INTERNATIONAL STANDARD

ISO 3070-3

Third edition
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Machine tools — Test conditions for testing the accuracy of boring and milling machines with horizontal spindle —

Part 3: Machines with movable column and movable table

Machines-outils — Conditions d'essai pour le contrôle de l'exactitude des machines à aléser et à fraiser à broche horizontale —

Partie 3: Machines à montant mobile et à table mobile

Reference number
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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 3070-3 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

This third edition cancels and replaces ISO 3070-0:1982 and ISO 3070-4:1998, of which it constitutes a technical revision.

ISO 3070 consists of the following parts, under the general title *Machine tools — Test conditions for testing the accuracy of boring and milling machines with horizontal spindle*:

— *Part 1: Machines with fixed column and movable table*

— *Part 2: Machines with movable column and fixed table*

— *Part 3: Machines with movable column and movable table*

Introduction

It is generally accepted that horizontal spindle boring and milling machines fall into three categories characterized by their particular configuration:

a) machines with fixed column and movable table;

b) machines with movable column and fixed table;

c) machines with movable column and movable table.

In the past, all these types of machines and associated terminology were described in ISO 3070-0:1982. The relevant accuracy tests were described in ISO 3070-2:1997, ISO 3070-3:1997 and ISO 3070-4:1998 respectively. However, ISO/TC 39/SC 2 decided to integrate the descriptions and the terminology of these machines into appropriate parts of ISO 3070 describing the accuracy tests and to renumber the parts of this series accordingly.

Machine tools — Test conditions for testing the accuracy of boring and milling machines with horizontal spindle —

Part 3: Machines with movable column and movable table

1 Scope

This part of ISO 3070 specifies, with reference to ISO 230-1, ISO 230-2 and ISO 230-7, geometric tests, machining tests, spindle tests and tests for checking the accuracy and repeatability of positioning by numerical control of general purpose, normal accuracy, horizontal spindle boring and milling machines having a movable column and movable table. This part of 3070 also specifies the applicable tolerances corresponding to these tests.

This type of machine can be provided with spindle heads of different types, such as those with sliding boring spindle and milling spindle, sliding boring spindle and facing head, or ram or milling ram.

This part of ISO 3070 concerns machines having movement of the column or column saddle on the bed (X axis), vertical movement of the spindle head (Y axis), movement of the boring spindle or ram (Z axis) and, possibly, a feed movement of radial facing slide in the facing head (U axis). Some machines also have an intermediate saddle with slideways between column and bed to achieve additional movement of the column parallel to the spindle axis (W axis).

NOTE In ISO 3070-1 spindle ram movement is designated as the W axis.

This part of ISO 3070 deals only with the verification of the accuracy of the machine. It does not apply to the operational testing of the machine (e.g. vibration, abnormal noise, stick-slip motion of components) nor to machine characteristics (e.g. speeds, feeds), as such checks are generally carried out before testing the accuracy.

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*

ISO 1101:2004, *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

3 Terminology and designation of axes

3.1 General

A boring and milling machine is a machine tool in which the principal cutting motion is the rotation of the cutting tool against the non-rotating workpiece and where the cutting energy is brought by the cutting tool rotation.

The cutting movement is generated by the rotation of the spindle(s) and, possibly, of the facing head.

3.2 Types of movement

The feed movements are as follows:

a) transverse and possible rotary movements of the table;

b) vertical movement of the spindle head;

c) axial movement of the spindle;

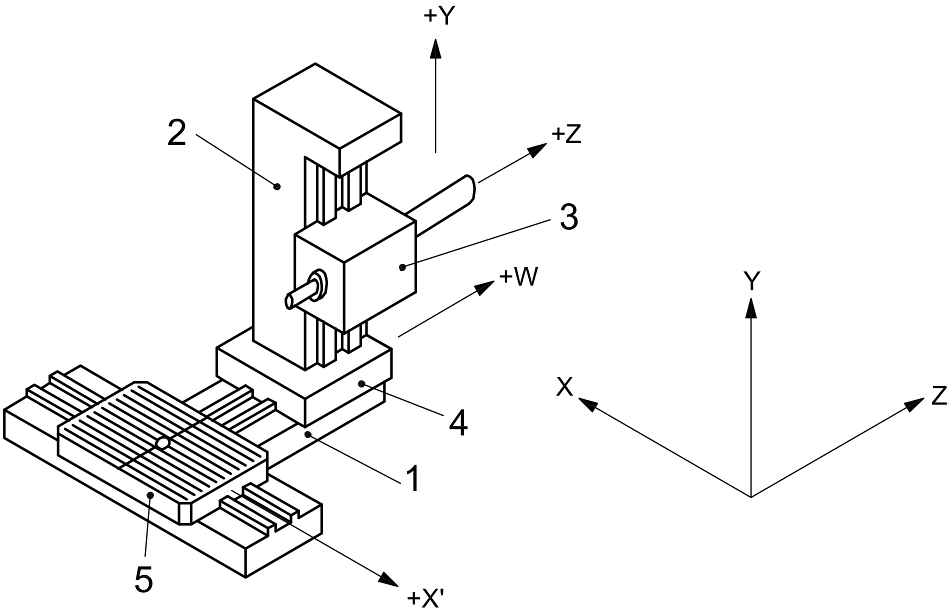
d) axial movements of the column on its fixture, parallel to the axis of the spindle;

e) possible movement of radial facing slide.

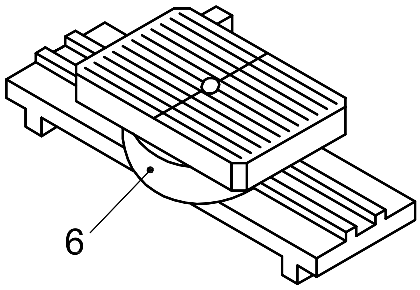
Table 1 provides the nomenclature for various structural components of machines shown in Figure 1. Figure 1 shows two possible machine configurations: one with a non-rotary table and the other with an integral rotary table.

Table 1 — Nomenclature (see Figure 1)

Figure 1 ref.	English	French	German
1	bed	banc	Maschinenbett
2	column	montant du chariot porte-broche	Maschinenständer
3	spindle head	chariot porte-broche	Spindelstock
4	column saddle	traînard du montant	Zwischenschlitten (für den Spindelstock)
5	table	table	Aufspanntisch
6	rotary table	table pivotante	Drehtisch



a) Machine with non-rotary table



b) Machine slide with integral rotary table

NOTE For components 1 to 6, see Table 1.

Figure 1 — Possible boring and milling machine configurations

4 Definition of the machining operations carried out on these machines

4.1 Boring operations

Boring is a machining operation for generating holes of various sizes and geometries in which the principal cutting motion is the rotation of single-point cutting tool against the non-rotating workpiece and where the cutting energy is brought by the cutting tool rotation.

Boring the diameter of cylindrical, conical, blind or through holes to the required size is achieved by using a boring bar to locate the cutting edge of the boring tool in a well-defined position with respect to the axis average line of the boring spindle.

In the case of coaxial bores situated on opposite faces of the same workpiece, the operation may be carried out using a boring bar, supported between the machine boring spindle and the steady stock located on the other side of the table. Alternatively, if the machine has a rotary table, such an operation can be carried out by rotating the table 180° to bore the opposite side of the workpiece with the same boring tool located on the boring bar that is mounted on the boring spindle without any steady support (reverse boring). Although more economical, this alternative method requires closer tolerances for table angular positioning as well as for the axis of rotation errors.

4.2 Milling operations

Milling is a machining operation to generate non-axisymmetrical (non-rotational) surfaces of various geometries in which the principal cutting motion is the rotation of a cutting tool with multiple cutting edges against the non-rotating workpiece and where the cutting energy is brought by the cutting tool rotation.

Milling operations mostly involve face milling or end milling. The tools are mounted either in the boring spindle taper (see Figure 2) or, as for face milling cutters, on the milling spindle nose.

5 Special remarks concerning particular elements

5.1 Spindle heads

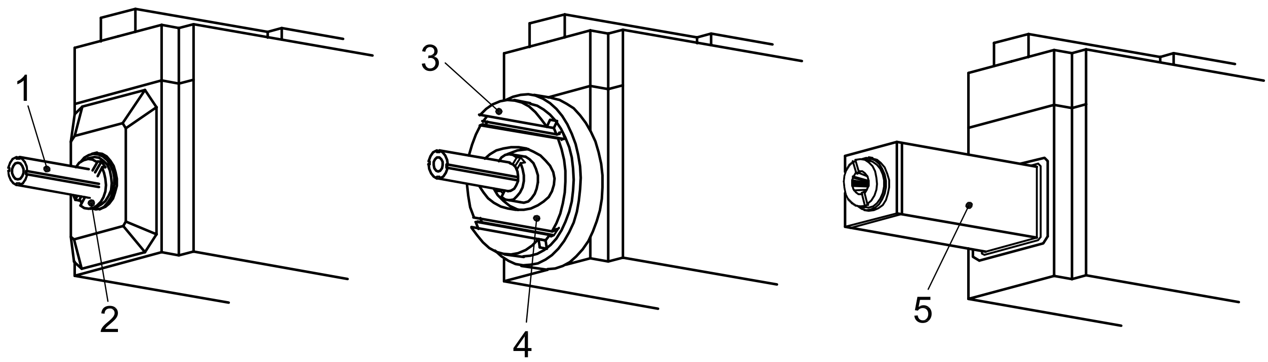
Reference should be made to Figure 2 for examples of the various types of head. Related nomenclature is given in Table 2.

Facing heads generally have a radial facing slide and are either integral or removable; the latter is considered an accessory.

It should be noted that the integral facing head may not always be mounted onto the milling spindle and may have its own bearing independent from the main spindle bearings.

Table 2 — Nomenclature (see Figure 2)

Figure 2 ref.	English	French	German
1	boring spindle	broche à aléser	Bohrspindel
2	milling spindle	broche à fraiser	Frässpindel
3	facing head	plateau à surfacer	Planscheibe
4	spindle head with facing head	tête de broche avec plateau à surfacer	Spindelstock mit Planscheibe
5	ram	coulisseau	Traghülse



a) **Spindle head for boring and milling** b) **Spindle head with facing head** c) **Spindle head with ram**

NOTE For elements 1 to 5, see Table 2.

Figure 2 — Types of spindle head

5.2 Tables

Tables may have rotary movements.

The two main rectilinear movements, the directions of which are perpendicular to each other, are used either for positioning the table or giving specified work feeds.

The rotary movement of the table may be used

a) for angular positioning in the plane of the table rotation,

b) as a circular work feed for milling operations,

c) for circular cutting movements for turning operations.

5.3 Steady blocks

Due to the decreasing use of long boring bars, there is an increasing tendency to treat steady blocks as optional parts or auxiliary equipment.

6 Preliminary remarks

6.1 Measuring units

In this part of ISO 3070, all linear dimensions, deviations and corresponding tolerances are expressed in millimetres; angular dimensions are expressed in degrees, and angular deviations and the corresponding tolerances are expressed in ratios (e.g. 0,00x/1 000) as the primary method; 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:

$$0{,}010/1\,000 = 10 \times 10^{-6} = 10\ \mu\text{rad} \approx 2\ \text{arcsec}$$

6.2 Reference to ISO 230

In applying this part of ISO 3070, 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 the measuring methods and recommended accuracy of the test equipment.

In the “Observations” block of the tests described in the following sections, the instructions are to be followed by reference to the corresponding clause or subclause 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 or another of those parts of ISO 230.

6.3 Testing sequence

The sequence in which the tests are presented in this part of ISO 3070 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.

6.4 Tests to be performed

When testing a machine, it is not always necessary or possible to carry out all the tests described in this part of ISO 3070. When the tests are required for acceptance purposes, it is for 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. The mere reference to this part of ISO 3070 for the acceptance tests, without specifying the tests carried out or without agreement on the relevant expenses, cannot be considered binding for any contracting party

6.5 Measuring instruments

The measuring instruments indicated in the tests described in the following sections are examples only.

Other instruments capable of measuring the same quantities and having the same, or a smaller, measuring uncertainty may be used. Linear displacement sensors shall have a resolution of 0,001 mm or better.

6.6 Machining tests

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

6.7 Software compensation

When built-in software facilities are available for compensating geometric, positioning, contouring and thermal deviations, their use during these tests should be based on agreement between the user and the supplier/manufacturer. When the software compensation is used, this shall be stated in the test report.

6.8 Minimum tolerance

When the tolerance for a geometric test is established for a measuring length different from that given in this part of ISO 3070 (see ISO 230-1:1996, 2.311), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

7 Geometric tests

7.1 Straightness and angular deviations of linear axes

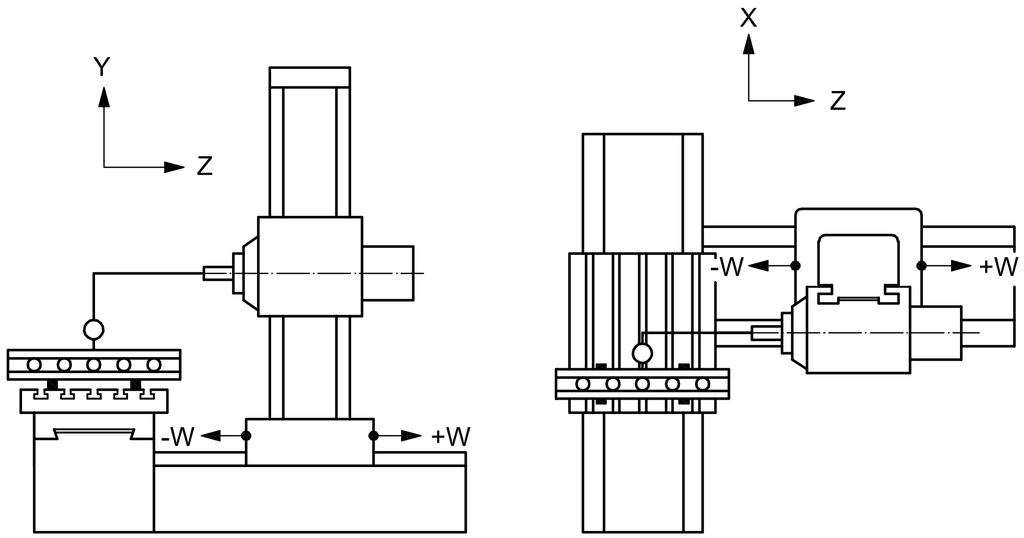
Object — **G1**

Checking of the straightness of the column movement (W axis):

a) in the YZ plane (vertical plane) (EYW);

b) in the ZX plane (horizontal plane) (EXW).

