INTERNATIONAL STANDARD

**ISO 3070-2**

Third edition
2007-12-15

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

## Part 2: Machines with movable column and fixed table

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

*Partie 2: Machines à montant mobile et à table fixe*



Reference number
ISO 3070-2:2007(E)



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Published 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 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 3070-2 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 3070-3:1997, 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 2: Machines with movable column and fixed 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 fixed table. This part of ISO 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 movements of the column on the bed;

b) vertical movement of the spindle head;

c) axial movement of the spindle;

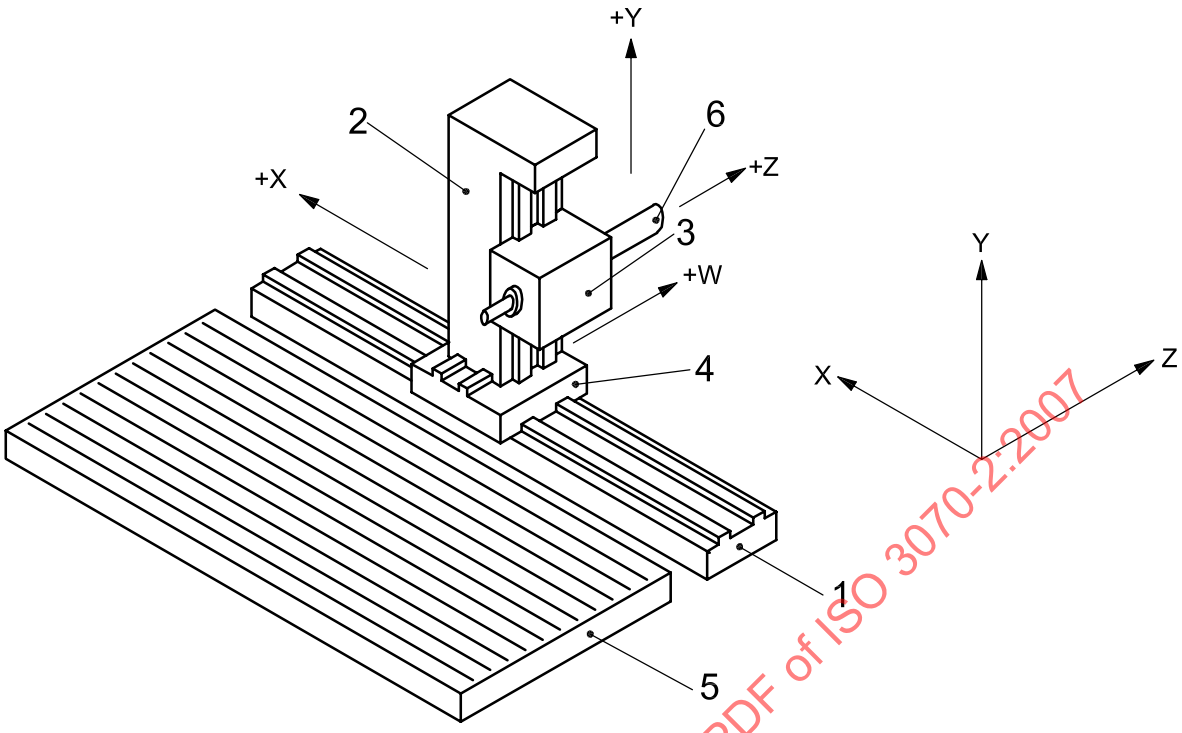
d) possible movement of radial facing slide in the facing head.

It should be noted that the column may be mounted on slideways to achieve a small additional longitudinal feed movement of the column parallel with the spindle axis.

Table 1 provides the nomenclature for various structural components of machines shown in Figure 1. Figure 1 shows a typical configuration of such machines.

**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 | fixed table | table fixe | Aufspanntisch |
| 6 | spindle | broche | Spindel |




NOTE For components 1 to 6, see Table 1.

