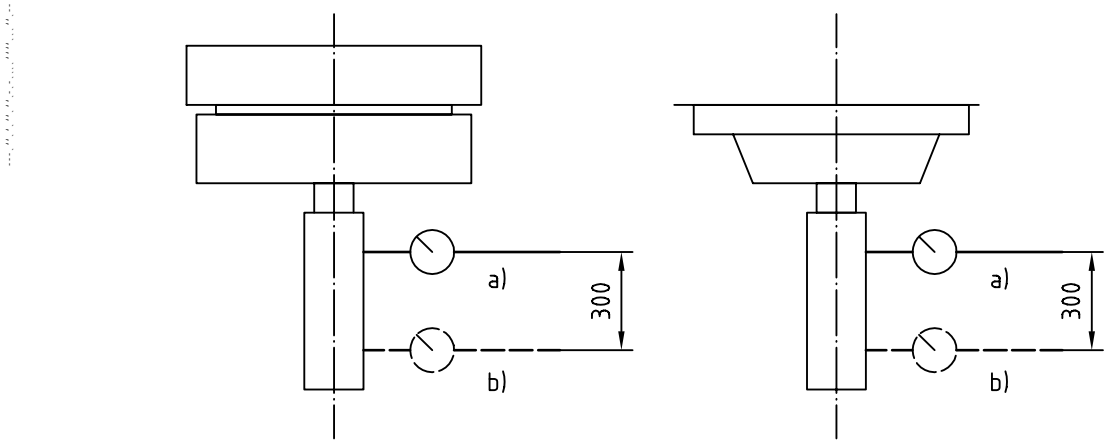
Checking of run-out of internal taper of the milling spindle:

a) at the spindle nose;

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

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

Diagram



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

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

Measuring instruments

Dial gauge and test mandrel

Observations and references to ISO 230-1:1996 5.612.3

Attach a dial gauge to the milling head and insert the test mandrel in the spindle.

Place the dial gauge 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).

Object **G13**

Checking of the milling spindle:

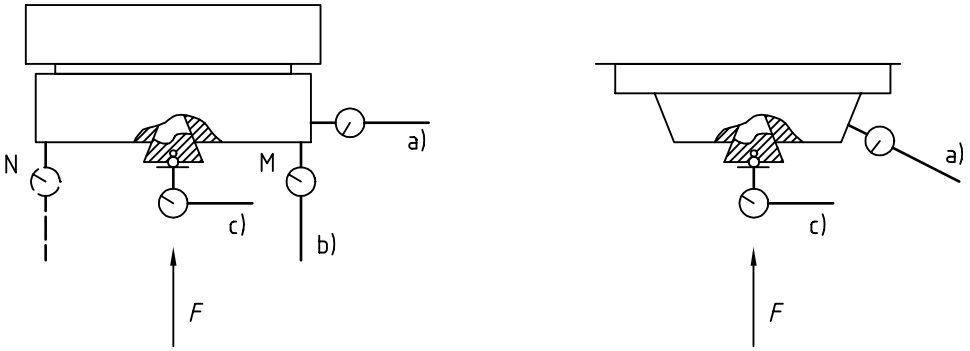
a) run-out of external surface;

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

c) periodic axial slip.

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

Diagram



Tolerance

	$D \leqslant 200$	$D > 200$
a)	0,010	0,015
b)	0,015	0,020
c)	0,010	0,015

where D = external diameter of the spindle-nose face.

Measured deviation

D = . . .

a)

b)

c)

Measuring instruments

Dial gauge

Observations and references to ISO 230-1:1996

Attach a dial gauge support and a dial gauge to the milling head or fixed part of the machine.

a) 5.612.2
Place the dial-gauge stylus normal to the generating line, rotate the milling spindle and record the indication.

b) 5.632
Place the dial-gauge stylus as close as possible to 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 dial gauge.
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 dial-gauge 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.