Diagram



a) b)

Tolerance	**Measured deviation**
a) and b) 0,02 for measuring lengths up to 1 000 0,03 for measuring lengths above 1 000 Local tolerance: 0,006 for any measuring length of 300	a) b)

Measuring instruments

Straightedge, linear displacement sensor/support and gauge blocks or optical methods or microscope and taut wire

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

Table and spindle head shall be locked. Set a straightedge on the table, parallel to the column movement (W axis) for a) vertically and b) horizontally (parallel means that the reading of the linear displacement sensor touching the straightedge at both ends of the movement is the same value).

If the spindle can be locked, mount the linear displacement sensor on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

The stylus shall be normal to the reference face of the straightedge.

Traverse the column in the W-axis direction and note the readings.

Object **G2**

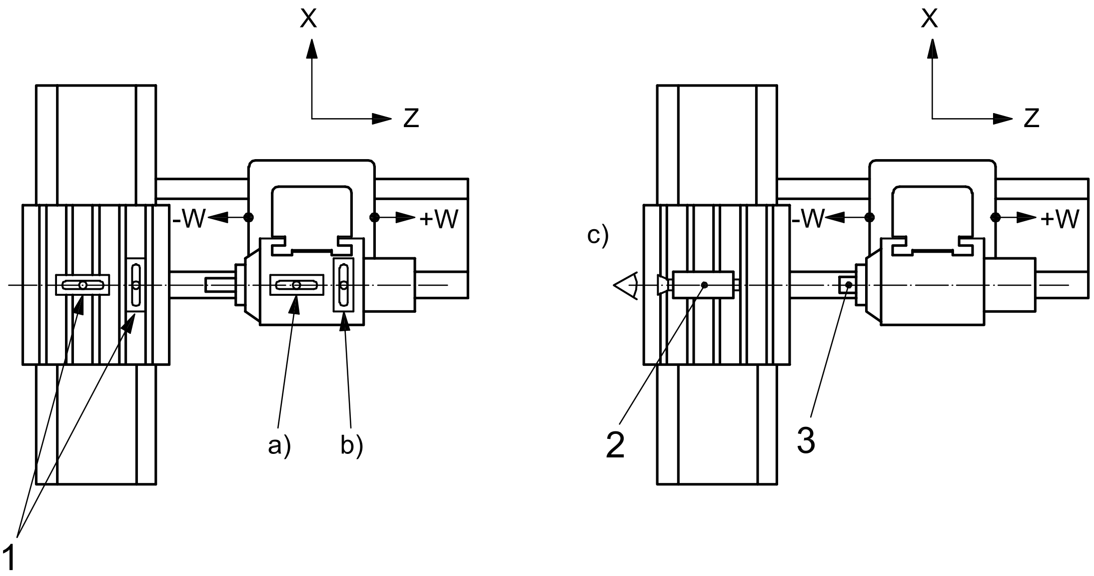
Checking of the angular deviation of the column movement (W axis):

a) in the YZ plane (EAW: pitch);

b) in the XY plane (ECW: roll);

c) in the ZX plane (EBW: yaw).

Diagram



Key

1 reference level
2 autocollimator
3 mirror

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

Measuring instruments

a) Precision level, laser interferometer or other optical angular deviation measuring instruments

b) Precision level

c) Laser interferometer 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 spindle head:

a) (EAW: pitch) in the Z-axis direction (set vertically for an autocollimator);

b) (ECW: roll) in the X-axis direction;

c) (EBW: yaw) in the Z-axis direction (set horizontally for an autocollimator).

The reference level shall be located on the table and the spindle head shall be in mid-travel.

When W-axis motion causes an angular movement of both spindle head and table, differential measurements of the two angular movements shall be made and this shall be stated.

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

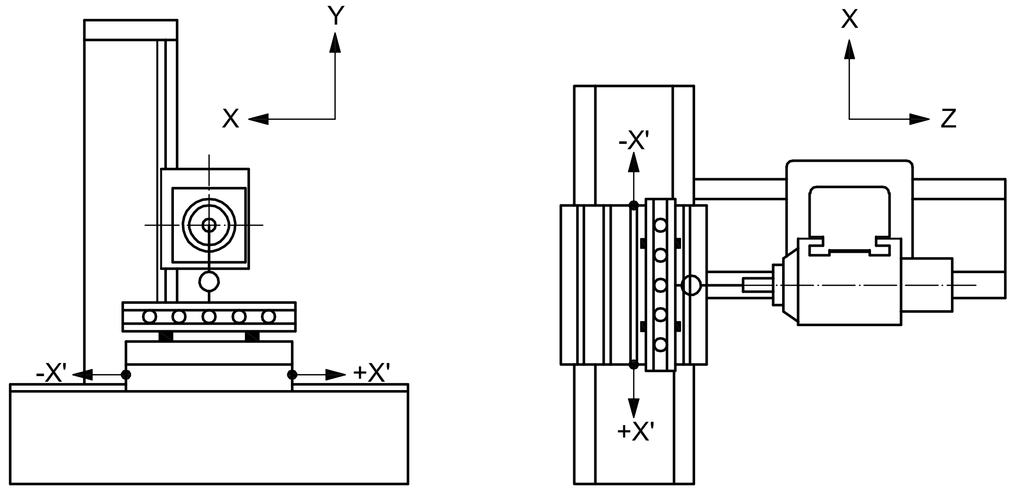
Object **G3**

Checking of the straightness of the table movement (X axis):

a) in the XY plane (vertical plane) (EYX);

b) in the ZX plane (horizontal plane) (EZX);

Diagram



a) b)

Tolerance	Measured deviation
a) and b) 0,02 for measuring lengths up to 1 000 Add 0,01 to the preceding tolerance for each 1 000 increase in length beyond 1 000 Maximum tolerance: 0,05 Local tolerance: 0,006 for any measuring length of 300	a) b)

Measuring instruments

Straightedge, linear displacement sensor/support and gauge blocks or optical methods

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

Set a straightedge at the middle position of the table, parallel to the X-axis table movement for a) vertically and b) horizontally (*parallel* means that the reading of the linear displacement sensor touching the straightedge at both ends of the movement is the same value).

If the spindle can be locked, mount the linear displacement sensor on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

The stylus shall be normal to the reference face of the straightedge.

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

Object **G4**

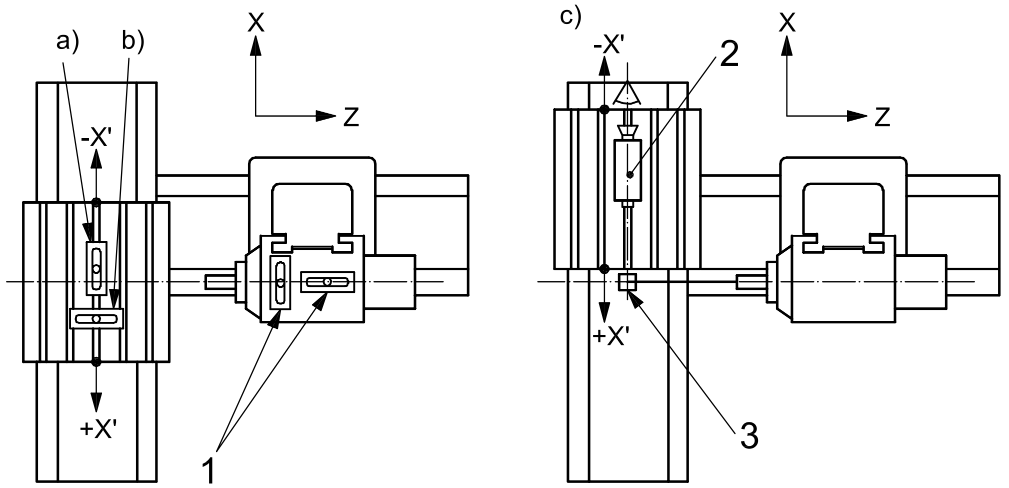
Checking of the angular deviation of the table movement (X axis):

a) in the XY plane (ECX: pitch);

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

c) in the ZX plane (EBX: yaw).

Diagram



Key

1 reference level
2 autocollimator
3 mirror

Tolerance	Measured deviation
a), b) and c) X ⩽ 4 000: 0,04/1 000 X > 4 000: 0,06/1 000 Local tolerance: 0,02/1 000 for any measuring length of 300	a) b) c)

Measuring instruments

a) Precision level, laser interferometer or other optical angular deviation measuring instruments

b) Precision level

c) Laser interferometer 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 table:

a) (ECX: pitch) in the X-axis direction (set vertically for an autocollimator);

b) (EAX: roll) in the Z-axis direction (set vertically for an autocollimator);

c) (EBX: yaw) in the X-axis direction (set horizontally for an autocollimator).

The reference level shall be located on the spindle head and the spindle head shall be in mid-travel.

When X-axis motion causes an angular movement of both spindle head and work-holding table, differential measurements of the two angular movements shall be made and this shall be stated.

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

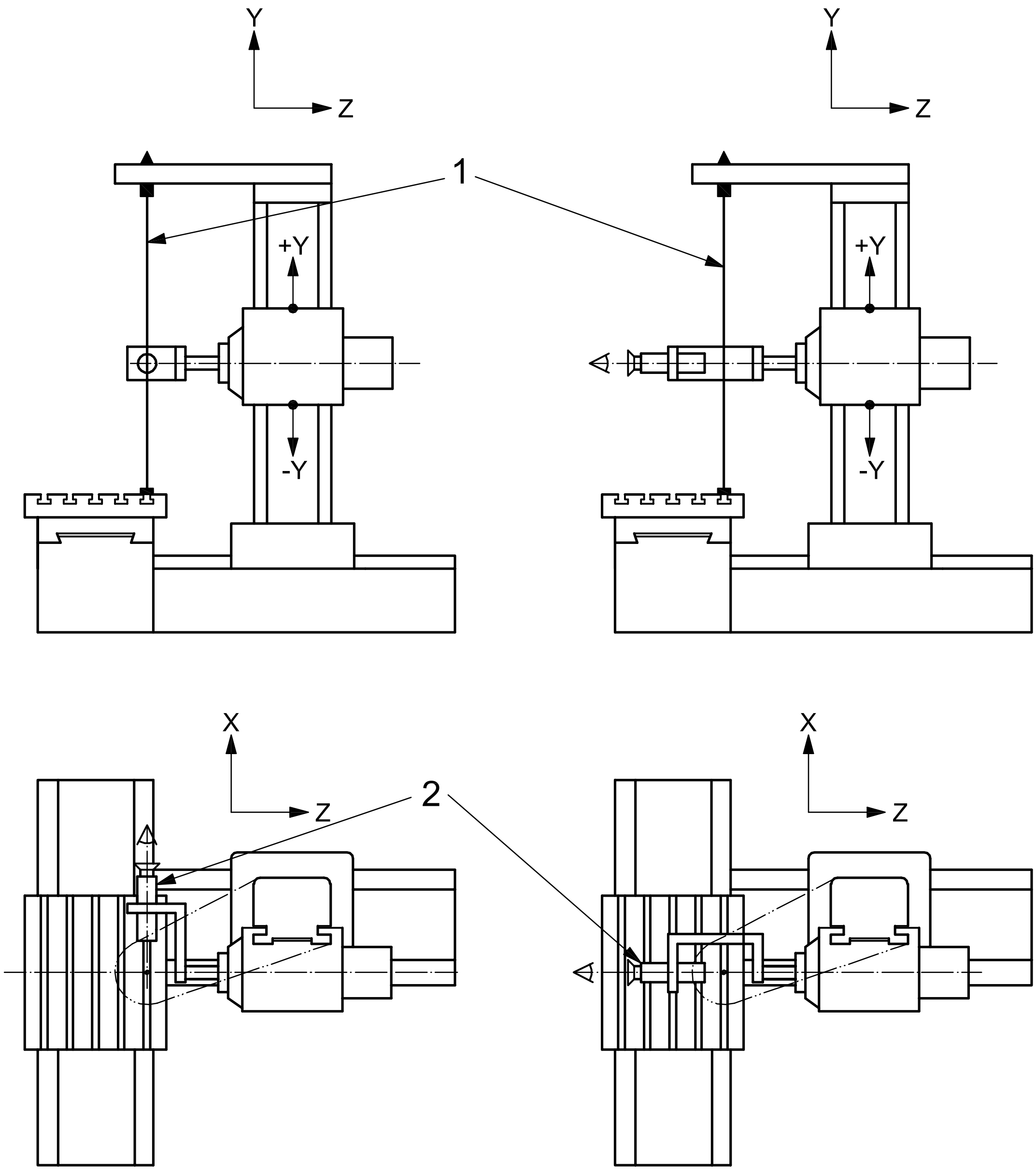
Object | **G5**

Checking of the straightness of the spindle head movement (Y axis):

a) in the YZ plane (vertical plane parallel to spindle axis) (EZY);

b) in the XY plane (vertical plane square to the spindle axis) (EXY).

Diagram



a) b)

Key

1 taut wire

2 microscope

Tolerance	Measured deviations
a) and b) 0,02 for any measuring length up to 1 000 Add 0,01 to the preceding tolerance for each 1 000 increase in length up to 4 000. Add 0,02 for each 1 000 increase in length over 4 000	a) b)

Measuring instruments

Microscope and taut wire or optical methods

Observations and references to ISO 230-1:1996 **5.232.12 or 5.232.13**

The column and table shall be locked and the table shall be locked in mid-travel.

The taut wire shall be tightened between fixed parts independent of, or integral to, the machine, as near as possible to the vertical slideways of the column.

If the spindle can be locked, lock it during measurements; the microscope or alignment telescope may be mounted on it. If the spindle cannot be locked, mount the microscope on the spindle head of the machine.