**Figure 1 — Machine with movable column and fixed table**



## 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 a 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.

### 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

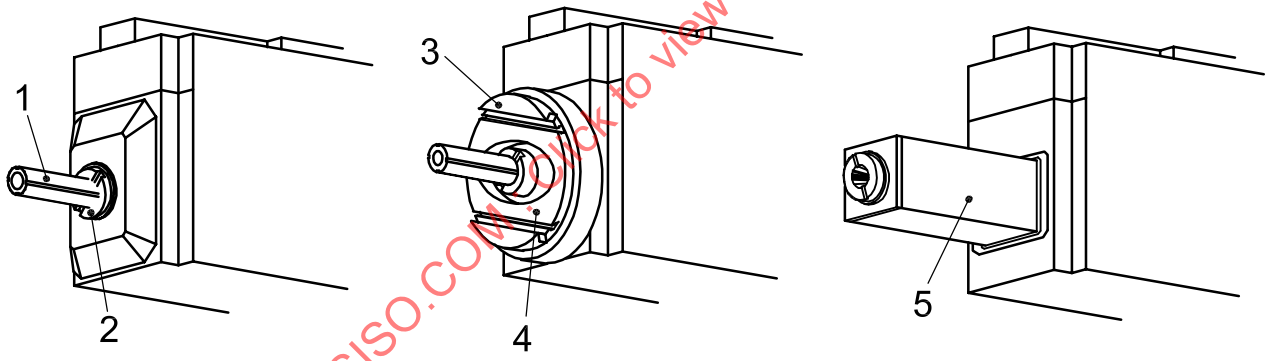
Reference should be made to Figure 2 for examples of the various types of head. Related nomenclature is given in Table 2.

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 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. 0,00$x$/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

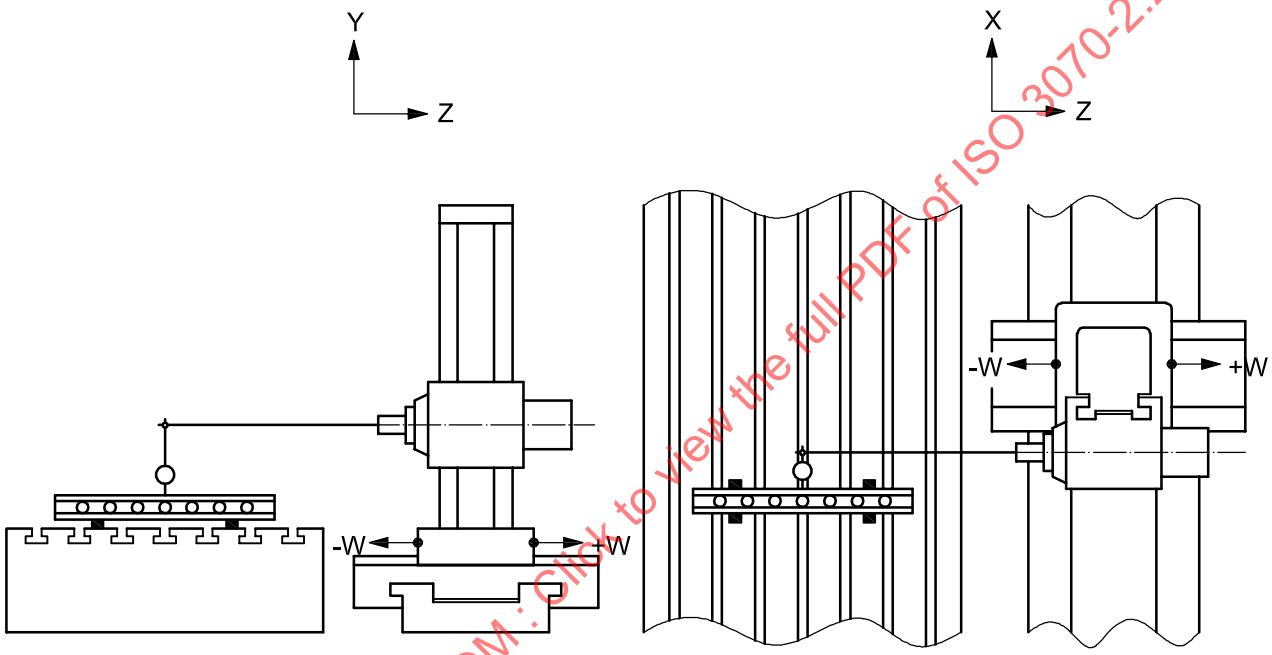
When the tolerance for a geometric test is established for a measuring length different from that given in this part of ISO 3070 (see ISO 230-1:1996, 2.311), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

# 7 Geometric tests

## 7.1 Straightness and angular deviations of linear axes

| **Object** | **G1** |
|---|---|
| Checking of the straightness of the column movement (W axis):<br>a) in the YZ plane (vertical plane) (EYW);<br>b) in the ZX plane (horizontal plane) (EXW).<br>NOTE In the case of column saddle provoked for movement of the column. | |

**Diagram**




a) b)

| **Tolerance** | **Measured deviation** |
|---|---|
| a) and b)<br>0,02 for measuring lengths up to 1 000<br>0,03 for measuring lengths above 1 000<br>Local tolerance: 0,006 for any measuring length of 300 | a)<br>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 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, 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 shall be normal to the reference face of the straightedge.