Object **G14**

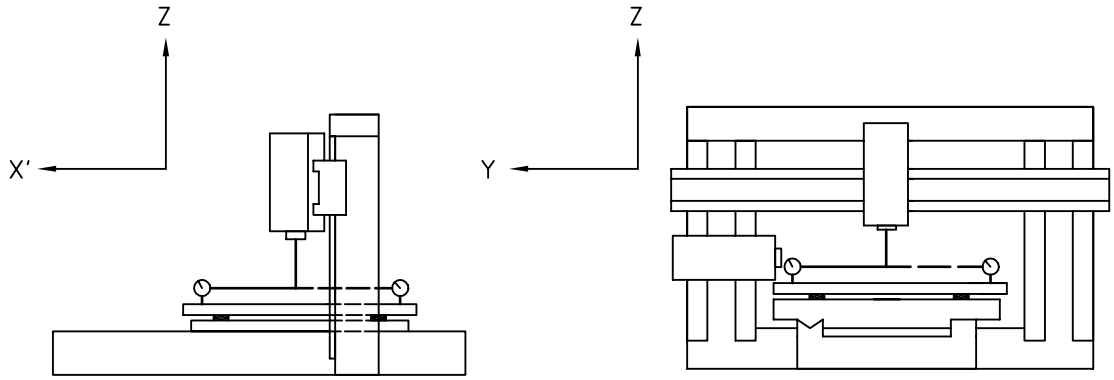
Checking of squareness between the vertical milling spindle axis of rotation and

a) the X-axis movement of the table;

b) the Y-axis movement of the spindle head.

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

Diagram



a) b)

Tolerance	**Measured deviation**
0,04/1 000 [1)]	

1) Distance between the two measuring points touched.

Measuring instruments

Dial gauge/support arm and straightedge or surface plate

Observations and references to ISO 230-1:1996 5.512.32

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

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

Attach the supporting arm with dial gauge to the milling spindle and adjust the stylus of the dial gauge to touch the straightedge and record the indication. Then rotate the spindle by 180° and record the new indication. Calculate the difference between the two readings divided by the distance between the two measurement points.

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

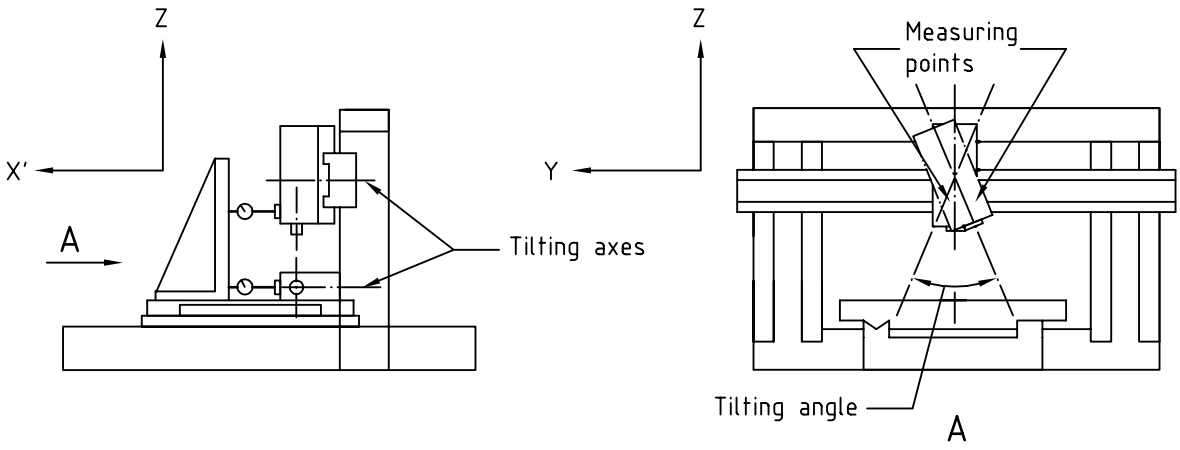
6.4 Swivelling milling head

Object **G15**

Checking of parallelism of the milling-head swivel axis to the table (X-axis) movement when the milling head swivels.