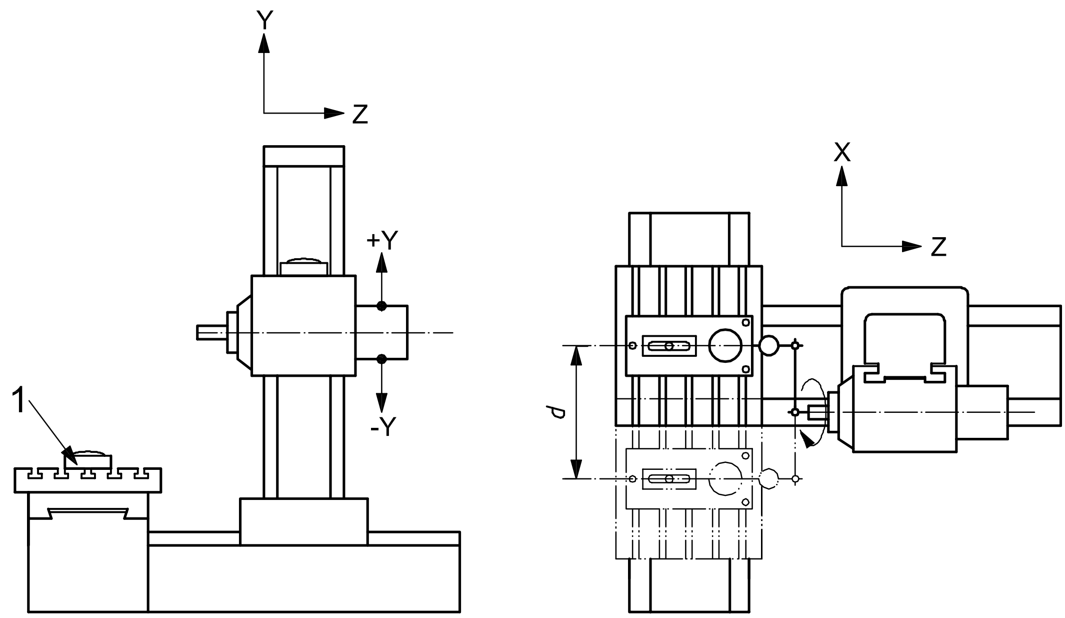
Object		**G6**

Checking of the angular deviations of the spindle head movement (Y axis):

a) in the YZ plane (EAY);

b) in the ZX plane (EBY, roll).

Diagram



a) b)

Key

1 reference level

Tolerance	**Measured deviation**
a) and b)	a)
Y ⩽ 4 000: 0,04/1 000	b)
Y > 4 000: 0,06/1 000	

Measuring instruments

a) Precision level, laser interferometer or other optical angular deviation measuring instruments

b) Cylindrical square, level and linear displacement sensors/support arm

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

a) Place a level on the spindle head in the Z-axis direction. The reference level shall be located on the table and the spindle head shall be in the middle of its travel range.

b) Mount a surface plate on the table and adjust it so that its face is levelled.

Place a cylindrical square on the surface plate so that it is touched it by the stylus of the linear displacement sensor mounted on a special arm fixed to the spindle head. Place a level also on the surface plate in the Z-axis direction.

Note the readings at the measuring positions of the spindle head travel (Y axis).

Move the table distance, d, and reset the linear displacement sensor so that the stylus touches the cylindrical square.

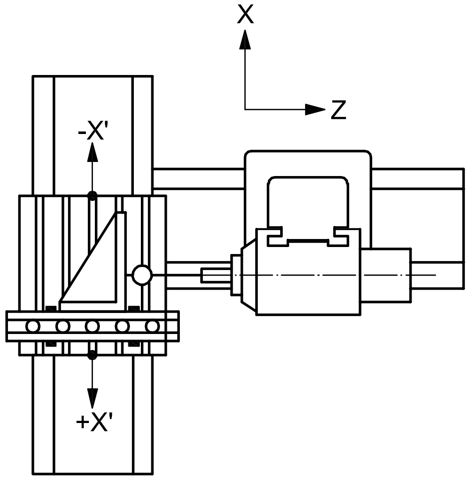
When the level is shown as different because of roll in the table movement, adjust the level of the surface plate so that it is the same as that of the first position, then note readings at the same measuring positions.

For each measuring position, calculate the differences between two readings, then the difference between maximum and minimum divided by distance, d, to give the angular deviation.

Measurements shall be carried out at a minimum of five positions equally spaced along the travel in both directions of up and down movements.

NOTE The levelling difference between the two locations of the table directly influences the measurement results.

7.2 Squareness between linear axes

Object	**G7**
Checking of the squareness between the table movement (X axis) and the column movement (W axis).	
Diagram	
	
Tolerance 0,03 for any measuring length of 1 000	**Measured deviation**
Measuring instruments Straightedge, square and linear displacement sensor/support	
Observations and references to ISO 230-1:1996 **5.522.4** Lock the spindle head in mid-travel. Align the straightedge parallel to the column movement (W axis) and press the square against it (*parallel* means that the reading of the linear displacement sensor touching the straightedge at both ends of the movement is the same value). Lock the column in mid-travel. If the spindle can be locked, mount the linear displacement sensor on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head. Apply the stylus of the linear displacement sensor to the reference face of the square. Move the table in the X direction and note the readings. NOTE This test can be carried out, without using a straightedge, by directly applying the stylus of the linear displacement sensor to the two faces of the square.	

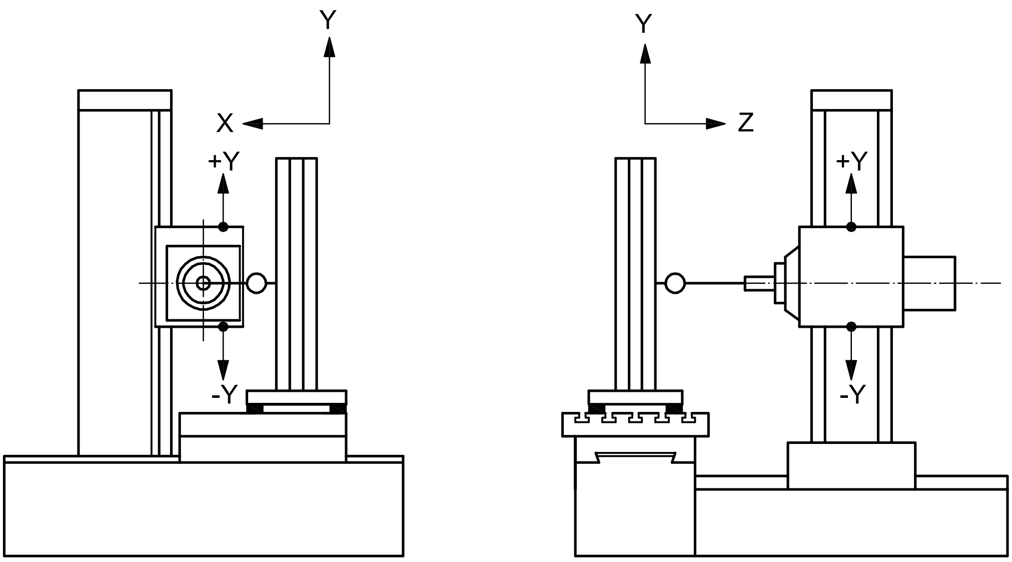
Object **G8**

Checking of the squareness of the spindle head movement (Y axis) to

a) the table movement (X axis),

b) the column movement (W axis).

Diagram



a) b)

Tolerance	**Measured deviation**
a) and b)	a)
0,03 for any measuring length of 1 000	b)

Measuring instruments

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

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

Mount a surface plate on the table and adjust it so that its surface is parallel to both X- and W-axis movements. Place the cylindrical square on the surface plate.

Lock the table and column saddle in mid-travel.

If the spindle can be locked, the linear displacement sensor may be mounted on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

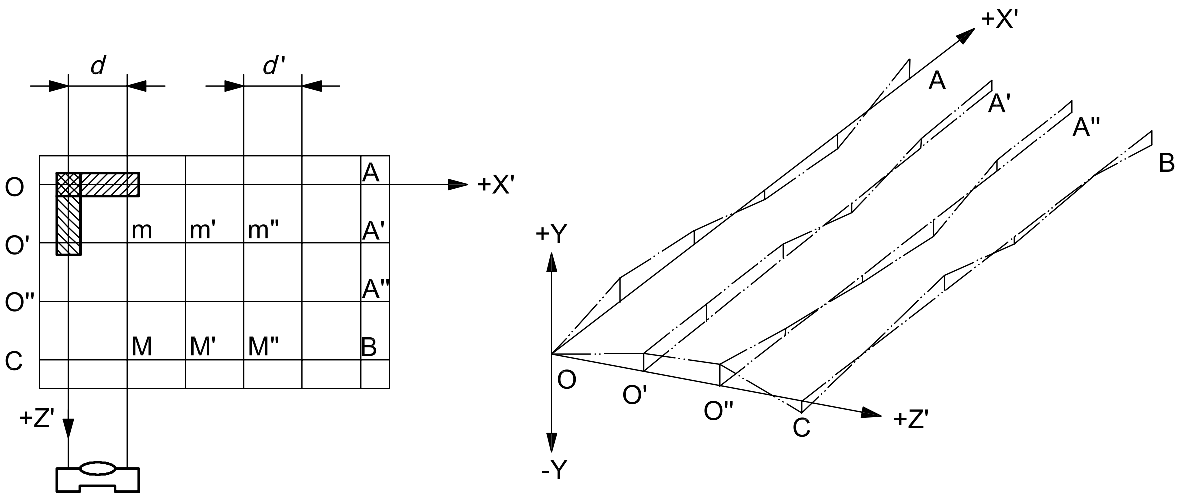
a) Apply the stylus of the linear displacement sensor to the cylindrical square in the X-axis direction and move the head in the Y-axis direction through the measuring length, noting the maximum difference between the readings.

b) Apply the stylus of the linear displacement sensor to the cylindrical square in the W-axis direction and carry out the same procedure as specified above.

7.3 Table

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

Diagram



Tolerance	**Measured deviation**
For the longer side, a length of O-X or O-Z 0,03 for measuring lengths up to 1 000 (flat to concave) Add 0,01 to the preceding tolerance for each 1 000 increase in length beyond 1 000. Maximum tolerance: 0,06 Local tolerance: 0,015 for any measuring length of 300	

Measuring instruments

Precision level or straightedge, gauge blocks and linear displacement sensor or optical or other equipment

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

The table and the column saddle may be locked in mid-travel.

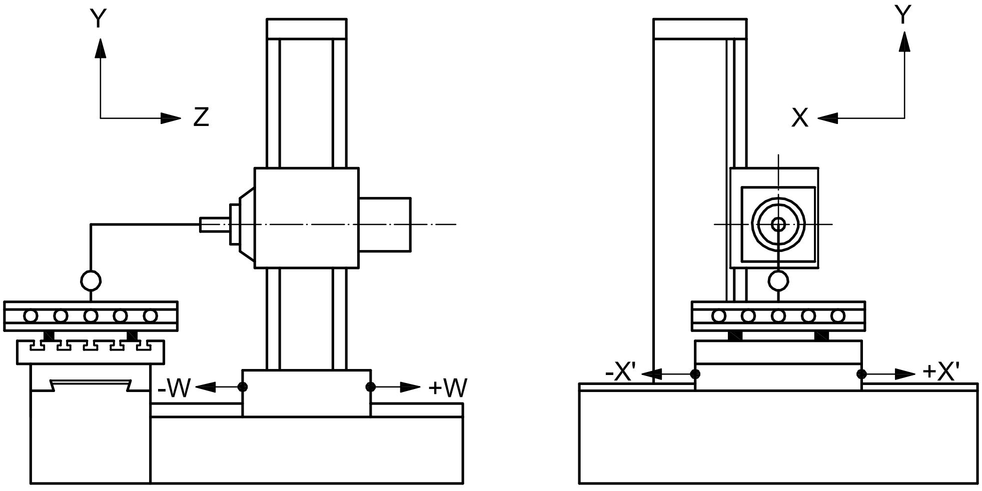
Object | **G10**

Checking of the parallelism of the table surface relative to:

a) the column movement (W axis);

b) the table movement (X axis).

Diagram



a) b)

Tolerance	**Measured deviation**
a) and b)	a)
0,04 for measuring lengths up to 1 000	b)
Add 0,01 to the preceding tolerance, for each 1 000 increase in length beyond 1 000.	
Maximum tolerance: 0,06	
Local tolerance: 0,015 for any measuring length of 300	

Measuring instruments

Linear displacement sensor, straightedge and gauge blocks

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

If the spindle can be locked, the linear displacement sensor may be mounted on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

Place the stylus of the linear displacement sensor in a vertical plane approximately coaxial with the spindle axis.

Set the straightedge on the table parallel to the table surface and traverse the table or saddle through the measuring length, noting the variation in reading. If the traverse travel is longer than 1 600, carry out the inspection by successive movement of the straightedge.

a) Carry out the test with the table locked in mid-travel.

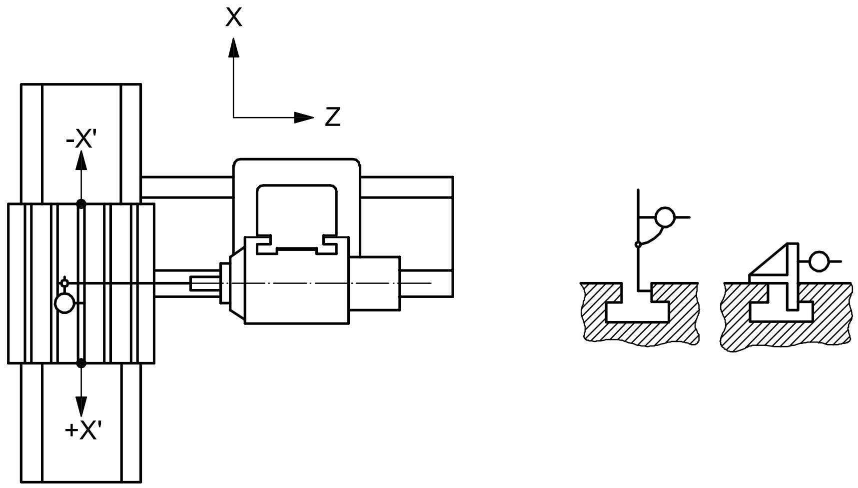
b) Carry out the test with the column and spindle head locked.

Direct measurement of the table surface without using a straightedge is also possible using a linear displacement sensor and gauge block.

For rotary type tables, the test shall be carried out at each of the following indexed positions of the rotary table: 0°, 90°, 180° and 270°.

Object	**G11**
Checking of the parallelism of the median or reference T-slot to the table movement (X axis).	