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

**Object** **G2**

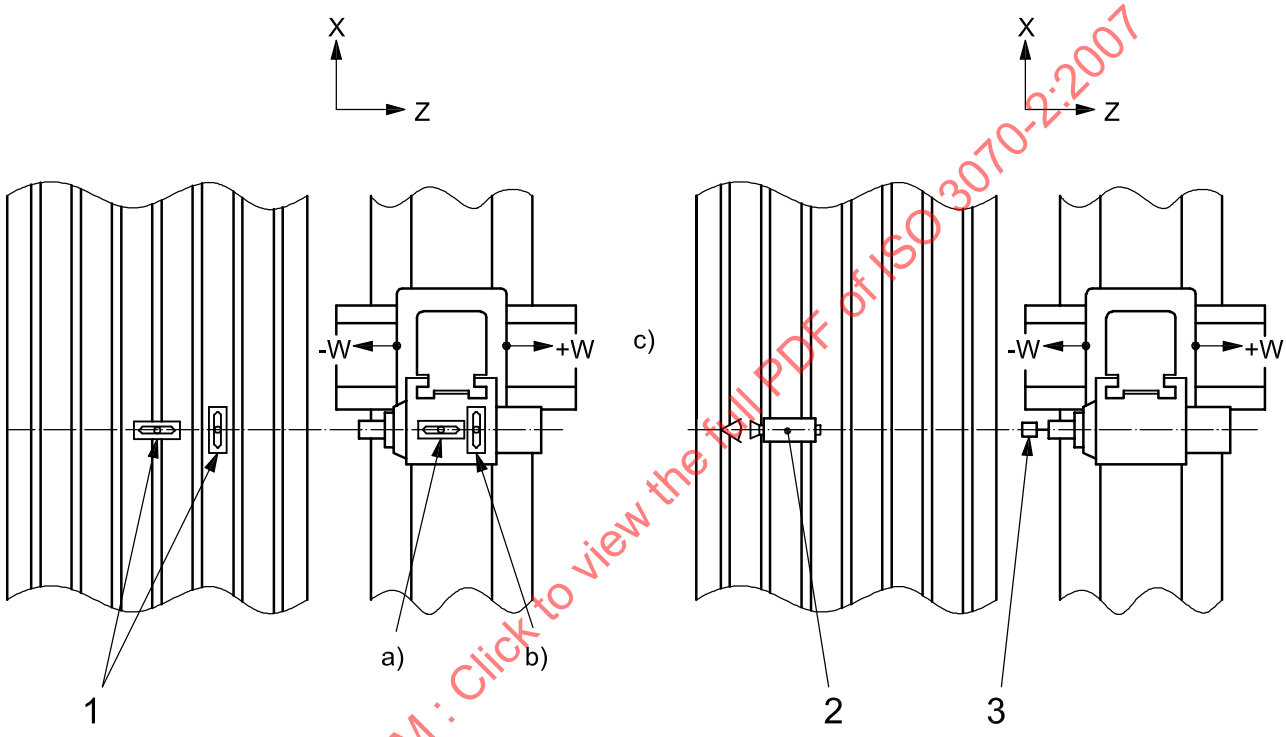
Checking of the angular deviation of the column movement (W axis):

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 fixed table and the spindle head shall be in mid-travel.

When W-axis motion causes an angular movement of both spindle head and fixed 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.