NOTE This test shall be applied to the horizontal swivelling milling head also.

Diagram



Tolerance	**Measured deviation**
For dial gauge placed at 500 mm from the milling-head tilting axis 0,02 for $\alpha \leqslant 10°$ 0,03 for $10° < \alpha \leqslant 20°$ 0,04 for $\alpha > 20°$	α = . . .

Measuring instruments

Square, surface plate, adjustable blocks and dial gauge

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.

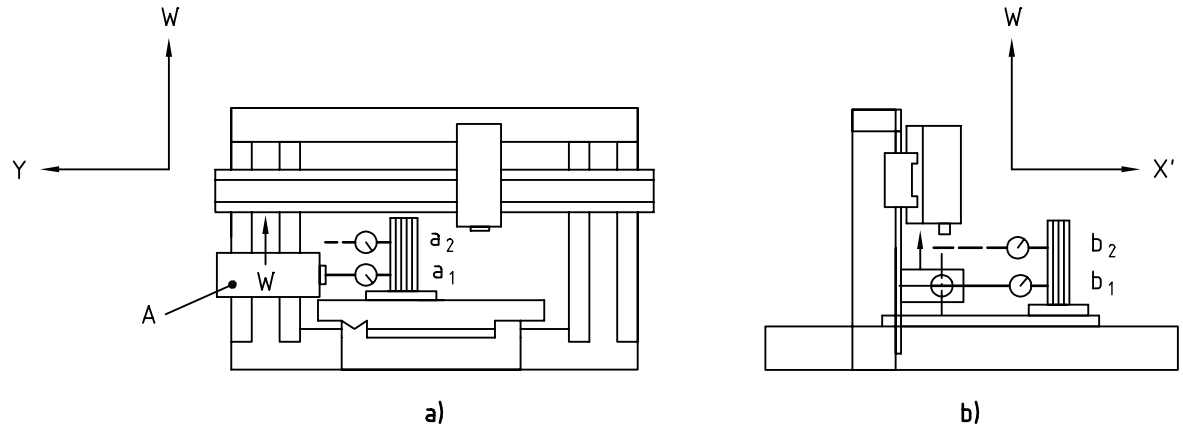
Attach a dial gauge to the milling head so that the stylus of a dial gauge is 500 mm from the milling-head swivel axis.

Apply the stylus of the dial gauge to the flat-square face in the X-direction, rotate the milling head and record readings.

6.5 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 a) the movement of the vertical milling head (Y-axis); b) the movement of the table (X-axis).	

Diagram



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

Measuring instruments

Cylindrical square, surface plate, adjustable blocks and dial gauge

Observations and references to ISO 230-1:1996 5.522.4

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

Attach a dial gauge/support to the milling head A.

a) Apply the stylus of the dial gauge to the cylindrical square in the Y-direction, then move the milling head A through the measuring length a_1a_2 and record the maximum difference of dial gauge readings. For more precise measurements, rotate the cylindrical square by 180° and repeat the checking in the same order. Calculate the average value at each measuring position and record the maximum difference.

b) Check subsequently in the X-direction through the mesuring length b_1b_2.

Object	**G17**

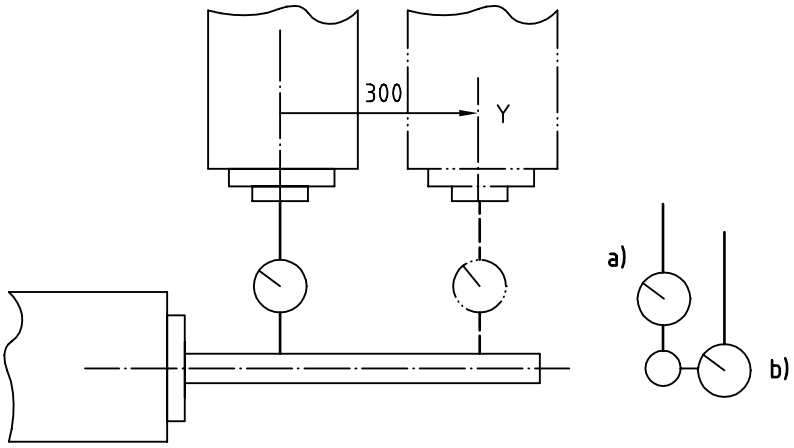
Checking of parallelism of the horizontal milling-spindle axis to the horizontal movement of the vertical milling head (Y-axis)

a) in the vertical YZ-plane;

b) in the horizontal XY-plane.