Diagram



Tolerance	**Measured deviation**
0,03 for any measuring length of 1 000 Maximum tolerance : 0,04	

Measuring instruments

Linear displacement sensor and cross-square

Observations and references to ISO 230-1:1996 5.422.21

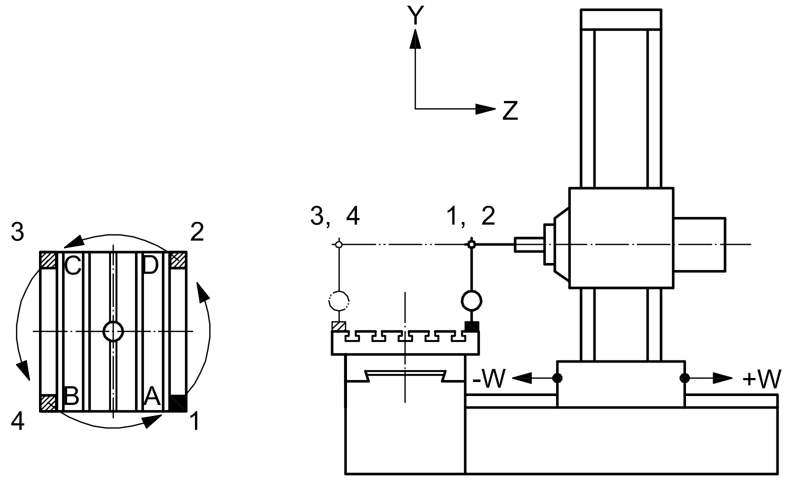
If the spindle can be locked, the linear displacement sensor may be mounted on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

The stylus of the linear displacement sensor may be made to touch the reference face of the T-slot either directly or using a cross-square.

7.4 Indexing or rotary table

Object	**G12**
Checking of the face run-out of the table surface in its rotating movement.	

Diagram



Key

1, 2, 3, 4 measuring points

A, B, C, D table corners

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

Measuring instruments

Linear displacement sensor/support and gauge block

Observations and references to ISO 230-1:1996 5.632

With the linear displacement sensor in position 1, place a gauge block near corner A of the table and perform a measurement. Remove the gauge block and rotate the table until corner B comes to the measuring position and perform a measurement by inserting the same gauge block. Carry out the same operation at corners C and D by rotating the table.

Repeat the same process, placing the linear displacement sensor in the successive positions 2, 3 and 4 or at least in position 2.

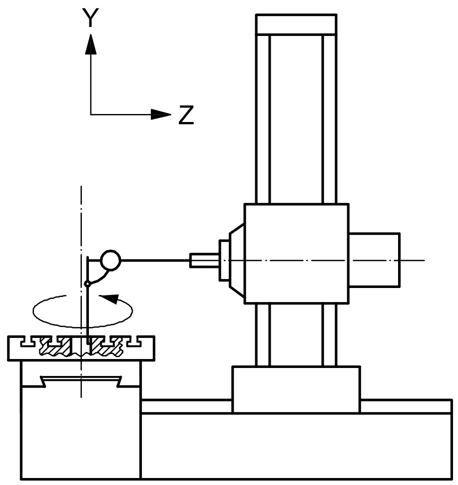
For each of those positions, record the difference between the maximum and minimum readings.

Use the greatest of these differences as the value of the face run-out

Lock the table each time before taking measurements, if applicable.

Object	**G13**
Checking of the run-out of the centring hole of the table in relation to its axis of rotation.	

Diagram



Tolerance	**Measured deviation**
0,015	

Measuring instruments

Linear displacement sensor/support and possibly test mandrel

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

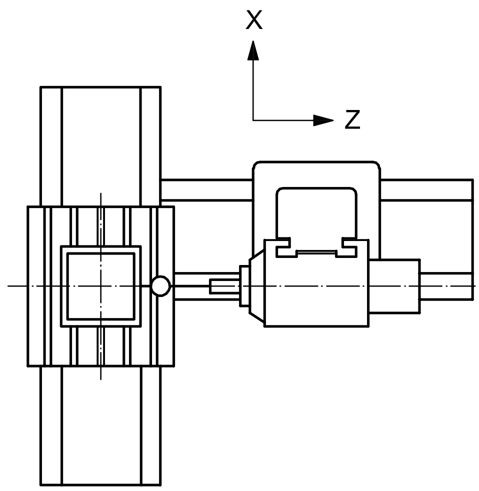
If the spindle can be locked, the linear displacement sensor may be mounted on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

Set the stylus of the linear displacement sensor coaxial with the axis of the centring hole and as near as possible to the table surface.

Rotate the table and record the difference between the maximum and the minimum reading as the measured deviations.

Checking may also be carried out using a test mandrel inserted into the centre hole.

Object		**G14**
Checking of the accuracy of the table angular positions at 0°, 90°, 180° and 270° a) for a rotary indexable table with only four fixed positions 90° apart; b) for a rotary indexable table with any number of fixed positions; c) for a rotary table capable of any angle positioning.		
Diagram		



Tolerance	**Measured deviation**
a) 0,03 for any measuring length of 500	a)
b) 0,05 for any measuring length of 500	b)
c) 0,075 for any measuring length of 500	c)

Measuring instruments

Square and linear displacement sensor/support

Observations and references to ISO 230-1:1996 **6.41, 6.42, 6.43 and Annex A.5**

Set a square on the table with one edge parallel to the table movement (X axis).

Index the table four times in one direction (90°, 180°, 270° and 360°) and check in every position the parallelism between the table movement and the corresponding edge of the square.

Index the table four times in the opposite direction (270°, 180°, 90° and 0°) and check again the parallelism in every position. The maximum difference of the eight readings shall not exceed the tolerance.

NOTE Test P6 presents a test procedure for NC rotary tables.

7.5 Boring spindle

Object | **G15**

Checking of the boring spindle:

a) run-out of the internal taper, with the spindle retracted

1) at the mouth of the taper,

2) at a distance of 300 mm from the spindle nose;

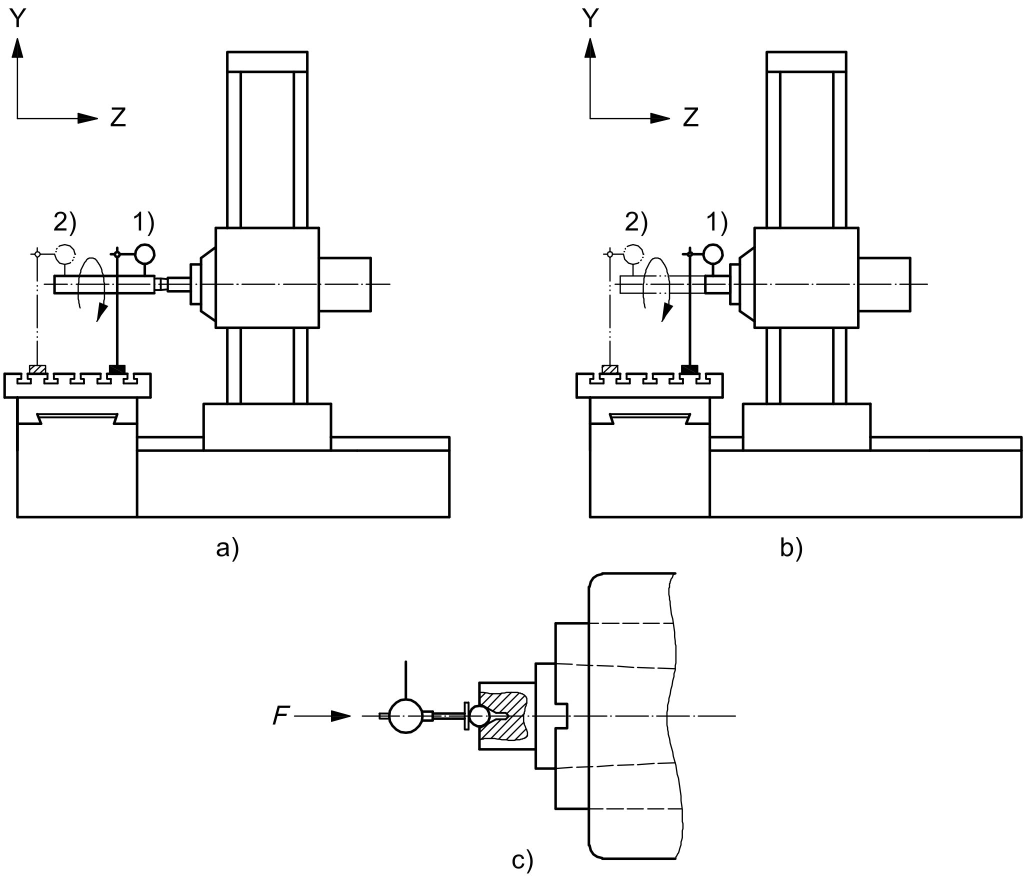
b) run-out of the external diameter with

1) the spindle retracted,

2) the spindle extended by 300 mm;

c) periodic axial slip, with the spindle retracted.

Diagram



Tolerance

		$D \leqslant 125$	$D > 125$
a) and b)	1)	0,01	0,015
	2)	0,02	0,03
c)		0,01	0,015

where D is the diameter of the boring spindle.

Measured deviation

a)

b)

c)

Measuring instruments

Test mandrel and linear displacement sensor

Observations and references to ISO 230-1:1996

a) 5.612.3

b) 5.612.2

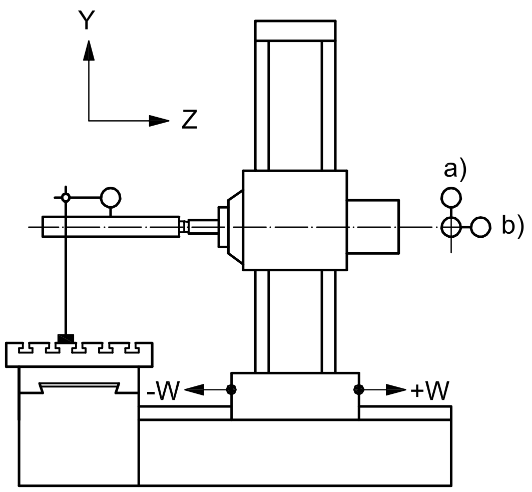
c) 5.622.1 and 5.622.2

The value and the direction of application of the force, F, shall be specified by the supplier/manufacturer.

When preloaded bearings are used, no force need be applied.

NOTE Test R1 is a spindle test for evaluating error motions of the spindle.

Object		**G16**
Checking of the parallelism of the boring spindle axis relative to the column movement (W axis): a) in the YZ plane (vertical); b) in the ZX plane (horizontal).		
Diagram		



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

Measuring instruments

Linear displacement sensor and test mandrel

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

The spindle head shall be locked in mid-travel and the spindle shall be retracted.

The table may be locked in the central position.

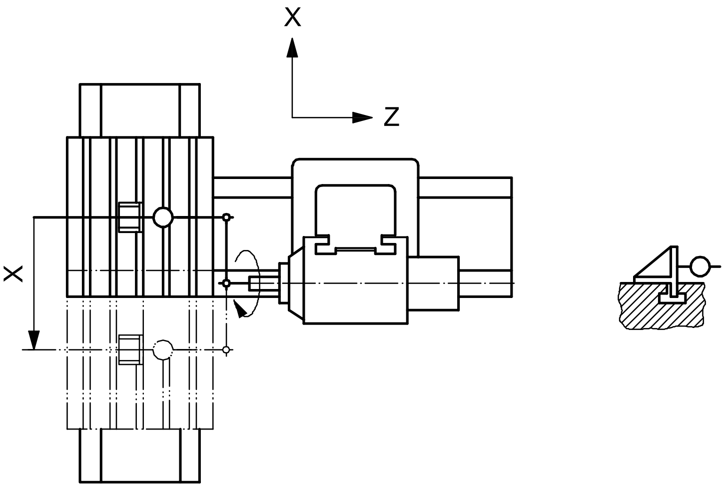
Measurement shall be carried out with the aid of the test mandrel mounted on the spindle nose.

Carry out the measurement at the mean position of run-out of the spindle rotation or evaluate the mean value of measurements taken at two positions of the spindle rotation 180° apart.

Object | **G17**

Checking of the squareness of the boring spindle axis relative to the table movement (X axis).

Diagram



Tolerance	**Measured deviation**
0,02/500 (500 is the distance between the two measuring points touched.)	

Measuring instruments

Linear displacement sensor/support and square block

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

The spindle head shall be locked in mid-travel (Y axis) and the spindle and, possibly, the ram shall be retracted.

The column shall be locked in the position nearest the table.

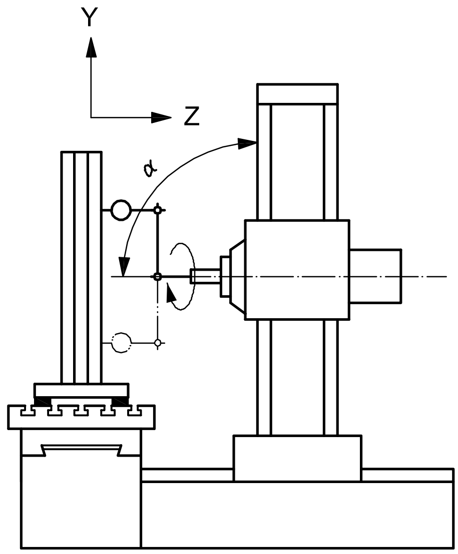
Place the stylus of the linear displacement sensor against the square block on the table.

Turn the boring spindle and move the table to touch the square block at the same point.

The difference between the two readings divided by the distance between the two measuring points defines the squareness deviation.

Object		**G18**
Checking of the squareness of the boring spindle axis relative to the spindle head movement (Y axis).		

Diagram



Tolerance	**Measured deviation**
0,02/500 with $\alpha \leqslant 90°$ (500 is the distance between the two measuring points touched.)	

Measuring instruments

Cylindrical square, adjustable blocks and linear displacement sensor/support

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

The spindle head shall be locked in mid-travel and the spindle and, possibly, the ram shall be retracted.

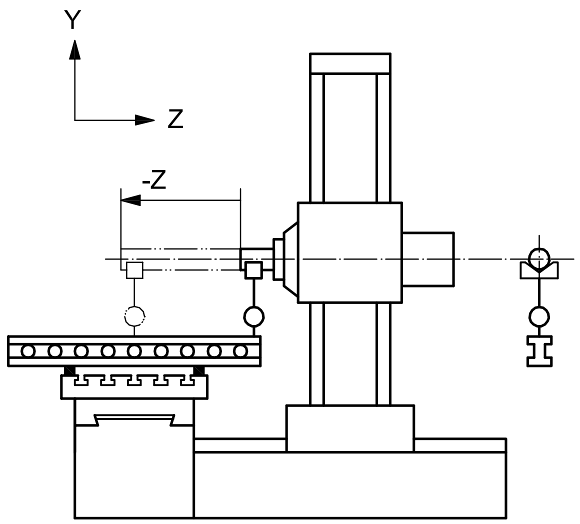
The column shall be locked in the position nearest the table.