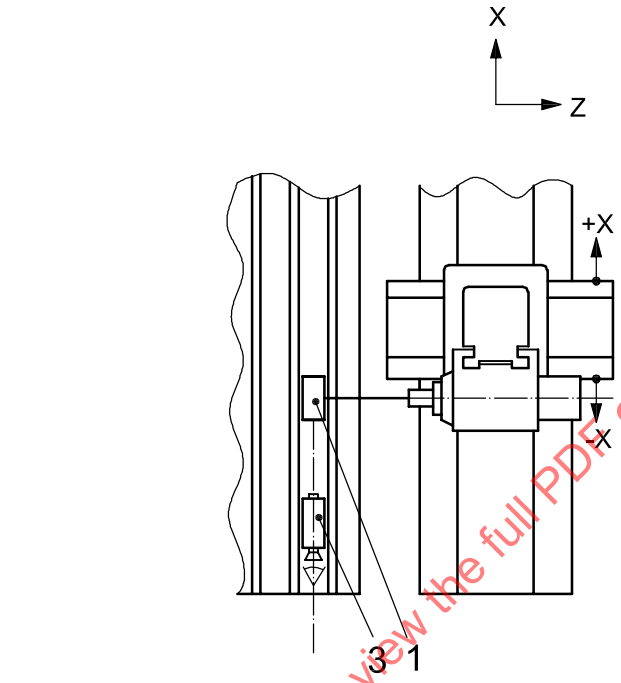
**Object** **G3**

Checking of the straightness of the column saddle movement (X axis):

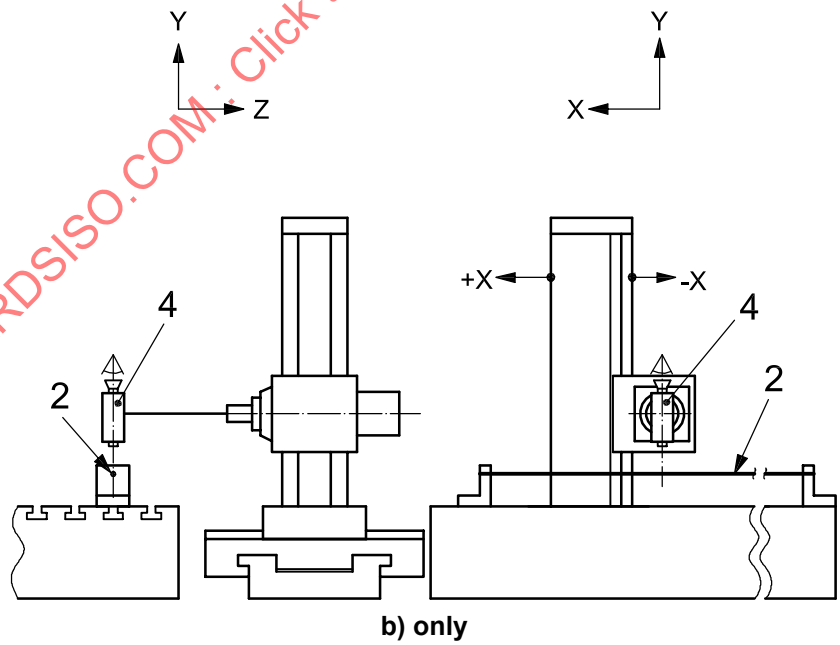
a) in the XY plane (vertical plane) (EYX);

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

**Diagram**




**a) and b)**




**b) only**

**Key**

1 target
2 taut wire
3 telescope
4 microscope

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

**Measuring instruments**

Optical method, microscope and taut wire

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

a) Taut wire is not recommended because of the sag of the wire. The alignment telescope may be fixed vertically on the work-holding table such that the optical beam is parallel to the X-axis movement of the column saddle movement (parallel means that displacement measurement readings at both ends of the movement are the same value.

If the spindle can be locked, the target mirror may be mounted on it. If the spindle cannot be locked, mount the target mirror on the spindle head.

Traverse the column saddle in the X-axis direction and note the readings.

b) When taut wire is used, the microscope shall be fixed on the spindle or spindle head. When the optical method is used, the telescope shall be set horizontally.