(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)	a)
0,03 for a measuring length of 300	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1:1996 5.422.3

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

Attach a dial gauge to the vertical milling head and adjust the stylus of the dial gauge to touch the test mandrel mounted on the horizontal milling spindle, a) vertically, b) horizontally, as near as possbile to the spindle nose.

Move the vertical milling head for the measuring length and record the indications.

Record the maximum difference of dial gauge readings.

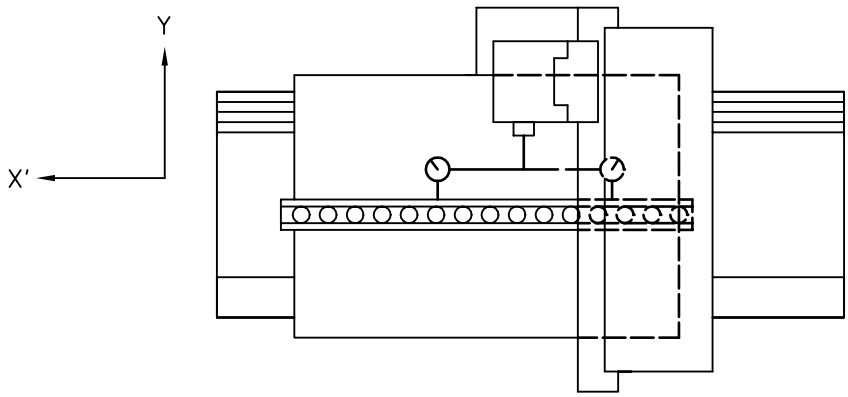
Tests shall be done at the mean position of the spindle rotation for both a) and b).

Object **G18**

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

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

Diagram



Tolerance	**Measured deviation**
0,04/1 000 [1)]	

1) Distance between the two measuring points touched.

Measuring instruments

Straightedge, dial gauge and support arm

Observations and references to ISO 230-1:1996 5.512.32

Place a straightedge horizontally at the centre of the table parallel to the X-axis movement of the table. Table is locked at mid-travel.

Horizontal milling head is locked in low-position.

Attach a support arm with dial gauge to the horizontal milling spindle and adjust the stylus of the dial gauge to touch the straightedge and record the indication. Then rotate the spindle by 180°. Record the new indication and calculate the difference between the two readings.

7 Machining tests

7.1 Flatness of test pieces by slab milling

Nature of test **M1**

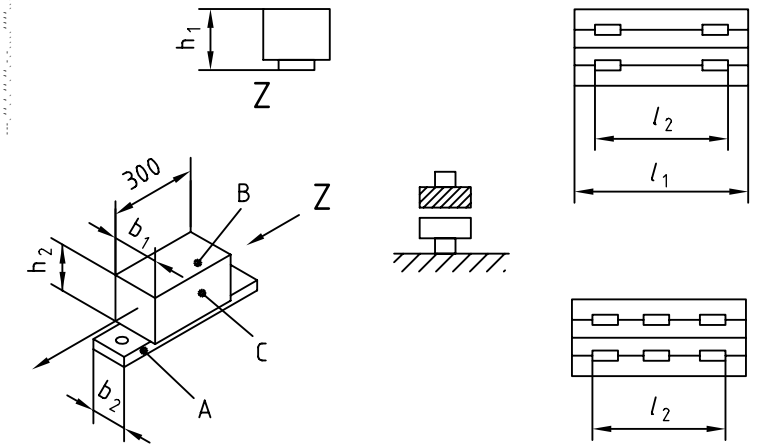
a) Slab milling of face B by automatic feed of the table along X-axis.

b) Milling of four test pieces for tables up to 2 000 mm in length.