The cylindrical square shall be set on the table parallel to the spindle head movement (Y axis).

Turn the spindle with the linear displacement sensor attached so that it touches the cylindrical square.

Object		**G19**
Checking of the parallelism of the boring spindle movement (Z axis) in the vertical plane relative to the column movement (W axis).		

Diagram



Tolerance	**Measured deviation**
For an extension of the spindle equal to $2D$: + 0,015 (upwards) $4D$: ± 0,02 $6D$: – 0,06 (downwards) where D is the diameter of the boring spindle. The extension of the spindle is limited to six times the spindle diameter and shall not exceed 900. The tolerance is limited to a spindle diameter of 150; when the spindle diameter is over 150, the tolerance shall be agreed upon between the user and the supplier/manufacturer.	

Measuring instruments

Straightedge, gauge block and linear displacement sensor

Observations and references to ISO 230-1:1996 **5.232.1 and 5.422.22**

Place the straightedge on the table vertically in a plane containing the spindle axis and adjust it parallel to the column movement (W axis).

The spindle rotation shall be locked.

Touch the functional surface of the straightedge with the linear displacement sensor fixed on the spindle nose.

Extend the spindle to the required length and record the linear displacement sensor readings for each successive position.

7.6 Milling spindle

Object — **G20**

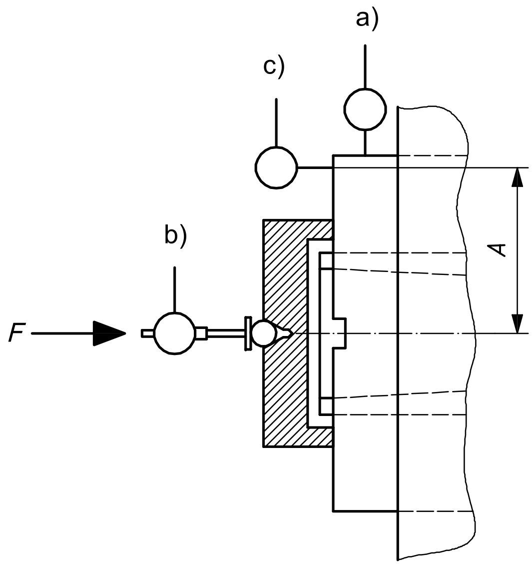
Checking of the milling spindle:

a) run-out;

b) periodic axial slip;

c) face run-out of the spindle nose (including periodic axial slip).

Diagram



Tolerance

	$D \leqslant 125$	$D > 125$
a)	0,01	0,015
b)	0,01	0,015
c)	0,02	0,03

where D is the diameter of the milling spindle.

Measured deviation

a)

b)

c)

Measuring instruments

Linear displacement sensor

Observations and references to ISO 230-1:1996

a) 5.612.2

b) 5.622.1 and 5.622.2

The value and direction of application of the force, F, shall be specified by the supplier/manufacturer.

When an axially preloaded bearing is used for spindle, no force F is needed.

c) 5.632

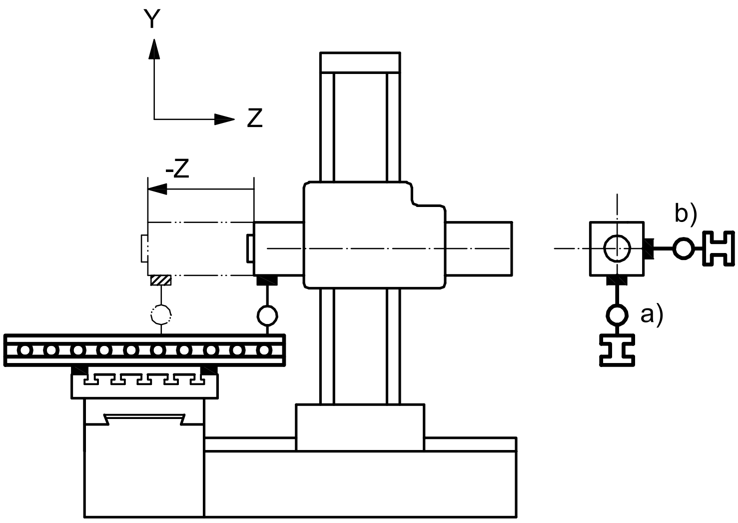
The distance, A, of the linear displacement sensor c) from the spindle axis shall be as large as possible.

NOTE Test R1 is a spindle test for evaluating error motions of the spindle.

7.7 Ram

Object	**G21**
Checking of the parallelism of the ram movement (Z axis) relative to the column movement (W axis): a) in the YZ plane (vertical plane); b) in the ZX plane (horizontal plane).	

Diagram



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

Measuring instruments

Straightedge, linear displacement sensor and adjustable blocks

Observations and references to ISO 230-1:1996 5.422.22

Set a straightedge on the table parallel to the column movement (W axis) for a) a vertical measurement and b) a horizontal measurement (parallel means that the readings of the linear displacement sensor touching the straightedge at both ends of the movement are the same value).

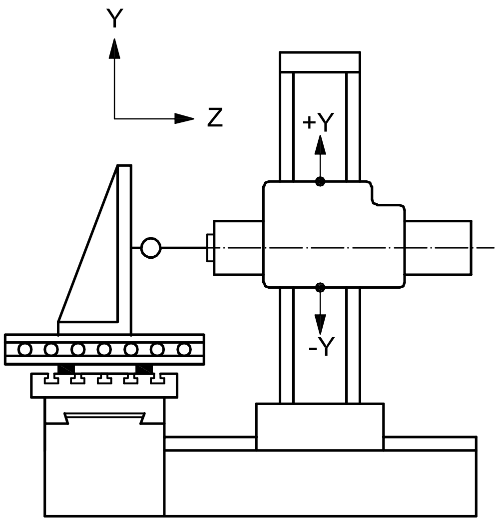
The column shall be locked in mid-travel. The spindle head shall be locked.

The ram movement shall be checked with respect to the straightedge using a linear displacement sensor fixed on the ram.

Object | **G22**

Checking of the squareness of the ram movement (Z axis) relative to the spindle head movement (Y axis).

Diagram



Tolerance	**Measured deviation**
0,03 for a measuring length of 500	

Measuring instruments

Straightedge, square, adjustable blocks and linear displacement sensor/support

Observations and references to ISO 230-1:1996 5.522.4

Set a straightedge on the table parallel to the ram movement (Z axis) using adjustable blocks and then place a square on it.

Check the parallelism between the free arm of the square and the spindle head movement.

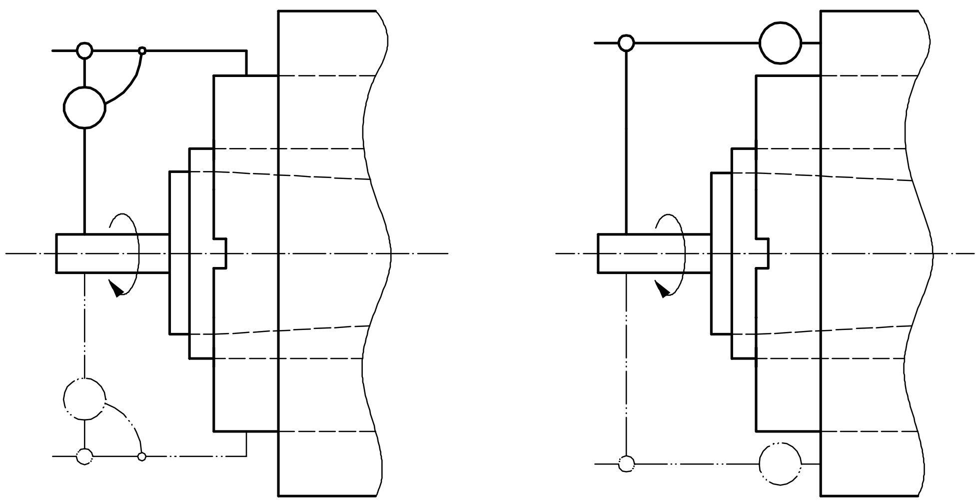
Object	**G23**

a) Checking of the concentricity of the milling spindle relative to the front centring of tools or accessories on the ram.

b) Checking of the squareness of the support face of tools or accessories on the ram relative to the rotation axis of the milling spindle.

NOTE These checks are valid only if there is a circular locating surface on the ram.

Diagram



a) b)

Tolerance	**Measured deviation**
a) 0,02	a)
b) 0,02/500	b)
(500 is the distance between the two measuring points touched.)	

Measuring instruments

Linear displacement sensor and test mandrel

Observations and references to ISO 230-1:1996

a) 5.442

The concentricity deviation is half of the maximum difference of the readings.

b) 5.512.42

7.8 Integral facing head

Object — **G24**

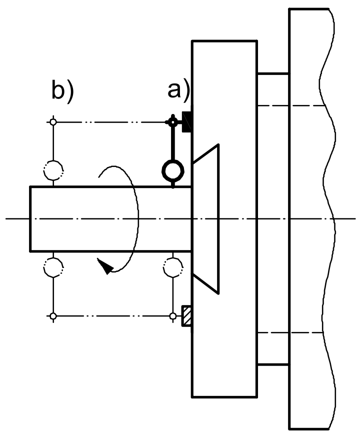
Checking of the coaxiality of the boring spindle rotating axis and of the facing head axis:

a) at the mouth of the spindle housing;

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

NOTE These checks are valid only when the facing head is mounted on bearings independent of those of the boring spindle.

Diagram



Tolerance

	$D \leqslant 125$	$D > 125$
a)	0,02	0,03
b)	0,03	0,04

where D is the diameter of the boring spindle.

Measured deviation

a)

b)

Measuring instruments

Linear displacement sensor and test mandrel

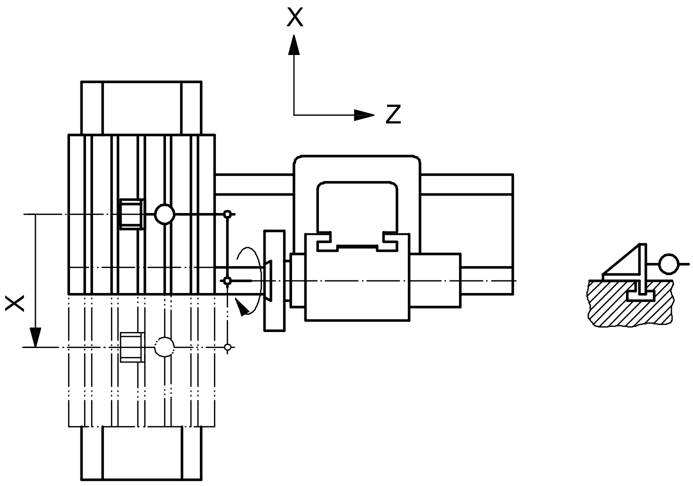
Observations and references to ISO 230-1:1996 5.442

A linear displacement sensor fixed on the facing head shall touch the boring spindle at the mouth and at 300.

For each operation, determine half the difference of the extreme readings to obtain the coaxiality deviation.

Object	**G25**
Checking of the squareness of the facing head rotation axis relative to the table movement (X axis). NOTE This check is valid only when the facing head is mounted on bearings independent of those of the boring spindle.	

Diagram



Tolerance	**Measured deviation**
0,02/500 (500 is the distance between the two measuring points touched.)	

Measuring instruments

Linear displacement sensor/rigid support and square block

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

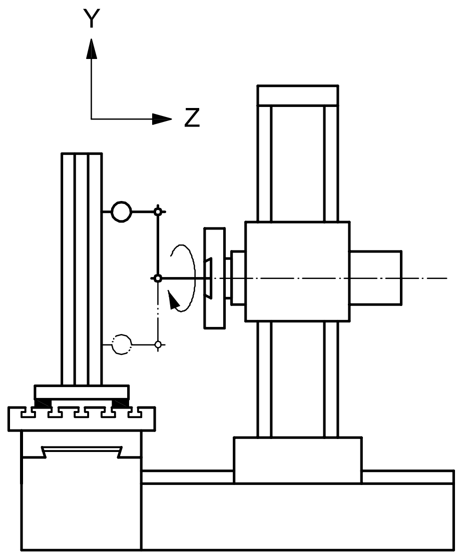
The spindle head shall be locked in mid-travel (Z axis) and the spindle shall be retracted.

The column shall be locked in the position nearest to the table.

Place the stylus of the linear displacement sensor on the facing head against the square block on the table.

Turn the facing head with the linear displacement sensor and move the table so as to touch the square block with the stylus at the same point.

The difference between the two readings divided by the distance between the two measuring points defines the squareness deviation.

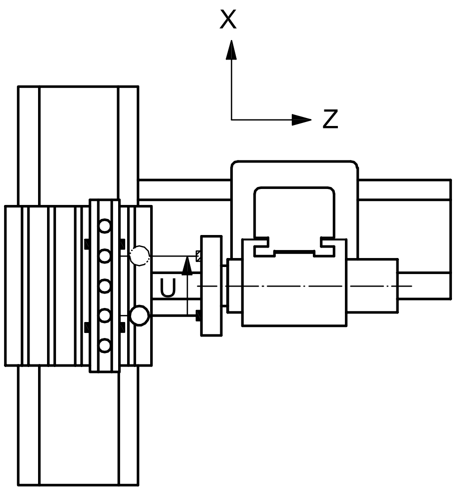
Object		**G26**
Checking of the squareness of the facing head rotation axis in relation to the spindle head movement (Y axis). NOTE This check is valid only when the facing head is mounted on bearings independent of those of the boring spindle.		
Diagram 		
Tolerance 0,02/500 (500 is the distance between the two measuring points touched.)	**Measured deviation**	
Measuring instruments Linear displacement sensor/rigid support, surface plate, gauge blocks and cylindrical square		
Observations and references to ISO 230-1:1996 **5.512.1 and 5.512.32** The spindle head shall be locked in mid-travel and the spindle shall be retracted. Set a cylindrical square on the table parallel to the spindle head movement (Y axis). Fix a linear displacement sensor to the facing head and place its stylus such that it can touch the cylindrical square. Turn the facing head with the linear displacement sensor so that it touches the cylindrical square. The difference between the two readings divided by the distance between the two measuring points defines the squareness deviation.		