**Object** **G4**

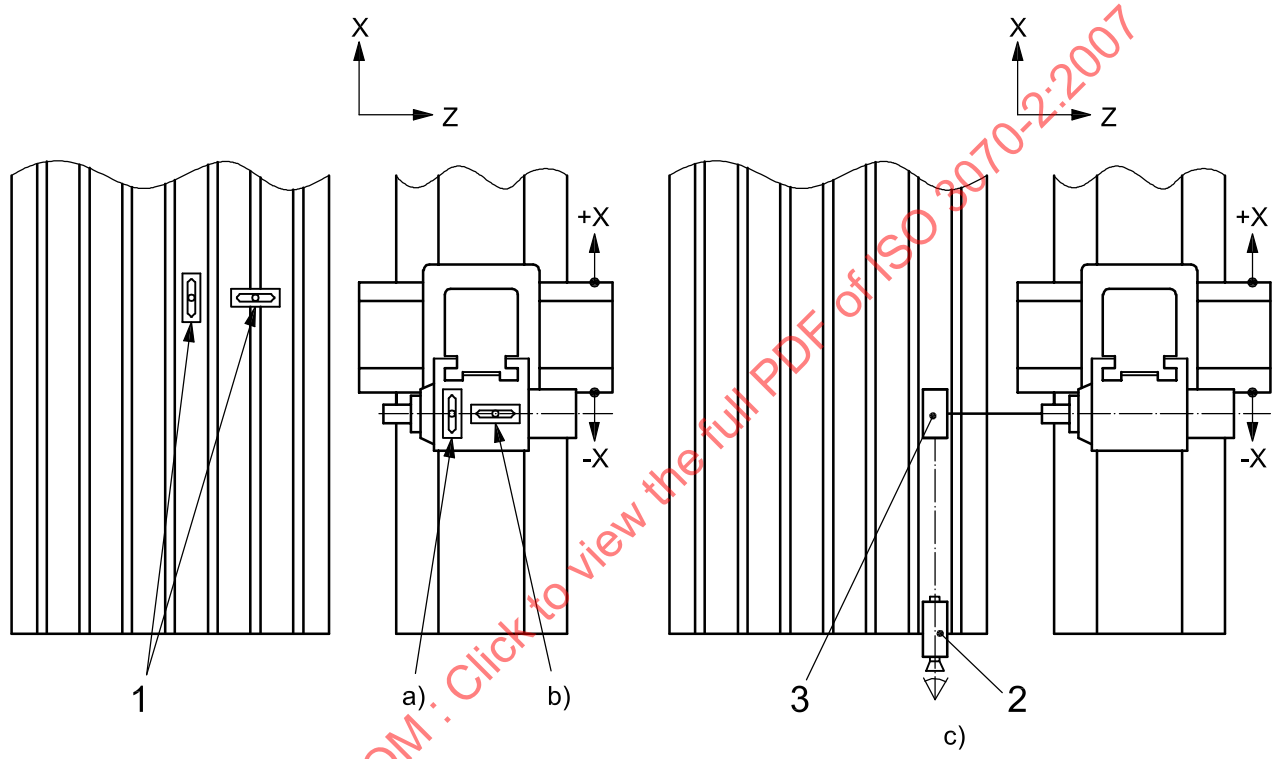
Checking of the angular deviation of the column saddle movement (X axis):

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) | a) |
| $X \leqslant 4\,000$: 0,04/1 000 | b) |
| $X > 4\,000$: 0,06/1 000 | c) |
| Local tolerance: 0,02/1 000 for any measuring length of 300 | |

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

b) (EAX: roll) in the Z-axis direction;

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

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

When X-axis motion causes an angular movement of both spindle head and fixed 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.