For a table length in excess of 2 000 mm, it may be agreed to lay six (or eight) test pieces out as shown in the diagram.

(Test to be carried out in the absence of any other special requirement, e.g., production of a special part required by the user.)

Diagram



$b_1 = h_1 = 150$ mm
$b_2 = h_2 = 110$ mm

l_1 is the length of the table;

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

$l_1 - l_2 = 600$ mm

Test	Check to be applied	Tolerance	Measuring instrument	Observations and references to ISO 230-1:1996
a)	Flatness of face B of each test piece	0,02	Straightedge and gauge blocks or dial gauge and surface plate micrometer	3.1, 3.22, 4.1, 4.2, 5.321 and 5.412.2 Before starting the test: — ensure that faces A are flat; — orientate block(s) parallel to the movement of the table (X-axis); — with milling cutter mounted on milling spindle, the following tolerances are recommended: 1) run-out $\leqslant$ 0,02 2) camming $\leqslant$ 0,03
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		

Test conditions

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

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

All test pieces shall have the same hardness.

7.2 Milling of lateral faces

Object	**M2**

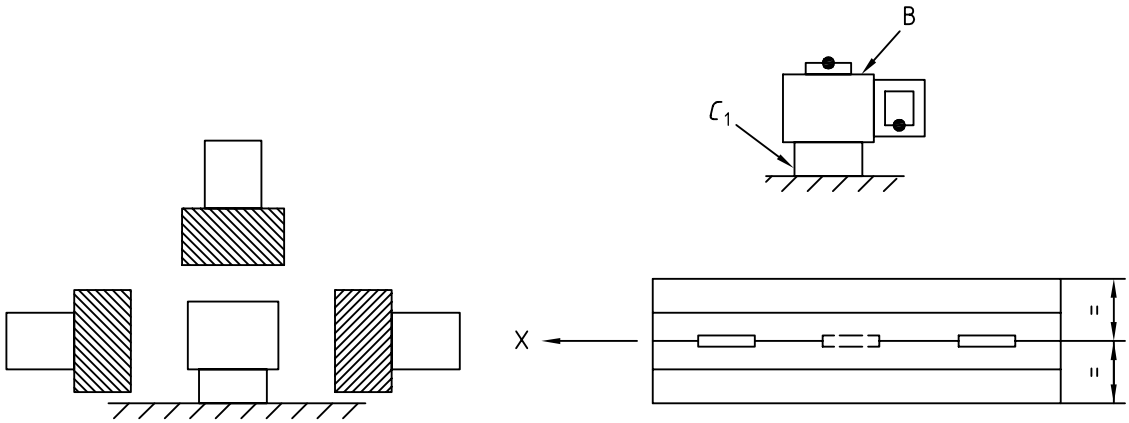
Milling of one of the lateral faces of two or three test pieces placed on the table along the X-axis.

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.)

(Test to be carried out in the absence of any other special requirement, e.g., production of a special part required by the user.)

Diagram



Same test piece as for M1

Check to be applied	Tolerance	Measuring instrument	Observations and references to ISO 230-1:1996
Squareness of side face C and face B	0,02/300	Precision level	3.1, 3.22, 4.1, 4.2, 5.321 and 5.512.2 Orientate block(s) parallel to X-axis movement of the table.

Test conditions

Machining shall be carried out with an end mill or insert cutter mounted on a horizontal milling spindle.

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

All test pieces shall have the same hardness.