Object **G27**

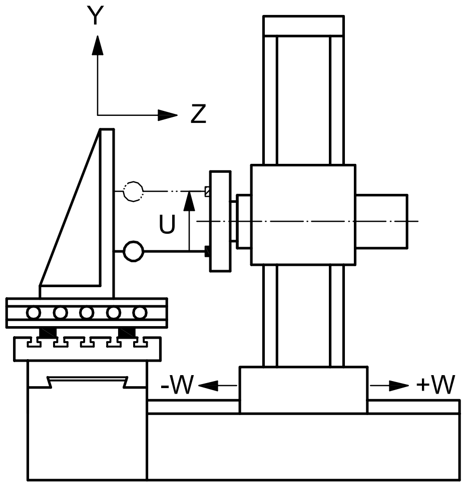
a) Checking of the parallelism of the radial facing slide movement (U axis) in the horizontal plane relative to the table movement (X axis).

b) Checking of the squareness of the radial facing slide movement (U axis) in the vertical plane relative to the column movement (W axis).

Diagram



a)



b)

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

Measuring instruments

a) Straightedge, linear displacement sensor/support and gauge blocks

b) Straightedge, square, linear displacement sensor/support and gauge blocks

Observations and references to ISO 230-1 :1996

a) 5.422.2 and 5.422.5

Set a straightedge horizontally on the table parallel to the table movement (X axis), using a linear displacement sensor fixed on the radial facing slide of the facing head.

Move the radial facing slide (U axis), and record the difference of the readings.

Repeat the test after turning the facing head by 180°.

b) 5.522.4

Set a straightedge vertically on the table parallel to the column movement (W axis), using a linear displacement sensor fixed on the radial facing slide of the facing head and place a square on it.

The stylus of linear displacement sensor fixed on the radial facing slide touches the square.

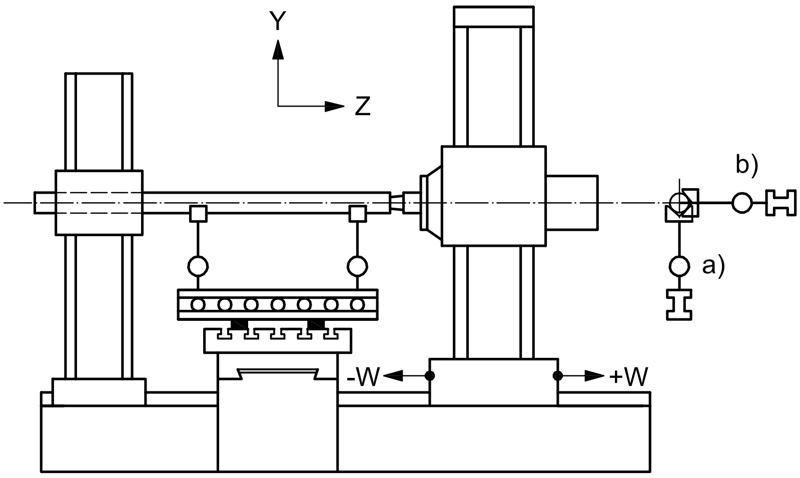
Move the radial facing slide vertically and record the difference between the readings.

Repeat the same operation after turning the facing head by 180°.

7.9 Steady block

Object	G28
Checking of the coincidence of the steady block bore with the boring spindle axis: a) in the vertical plane (YZ plane) (for machines having synchronized movements of the steady block and spindle head); b) in the horizontal plane (ZX plane).	

Diagram



Tolerance	Measured deviation
a) 0,04 for a measuring length of 1 000	a)
b) 0,03 for a measuring length of 1 000	b)

Measuring instruments

Linear displacement sensor, straightedge and boring bar or test mandrel

Observations and references to ISO 230-1:1996

Due to the great distance between supports, a cylindrical bar or a test mandrel shall be used having sufficient length to pass completely through the steady block while mounted in the boring spindle when in its retracted position.

A straightedge shall be set parallel to the column movement (W axis) by using a linear displacement sensor set at the ends of the boring bar, then the column shall be locked in mid-travel and the boring bar retracted.

A linear displacement sensor shall be set on the cylindrical bar or test mandrel with the stylus touching the functional surface of the straightedge.

The measurement is made at the two extremities: spindle end and steady block end.

Test a) shall be carried out setting the spindle head and steady block first in the high position, then in the low position, or vice versa.

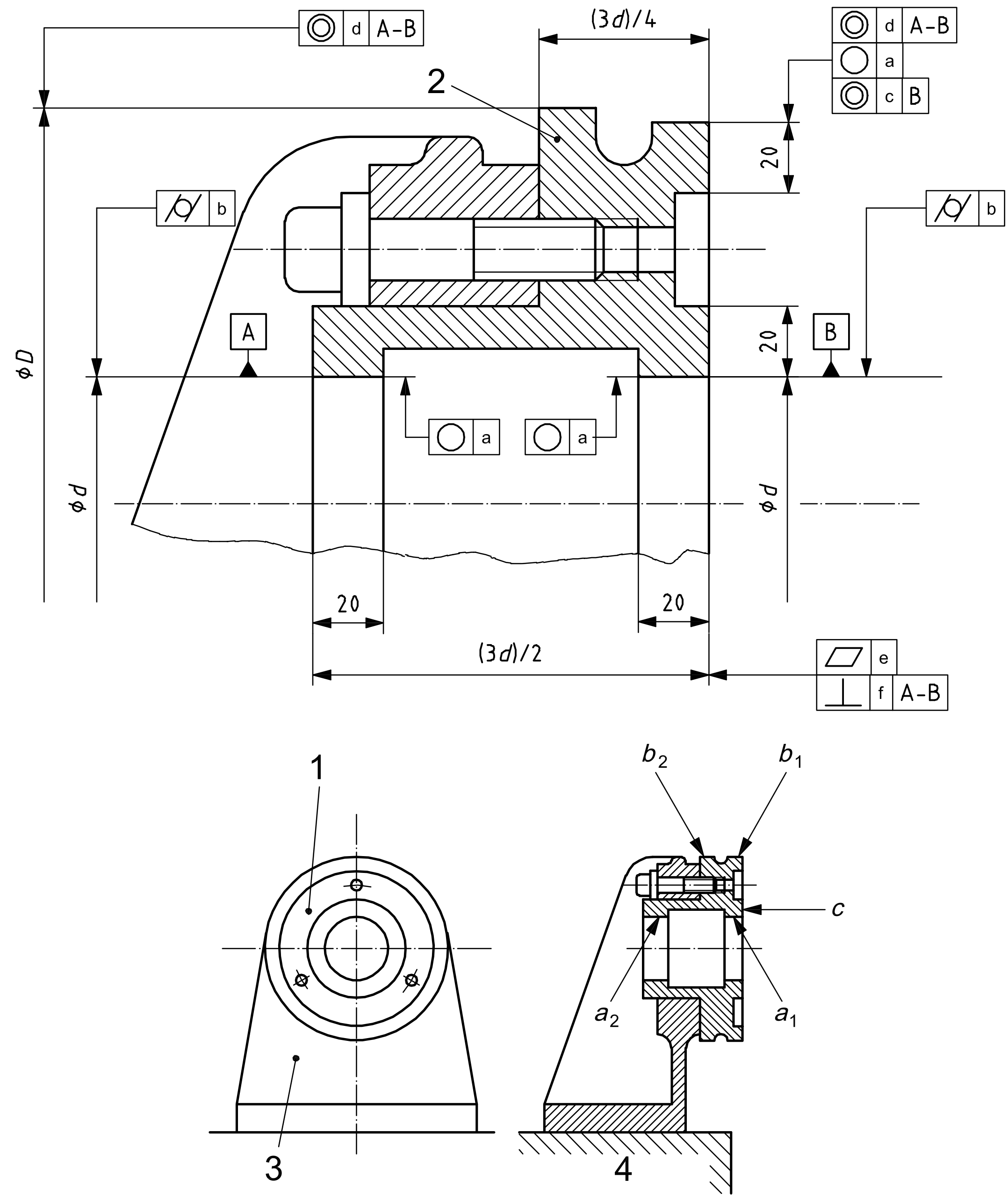
Test b) shall be carried out setting the spindle head and steady block locked in mid-travel and with the table and possibly the table base locked in the central position.

In the case of large machines, it may be desirable to use two short test mandrels, placed on the spindle nose and on the steady block bore, instead of a single mandrel.

8 Machining tests

Nature of test	**M1**
Machining of a single test piece including: a) boring of the internal cylindrical holes, a_1 and a_2; b) turning of the external cylindrical surfaces, b_1 and b_2; c) facing of the surface, c. NOTE Facing testing only applies to machines having both a sliding boring spindle and either an integral or a detachable facing head, or an independent milling spindle.	

Diagram, sizes and mounting of the test piece (given only as an example)



The boring diameter, d, shall be equal to, or slightly greater than, the boring spindle diameter.

The turning diameter, D, shall be determined so that the value [$(D - d)/2$] is equal to or slightly less than the maximum travel of the radial facing slide.

NOTE Test piece material: cast iron.

Key

1 test piece

2 test piece detail

3 mounting fixture

4 table

a See No. 1, p. 40.

b See No. 2, p. 40.

c See No. 3, p. 40.

d See No. 4, p. 40.

e See No. 5, p. 40.

f See No. 6, p. 40.

No.	Check to be made	Tolerance	Measured deviation	Measuring instruments	Observations and references to ISO 230-1:1996
1	CIRCULARITY [a] of the internal cylindrical holes, a_1 and a_2, and of the external cylindrical surface, b_1 (ISO 1101:2004, 18.3): — machined from the sliding spindle; — machined from column movement.	a_1 and a_2: $d \leqslant 125$: 0,007 5 $d > 125$: 0,01 b_1: $D \leqslant 300$: 0,01 $300 < D \leqslant 600$: 0,015 For each 300 mm increase in diameter, add 0,005.		Bore gauge and micrometer or measuring instruments having the appropriate measurement uncertainty	3.1, 3.22, 4.1, 4.2, 5.442, 5.512.42 and 5.611.3 Before commencing the test, ensure that the mounting surface which bears on the table is flat and that the test piece surface which bears on the mounting is square to the axis of its housing. DIRECTIONS FOR MACHINING 1) Boring and finishing of the two internal cylindrical holes, a_1 and a_2. These holes are machined by axial movement of the sliding boring spindle. 2) Turning of external cylindrical surface b_1. Short tool mounted on the facing head with column movement. 3) Movement of the column or ram of 300 mm and turning of external cylindrical surface b_2. Tool mounted on the facing head with the aid of a support or a tool holder having a suitable length. 4) Machining of surface c by automatic movement of the radial facing slide or by milling.
2	CYLINDRICITY [a] of the internal cylindrical holes, a_1 and a_2 (ISO 1101:2004, 18.4)	$d \leqslant 125$: 0,01 $d > 125$: 0,015			
3	CONCENTRICITY of the internal cylindrical hole a_1 and of the external cylindrical surface b_1 (ISO 1101:2004, 18.13).	0,025		Mandrel and linear displacement sensor	
4	COAXIALITY of the external cylindrical surfaces, b_1 and b_2, with the reference axis of the internal cylindrical holes, a_1 and a_2 (ISO 1101:2004, 18.13)	0,04 for a longitudinal movement of column of 300 mm		Mandrel and linear displacement sensor	
5	FLATNESS of the machined surface (ISO 1101:2004, 18.2)	0,015 for a diameter of 300 mm		Straightedge and gauge blocks	
6	SQUARENESS of the machined surface, c, with the reference axis of the internal cylindrical holes, a_1 and a_2 (ISO 1101:2004, 18.10)	0,025 for a diameter of 300 mm		Mandrel and linear displacement sensor or level and special support	

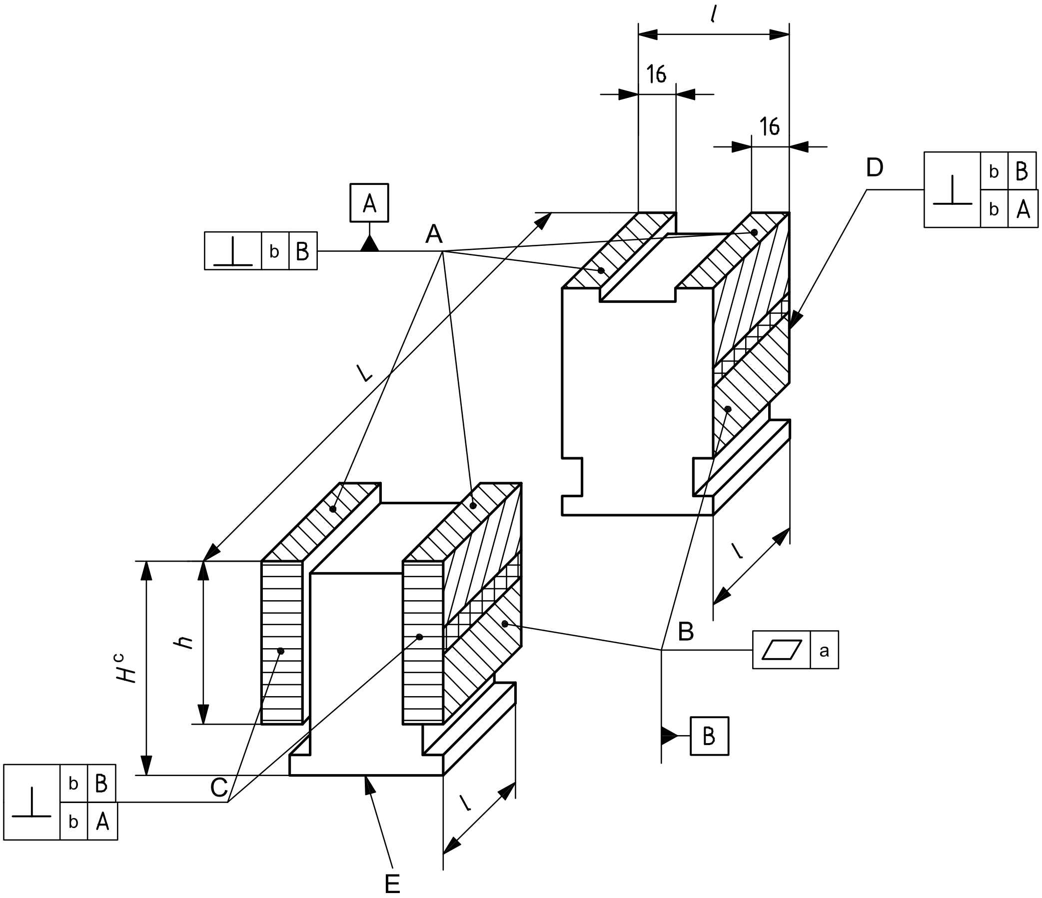
NOTE Definitions of circularity and cylindricity tolerances are given in ISO 1101.