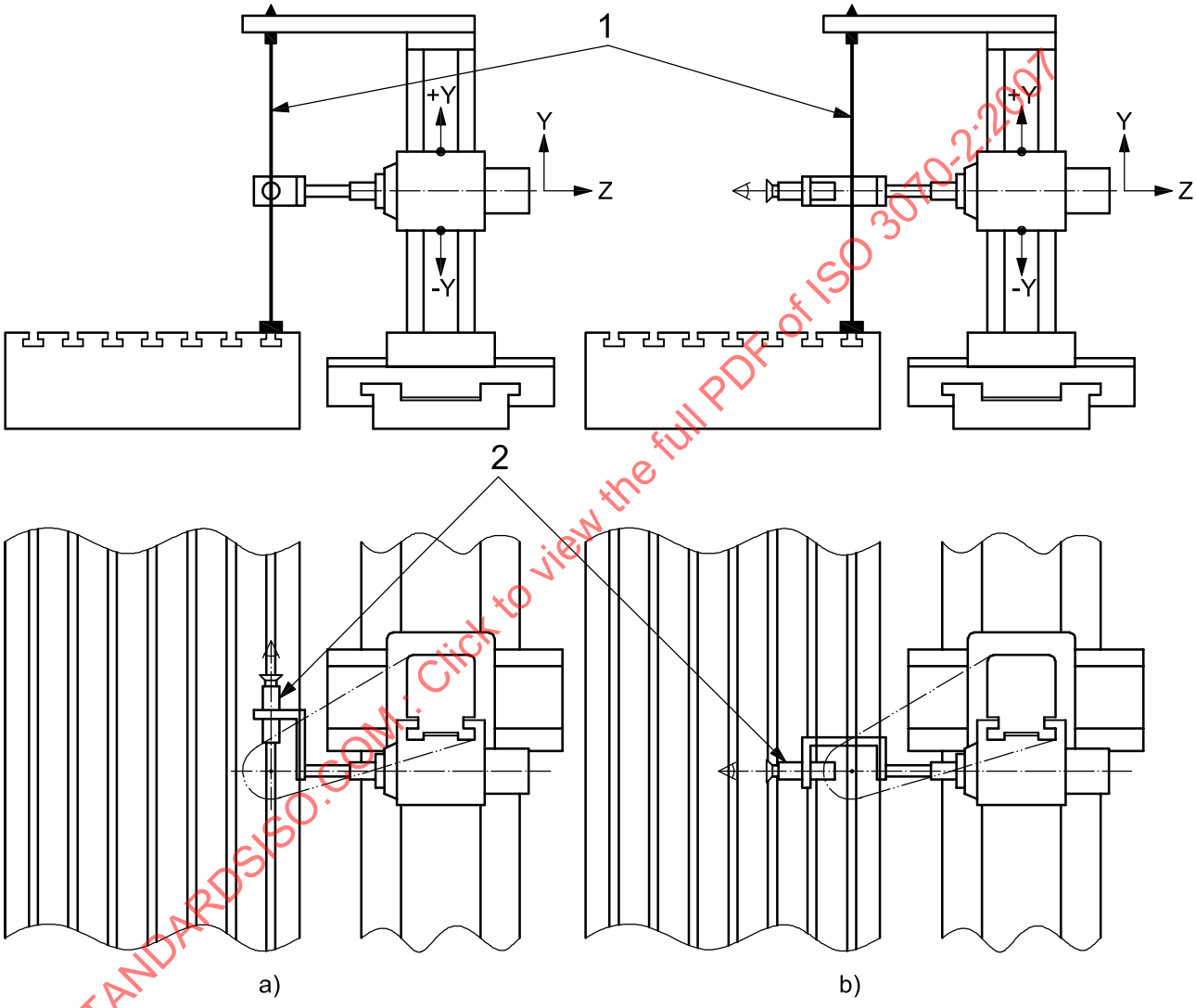
**Object** **G5**

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**




**Key**

1 taut wire

2 microscope

| **Tolerance** | **Measured deviation** |
|---|---|
| a) and b)<br>0,02 for any measuring length up to 1 000<br>Add 0,01 to the preceding tolerance for each 1 000 increase in length up to 4 000.<br>Add 0,02 for each 1 000 increase in length over 4 000. | a)<br>b) |

| **Measuring instruments**<br><br>Microscope and taut wire or optical methods | |
|---|---|
| **Observations and references to ISO 230-1:1996** | **5.232.1, 5.232.12 or 5.232.13** |
| The column saddle shall be locked and the column shall be locked in mid-travel.<br><br>The taut wire shall be tightened between the fixed table and another fixed part on the machine as near as possible to the vertical slideways of the column.<br><br>If the spindle can be locked, the microscope or the alignment telescope may be mounted on it. If the spindle cannot be locked, mount the microscope on the spindle head of the machine. | |