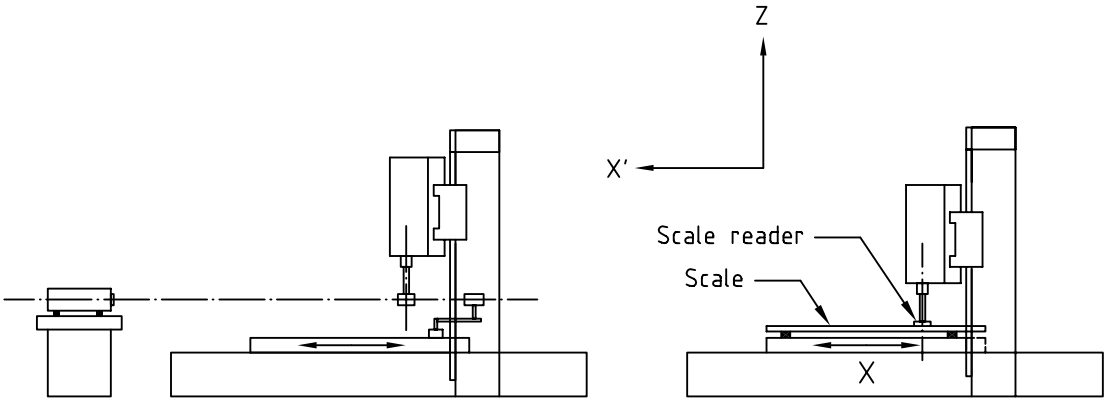
8 Accuracy and repeatability of positioning of numerically controlled axes

8.1 Linear axes

Object **P1**

Checking of accuracy and repeatability of positioning of the X-axis movement of the table.

Diagram



Tolerance		**Measuring length** ⩽ 500	⩽ 1 000	⩽ 2 000	**Measured deviations**
Axes up to 2 000 mm					
Bidirectional accuracy of positioning	A	0,020	0,025	0,032	
Unidirectional repeatability of positioning	$R\uparrow$ and $R\downarrow$	0,008	0,010	0,013	
Reversal value of 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 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

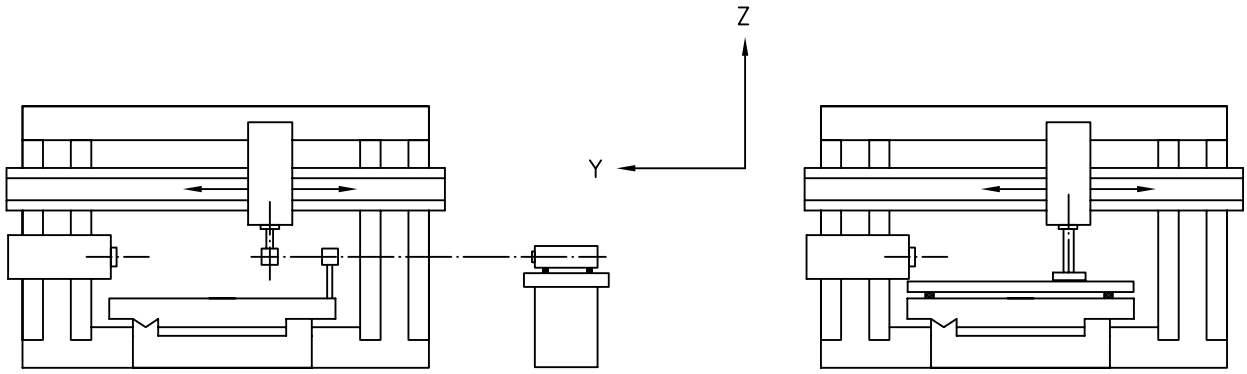
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the X-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the table and the interferometer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

Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1997, clauses 3, 4 and 7 shall be referred to.

Object **P2**

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

Diagram



Tolerance		**Measuring length**			**Measured deviations**
		⩽ 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↑ and R↓	0,008	0,010	0,013	
Reversal value of 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 of positioning	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

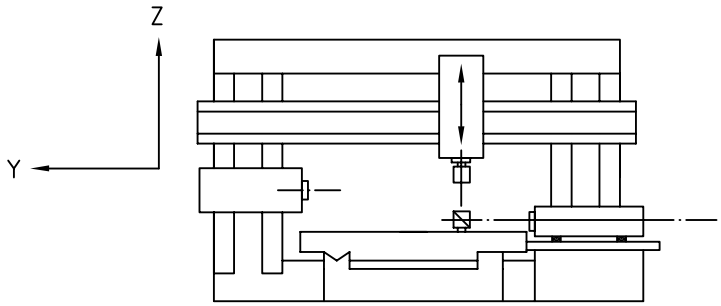
Observations and references to ISO 230-2

Relative measurement between the tool position and work-piece position is desired. 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 tool position and the interferometer on the table or on its extension.

Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1992, clauses 3, 4 and 7 shall be referred to.

Object	**P3**
Checking of accuracy and repeatability of positioning of the Z-axis movement of the vertical milling head or quill.	

Diagram



Tolerance		**Measuring length**		**Measured deviations**
		⩽ 500	⩽ 1 000	
Axes up to 2 000 mm				
Bidirectional accuracy of positioning	A	0,020	0,025	
Unidirectional repeatability of positioning	R↑ and R↓	0,008	0,010	
Reversal value of 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

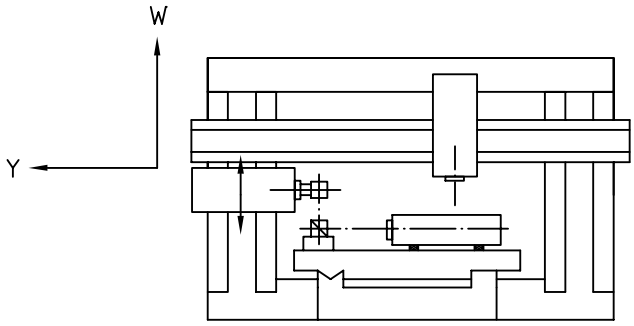
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Z-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the tool position and the interferometer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

Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1992, clauses 3, 4 and 7 shall be referred to.

Object **P4**

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

Diagram



Tolerance		**Measuring length**			**Measured deviations**
		⩽ 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↑ and R↓	0,008	0,010	0,013	
Reversal value of 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 of the axis	M	0,010	0,013	0,016	
Axes exceeding 2 000 mm					
Bidirectional systematic deviation of positioning	E	0,025 + 0,005 for each additional 1 000			
Range of the mean bidirectional positioning 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

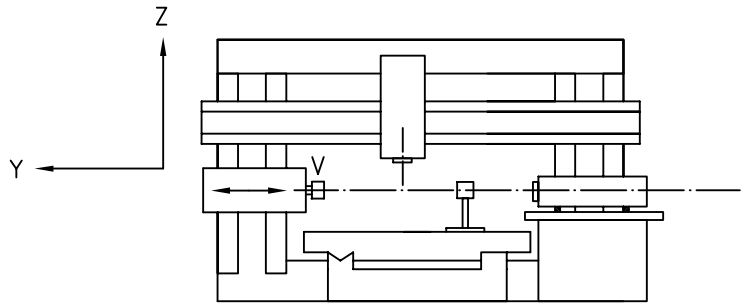
Observations and references to ISO 230-2

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 tool position and the interferometer on the table.

Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1992, clauses 3, 4 and 7 shall be referred to.

Object	**P5**
Checking of accuracy and repeatability of positioning of the V-axis movement of the horizontal milling head or quill.	

Diagram



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

Measuring instruments

Linear scale or laser measurement equipment

Observations and references to ISO 230-2

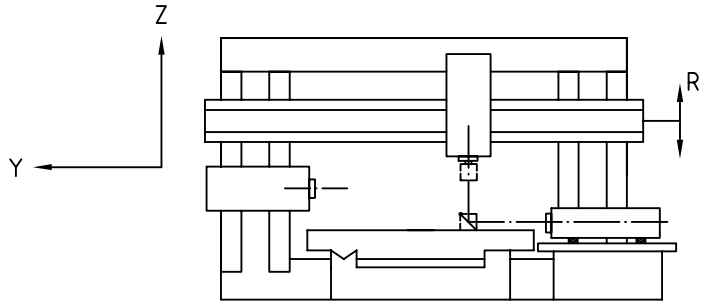
Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the Y-axis, the scale reader being on the tool position. When laser equipment is used, the reflector shall be set on the tool position and the interferometer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

Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1992, clauses 3, 4 and 7 shall be referred to.