Nature of test	M2
a) Milling of strips of surfaces A, C and D by automatic X-axis movement of the table, automatic vertical movement of the spindle head and manual W axis movement of the column saddle. b) Milling of surface B by automatic X-axis movement of the table and manual vertical movement of the spindle head at least in two cuts overlapping by about 5 to 10 mm.	

Diagram and dimensions of test pieces

$l = h$ = 150 mm for $L \leqslant$ 1 000 mm

l = 200 mm for $L >$ 1 000 mm



(Length of the test piece or distance between the opposite faces of two test pieces)
L = ½ X-axis travel of the table

Material: cast iron

a See No. 1, p. 42.

b See No. 2, p. 42.

c See No. 3, p. 42.

No.	Check to be applied	Tolerance	Measured deviation	Measuring instruments	Observations and references to ISO 230-1:1996
1	Surface B on each block shall be flat.	0,02		Surface plate, linear displacement sensor, coordinate measuring machine	
2	The planes containing the strips of surface A, C, and D shall be perpendicular to each other and to surface B.	0,02 for measuring length of 100		Square and gauge blocks	3.1, 3.22, 4.1, 4.2, 5.321 and 5.325.
3	The height, H, of the block (or blocks) shall be constant	0,03		Height gauge	

Cutting conditions and cutters

For a), with a shell end mill, mounted at the end of the spindle on a mandrel of a suitable length.

For b), face milling with the same cutter.

The cutter shall be sharpened on its arbor and, when mounted, shall conform to the following tolerances:

1) out of round (see ISO 1101) $\leqslant$ 0,01;

2) run-out $\leqslant$ 0,02;

3) camming $\leqslant$ 0,03.

Procedure

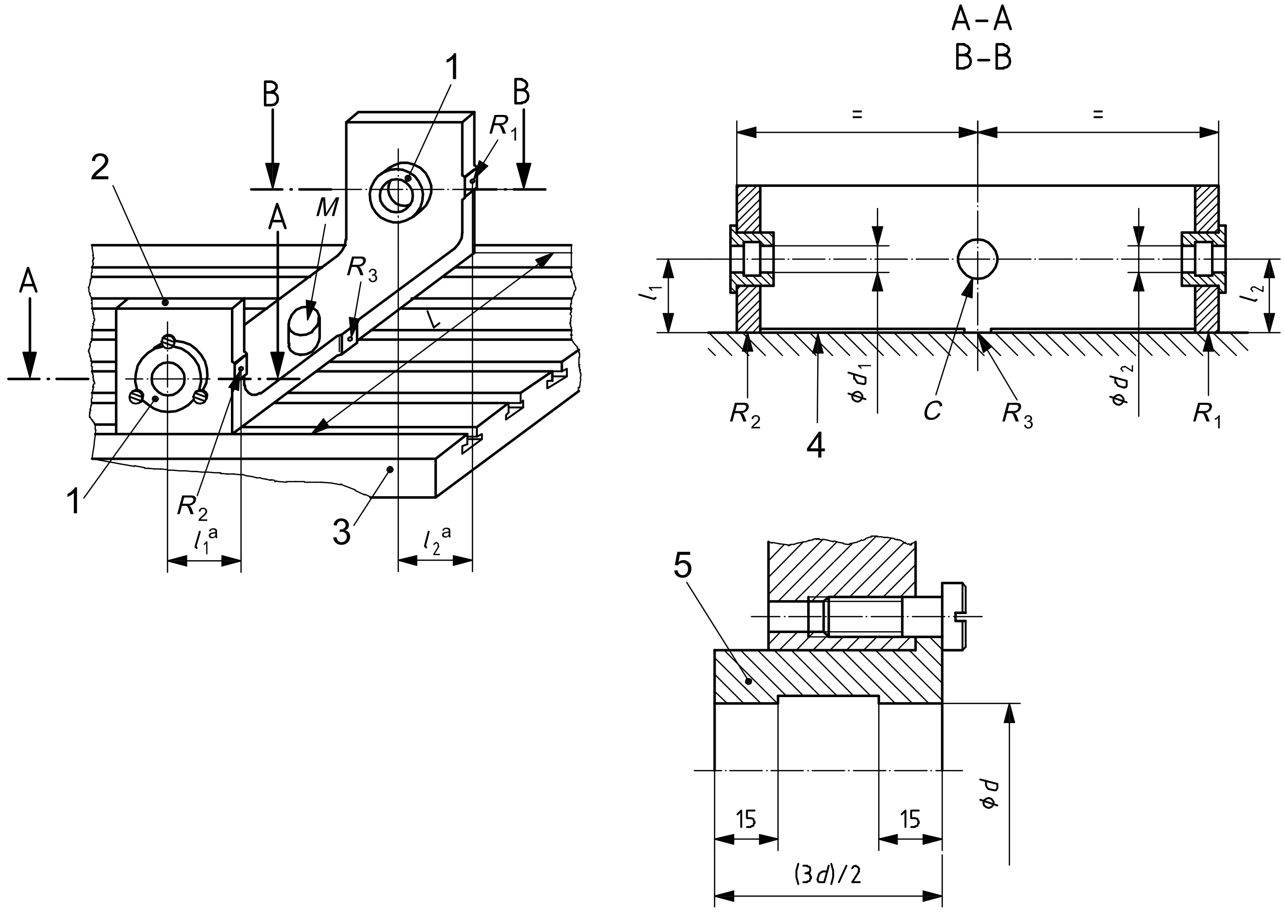
Before beginning the test, ensure that surface E is flat.

Test pieces shall be aligned parallel to the direction of the X-axis movement of the table so that the length, L, is equally distributed on either side of the table centre.

All non-operating slides shall be locked during cutting.

Nature of test	M3
Boring and finishing of two pieces mounted opposite each other on a single axis parallel with the surface and in a vertical plane coaxial with the centre of rotation of the table.	

Diagram and dimensions of test pieces



Key

1 test piece
2 mounting fixture
3 table
4 surface plate
5 test piece detail
C bore
M plug

The fixture length, L, shall be equal to, or slightly less than, the table width.

The bore diameters, d_1 and d_2, shall be equal to, or slightly greater than, half of the boring spindle diameter.

The upper right diagram (detail) shows the setup for measuring.

NOTE Test piece material: cast iron (CG8).

a See a), b), c), page 44.

Check to be made	Tolerance	Measured deviation	Measuring instruments	Observations and references to the ISO 230-1:1996
Checking the equidistance of the axes of the bores d_1 and d_2 in relation to a vertical plane through R_1, R_2 and R_3. (The distances l_1 and l_2 are equal.)	a) For rotary tables with only four fixed indexing positions 90° apart. 0,06 for length L = 1 000. b) For rotary tables with any number of fixed indexing positions 0,1 for length L = 1 000 c) For rotary table with automatic positioning for indexing and rotation 0,15 for length L = 1 000.		Test mandrels and linear displacement sensor/support or gauge blocks or height gauge or coordinate measuring machine.	3.1,3.22, 4.1, 4.2 and 5.432.1 When performing this test, the test pieces shall not be dismantled from the fixture (or support). The fixture with the test pieces mounted in it can be laid on a surface plate. Before commencing the test, ensure that the fixture surface which bears on the table is flat and that the bore axes intended for supporting the test pieces and the axis of centring, C, are equidistant from a vertical reference plane defined by the three blocks R_1, R_2 and R_3.

Procedure

Before mounting the fixture on the table, ensure that the axis of rotation of the table is situated exactly in the vertical plane through the boring spindle axis, then lock the table base on its slideways.

Arrange the mounting fixture on the table so that its centre bore, C, coincides exactly with the axis of rotation of the table, possibly using a plug, M.

Rotate the mounting fixture on the table, setting the reference blocks, R_1 and R_2, in a vertical plane through the boring spindle axis.

Clamp the mounting fixture on the table and assemble the test pieces as shown in the diagram.

Bore the first test piece to diameter, d.

Rotate the table by 180° and bore the second test piece similarly.

9 Checking accuracy and repeatability of positioning by numerical control

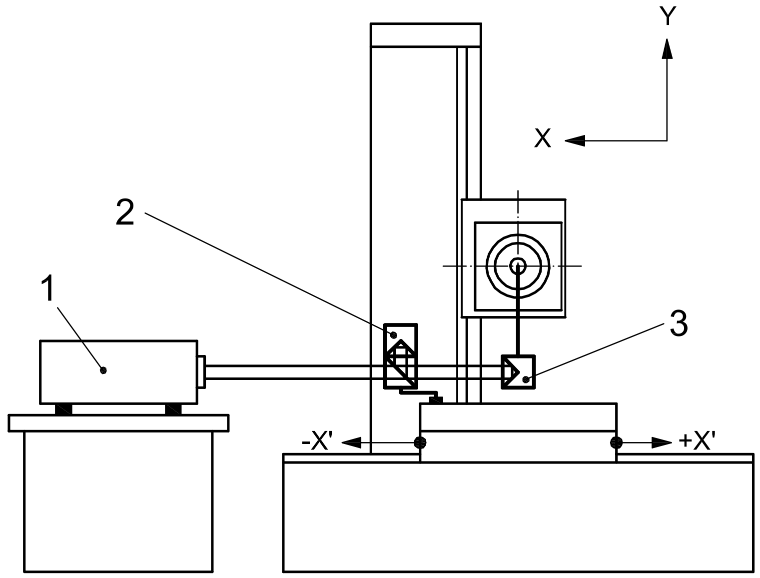
The tests are applied only to horizontal boring and milling machines, numerically controlled for linear and rotary positioning axes.

In performing the tests, reference should be made to ISO 230-2, especially for the environmental conditions, warming up of the machine, measuring methods, evaluation and interpretation of the results.

Object **P1**

Checking of the accuracy and repeatability of positioning of the table movement (X axis) by numerical control.

Diagram



Key
1 laser head
2 interferometer
3 reflector

Tolerance		Measured length			Measured deviation
		⩽ 500	⩽ 1 000	⩽ 2 000	
Bidirectional accuracy of positioning [a]	A	0,014	0,020	0,022	
Unidirectional repeatability of positioning [a]	$R\uparrow$ or $R\downarrow$	0,007	0,009	0,011	
Bidirectional repeatability of positioning	R	0,011	0,014	0,017	
Mean reversal value of the axis	$\overline{B}$	0,005	0,006	0,008	
Bidirectional systematic deviation of positioning [a]	E	0,008	0,011	0,013	
Range of the mean bidirectional positional deviation of the axis [a]	M	0,003	0,005	0,006	

[a] May provide a basis for machine acceptance.

Measuring instruments

Laser measurement equipment or standard length scale and microscope

Observations and references to ISO 230-2:2006 **Clause 2, 4.3.2 and 4.3.3**

The standard length scale or axis of the beam of the laser measurement equipment shall be set parallel to the travelling axis.

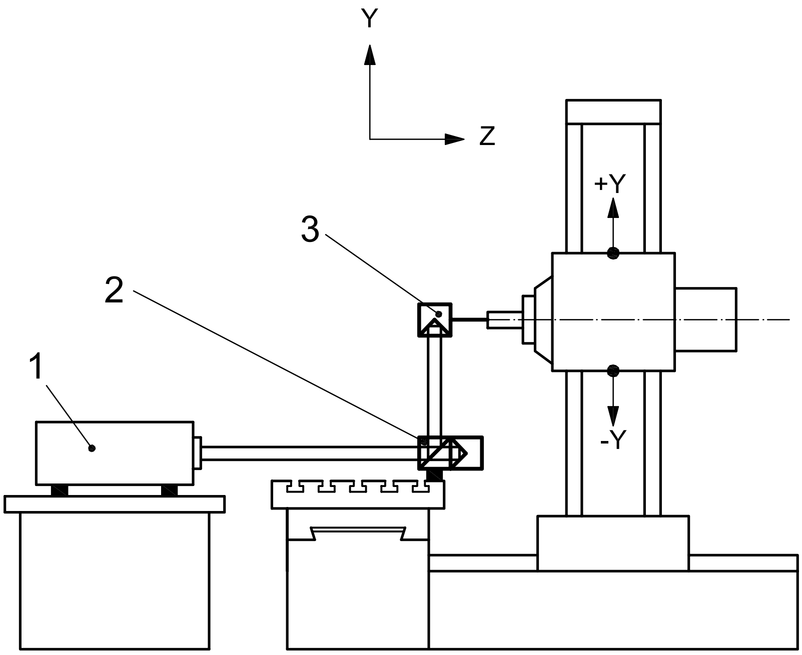
Rapid feed is used for positioning in principle, but an arbitrary feed rate may be used by agreement between the user and the supplier/manufacturer.

The position of the starting point of measurement shall be stated.

Object | **P2**

Checking of the accuracy and repeatability of positioning of the spindle head movement (Y axis) head by numerical control.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance		Measured length			Measured deviation
		⩽ 500	⩽ 1 000	⩽ 2 000	
Bidirectional accuracy of positioning [a]	A	0,014	0,020	0,022	
Unidirectional repeatability of positioning [a]	$R\uparrow$ or $R\downarrow$	0,007	0,009	0,011	
Bidirectional repeatability of positioning	R	0,011	0,014	0,017	
Mean reversal value of the axis	$\overline{B}$	0,005	0,006	0,008	
Bidirectional systematic deviation of positioning [a]	E	0,008	0,011	0,013	
Range of the mean bidirectional positional deviation of the axis [a]	M	0,003	0,005	0,006	

[a] May provide a basis for machine acceptance.

Measuring instruments

Laser measurement equipment or standard length scale and microscope

Observations and references to ISO 230-2:2006 **Clause 2, 4.3.2 and 4.3.3**

The standard length scale or axis of the beam of the laser measurement equipment shall be set parallel to the travelling axis.