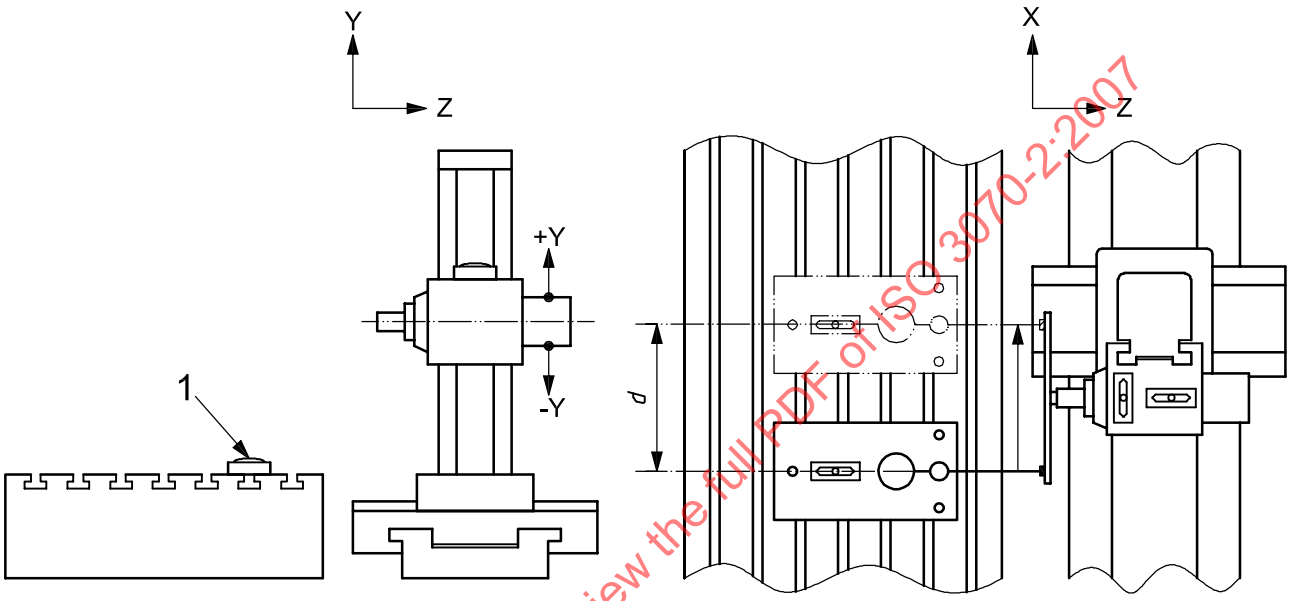
**Object** | **G6**

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) |
| $Y \leqslant 4\,000$: 0,04/1 000 | b) |
| $Y > 4\,000$: 0,06/1 000 | |

**Measuring instruments**

a) Precision level or optical angular deviation measuring instruments;

b) Surface plate, 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 work-holding table in the same direction.

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

b) Mount a surface plate on the fixed 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 surface plate with cylindrical square by the amount of distance, $d$, and adjust the level of the surface plate to that of the first position. Reset the linear displacement sensor, without moving the X axis, so that the stylus touches the cylindrical square again, then note the readings at the same measuring positions of spindle head travel.

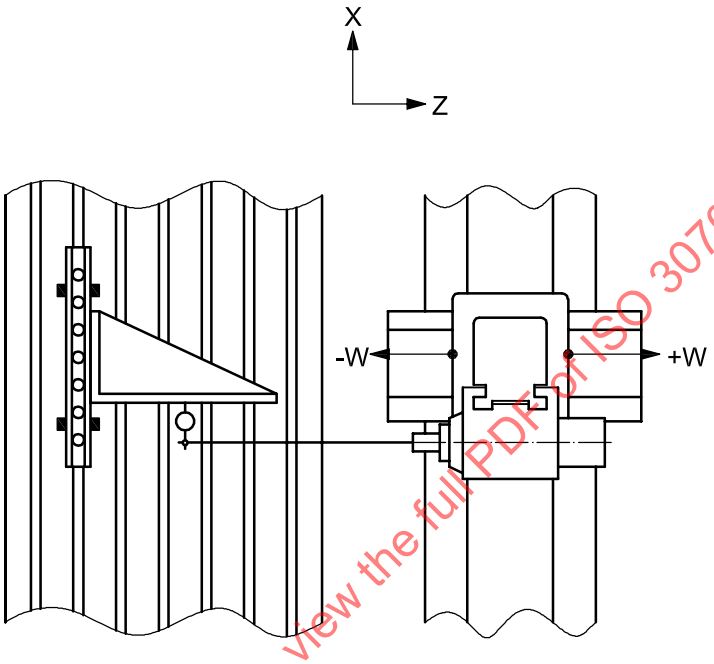
For each measuring position, calculate the differences between two readings, then the difference between maximum and minimum divided by distance, $d$, to give the angular deviation.

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

## 7.2 Squareness between coordinate axes

| **Object** | **G7** |
|---|---|
| Checking of the squareness between the column saddle movement (X axis) and the column movement (W axis). | |

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| 0,03 for any measuring length of 1 000 | |

**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 on the fixed table parallel to the column saddle movement (X 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 saddle in mid-travel on the bed.

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

NOTE This test can be carried out, without using a straightedge, by directly applying the styles of the linear displacement sensor to the two faces of the square.