Object **P6**

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

Diagram



Tolerance		**Measuring length**			**Measured deviations**
		⩽ 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↑ and R↓	0,008	0,010	0,013	
Reversal value of 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 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 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 tool position and the interferometer on the table.

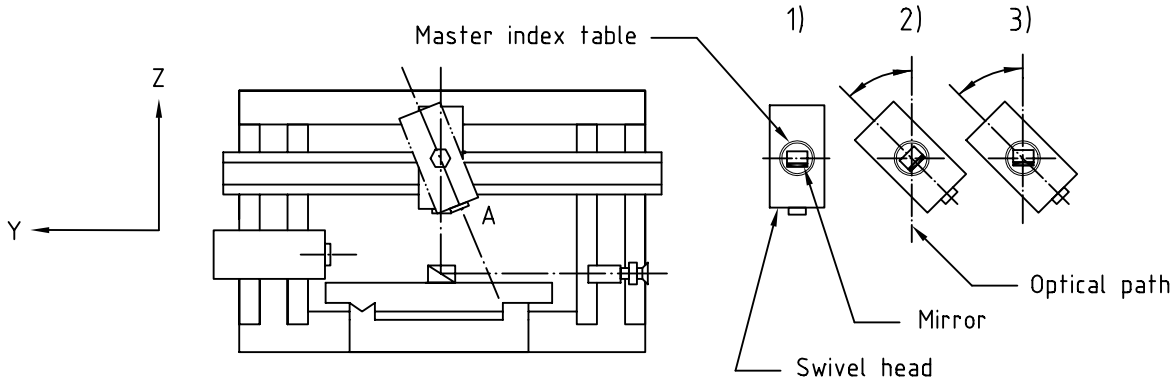
Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1992, clauses 3, 4 and 7 shall be referred to.

8.2 Rotary axes

Object **P7**

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

Diagram



Tolerance (in arcseconds)		**Measurement travel** $\leqslant 90^{o}$	**Measurement travel** $\leqslant 180^{o}$	**Measured deviations**
Bidirectional accuracy of positioning	A	12	16	
Unidirectional repeatability of positioning	$R\uparrow$ and $R\downarrow$	5	6	
Bidirectional systematic deviation of positioning	E	10	13	
Reversal value of 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 tilting head so that its rotation axis is parallel and near to the rotation axis of the head. Rotate the head by an indexable angle and then rotate back the index table so that the mirror comes back to its original position and check the angular deviation.

Concerning the test conditions, test programme and the presentation of the results, ISO 230-2:1992, clauses 3, 4 and 7 shall be referred to.

Annex A
(informative)

Equivalent terms in German and Italian
(see 4.1)

Ref.	German	Italian
1	Bett	Banco
2	Führungsbahn, Bett	Guida del banco
3	Tisch	Tavola (superficie di fissaggio)
4	Ständer, links	Montante sinistro
5	Ständer, rechts	Montante destro
6	Führungsbahn, Ständer rechts und links	Guide dei montanti
7	Querbalken (beweglich, fest)	Traversa mobile (o fissa)
8	Frässpindelstock, senkrecht	Testa a fresare verticale
9	Frässpindelstock, waagerecht	Testa a fresare orizzontale
10	Traverse	Traversa fissa
11	Unterschlitten	Slitta orizzontale
12	Traghülse (Pinole)	Cannotto
13	Werkzeug (Fräser)	Utensile (fresa)
14	Richtnut	Scanalatura di riferimento

Bibliography

[1] ISO 841:—[1)], *Industrial automation systems — Physical device control — Coordinate system and motion nomenclature.*

[2] ISO 8636-2:1988, *Machine tools — Test conditions for bridge-type milling machines — Testing of accuracy — Part 2: Gantry-type machines.*

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

ICS 25.080.20

Price based on 36 pages