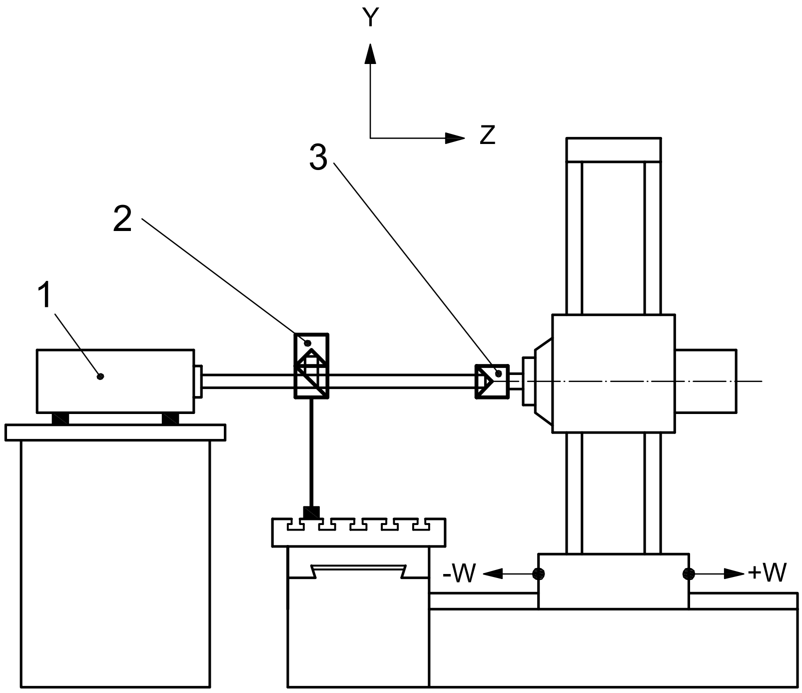
Rapid feed is used for positioning in principle, but an arbitrary feed rate may be used by agreement between the user and the supplier/manufacturer.

The position of the starting point of measurement shall be stated.

Object **P3**

Checking of the accuracy and repeatability of positioning of the column saddle movement (W axis) by numerical control.

Diagram



Key

1 laser head

2 interferometer

3 reflector

Tolerance		Measured length			Measured deviation
		⩽ 500	⩽ 1 000	⩽ 2 000	
Bidirectional accuracy of positioning [a]	A	0,014	0,020	0,022	
Unidirectional repeatability of positioning [a]	$R\uparrow$ or $R\downarrow$	0,007	0,009	0,011	
Bidirectional repeatability of positioning	R	0,011	0,014	0,017	
Mean reversal value of the axis	$\overline{B}$	0,005	0,006	0,008	
Bidirectional systematic deviation of positioning [a]	E	0,008	0,011	0,013	
Range of the mean bidirectional positional deviation of the axis [a]	M	0,003	0,005	0,006	

[a] May provide a basis for machine acceptance.

Measuring instruments

Laser measurement equipment or standard length scale and microscope

Observations and references to ISO 230-2:2006 **Clause 2, 4.3.2 and 4.3.3**

The standard length scale or axis of the beam of the laser measurement equipment shall be set parallel to the travelling axis.

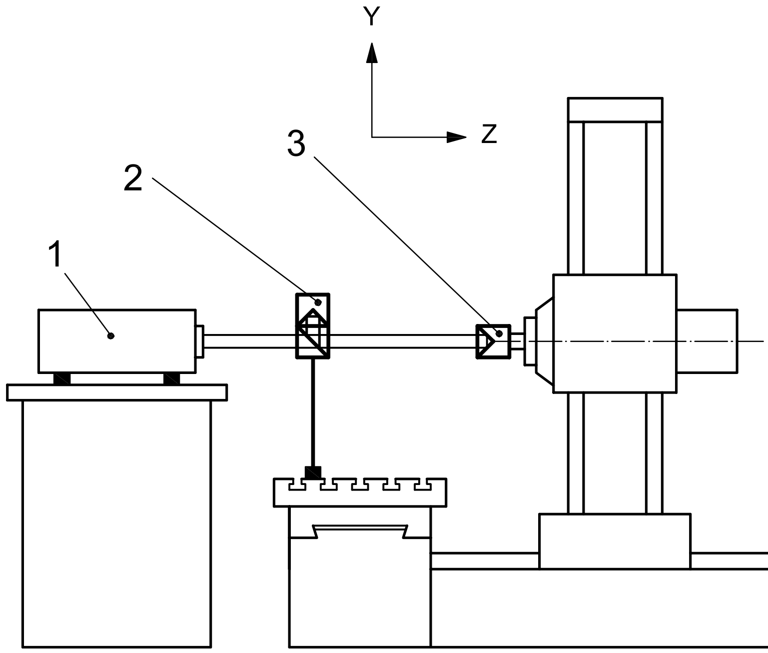
Rapid feed is used for positioning in principle, but an arbitrary feed rate may be used by agreement between the user and the supplier/manufacturer.

The position of the starting point of measurement shall be stated.

Object | **P4**

Checking of the accuracy and repeatability of positioning of the sliding boring spindle or ram movement (Z axis) of the table by numerical control.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance		Measured length		Measured deviation
		⩽ 500	⩽ 1 000	
Bidirectional accuracy of positioning [a]	A	0,017	0,022	
Unidirectional repeatability of positioning [a]	$R\uparrow$ or $R\downarrow$	0,007	0,011	
Bidirectional repeatability of positioning	R	0,014	0,017	
Mean reversal value of the axis	$\overline{B}$	0,006	0,008	
Bidirectional systematic deviation of positioning [a]	E	0,010	0,012	
Range of the mean bidirectional positional deviation of the axis [a]	M	0,004	0,005	

[a] May provide a basis for machine acceptance.

Measuring instruments

Laser measurement equipment or standard length scale and microscope

Observations and references to ISO 230-2:2006 **Clause 2, 4.3.2 and 4.3.3**

The standard length scale or axis of the beam of the laser measurement equipment shall be set parallel to the travelling axis.

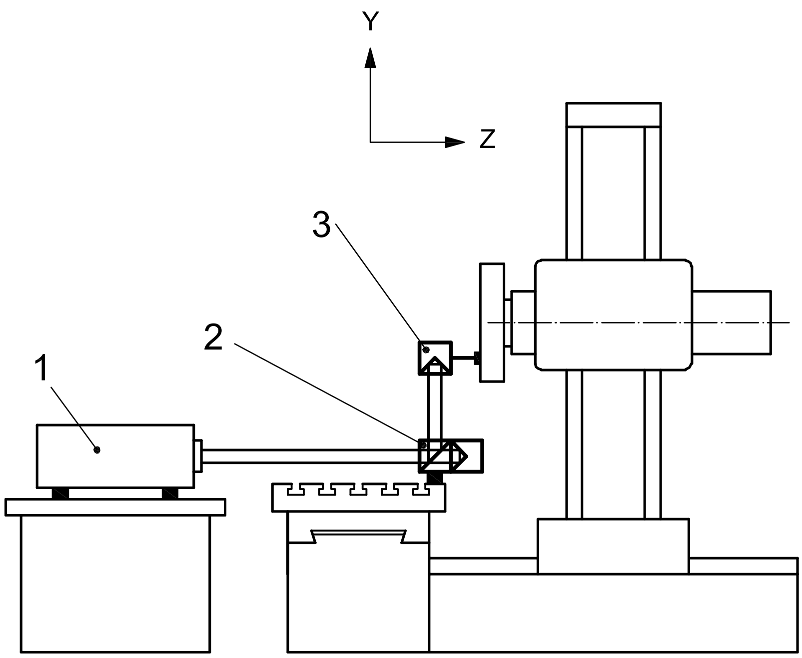
Rapid feed is used for positioning in principle, but an arbitrary feed rate may be used by agreement between the user and the supplier/manufacturer.

The position of the starting point of measurement shall be stated.

Object **P5**

Checking of the accuracy and repeatability of positioning of the radial facing slide movement (U axis) by numerical control.

Diagram



Key

1 laser head
2 interferometer
3 reflector

Tolerance		Measured length		Measured deviation
		⩽ 500	⩽ 1 000	
Bidirectional accuracy of positioning [a]	A	0,017	0,022	
Unidirectional repeatability of positioning [a]	$R\uparrow$ or $R\downarrow$	0,009	0,011	
Bidirectional repeatability of positioning	R	0,014	0,017	
Mean reversal value of the axis	$\overline{B}$	0,006	0,008	
Bidirectional systematic deviation of positioning [a]	E	0,010	0,012	
Range of the mean bidirectional positional deviation of the axis [a]	M	0,004	0,005	

[a] May provide a basis for machine acceptance.

Measuring instruments

Laser measurement equipment or standard length scale and microscope

Observations and references to ISO 230-2:2006 **Clause 2, 4.3.2 and 4.3.3**

The standard length scale or axis of the beam of the laser measurement equipment shall be set parallel to travelling axis.

Rapid feed is used for positioning in principle, but an arbitrary feed rate may be used by agreement between the user and the supplier/manufacturer.

The position of the starting point of measurement shall be stated.

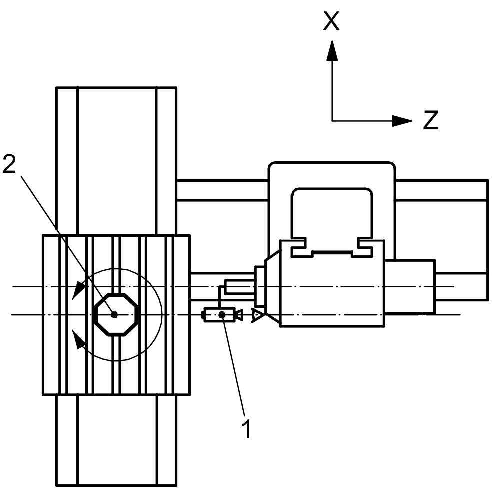
Object | **P6**

Checking of the accuracy and repeatability of angular positioning of a rotary table by numerical control:

a) rotary table with fixed indexing positions;

b) rotary table capable of any angle positioning.

Diagram



Key

1 autocollimator

2 polygon mirror

Tolerance (30° or 45° interval positioning)		For 360° a)	For 360° b)	Measured deviation
Bidirectional accuracy of positioning [a]	A	7 arcsec	11 arcsec	
Unidirectional repeatability of positioning [a]	$R\uparrow$ or $R\downarrow$	4 arcsec	6 arcsec	
Bidirectional repeatability of positioning	R	6 arcsec	8 arcsec	
Mean reversal value of the axis	$\overline{B}$	4 arcsec	6 arcsec	
Bidirectional systematic deviation of positioning [a]	E	4 arcsec	6 arcsec	
Range of the mean bidirectional positional deviation of the axis [a]	M	2 arcsec	4 arcsec	

[a] May provide a basis for machine acceptance.

Measuring instruments

Polygon and autocollimator or laser measuring equipment

Observations and references to ISO 230-2:2006 **Clause 2, 4.3.2 and 4.3.3**

Fix the autocollimator on the fixed part of the machine or independent of the machine and fix the polygon near to the centre of the table in alignment with the autocollimator at the first measuring rotary position.

The target position shall be 30° or 45° intervals or selected according to ISO 230-2.

The angular positioning feed rate is by rapid feed, but may be any feed rate by agreement between the user and the supplier/manufacturer.

10 Geometric accuracy of axes of rotation of tool-holding spindles

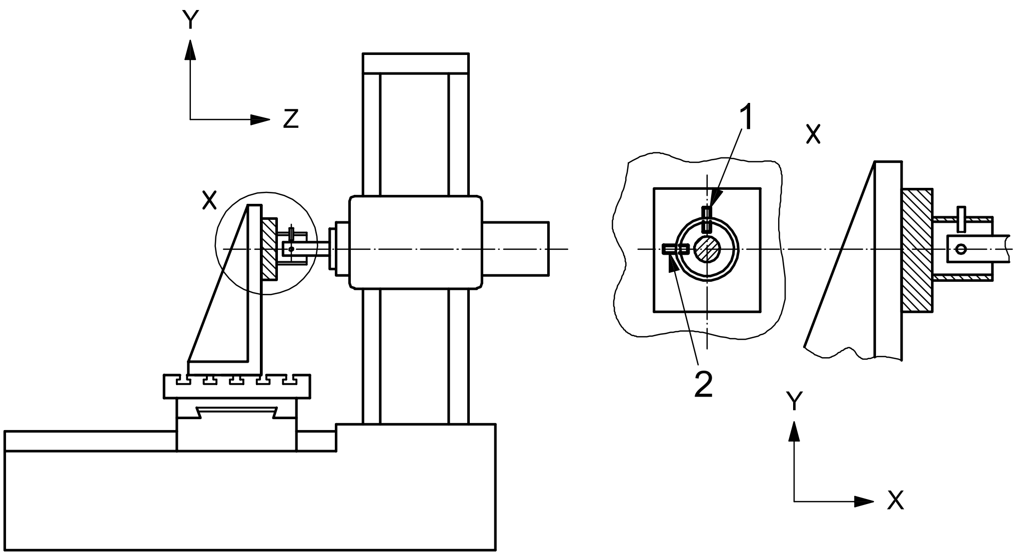
Object — **R1**

Checking of the radial error motion (ERC) of the tool-holding spindle (C).

This test shall be carried out for milling and boring spindles.

NOTE The boring spindle is retracted during the test, where applicable.

Diagram



Key

1 non-contacting linear displacement sensor

2 (second) non-contracting linear displacement sensor

Tolerance

	At percentage of maximum speed		
	10 %	50 %	100 %
Total radial error motion value, ERC	0,010	0,014	0,020

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

Measured deviation

Measuring instruments

Test mandrel or precision sphere, non-contacting linear displacement sensors and – in some cases – angular measuring device

Observations and references to ISO 230-7

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

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

The total error motion is defined in ISO 230-7:2006, 3.2.4 and the total error motion value is given in ISO 230-7:2006, F.3.4.

Total radial error motion value, ERC (using probes 1 and 2)

Radial error motion measurement is described in ISO 230-7:2006, 5.4.2. 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 (ISO 230-7:2006, 3.3.1) with a least-squares circle (LSC) centre (ISO 230-7:2006, 3.4.3) shall be provided.

For these tests the following parameters shall be stated:

— the radial and axial locations at which the measurements are made;

— identification of all artefacts, targets and fixtures used;

— the location of the measurement setup;

— the position of any linear or rotary positioning stages that are connected to the device under test;

— the direction angle of the sensitive direction, e.g. axial, radial or intermediate angles, as appropriate;

— the presentation of the measurement result, for example error motion value, polar plot, time-based plot, frequency content plot;

— the rotational speed of the spindle (zero for static error motion);

— the time duration in seconds or number of spindle rotations;

— the appropriate warm-up or break-in procedure;

— the frequency response of the instrumentation, given as hertz or cycles per revolution, including roll-off characteristics of any electronic filters and, in the case of digital instrumentation, the displacement resolution and sampling rate;

— the 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 could 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*

[2] ISO 3070-1, *Machine tools — Test conditions for testing the accuracy of boring and milling machines with horizontal spindle — Part 1: Machines with fixed column and movable table*

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