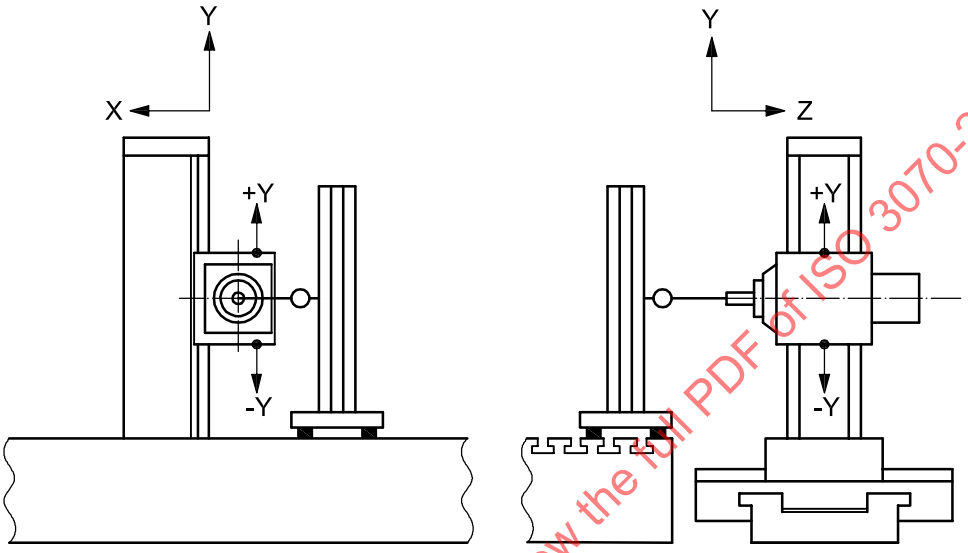
**Object** **G8**

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

a) the column saddle movement (X axis),

b) the column movement (W axis) (only in the case of a column saddle provided for W-axis movement of the column).

**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 fixed table as near as possible to the machine. Adjust it so that its surface is parallel to both column saddle (X-axis) and column (W-axis) movements. Place the cylindrical square on the surface plate.

Lock the column and the 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.

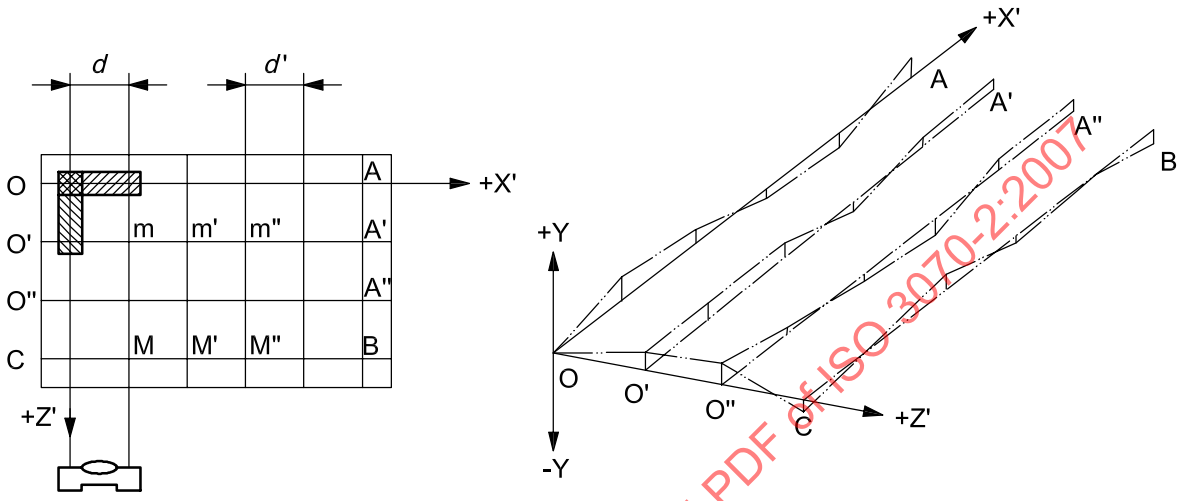
a) Apply the stylus of the linear displacement sensor to the cylindrical square in the X-axis direction and move the head in the Y-axis direction through the measuring length, noting the maximum difference between the readings.

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 Fixed table independent of the machine

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

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| For the longer side, length of O-X or O-Z<br><br>0,05 for measuring lengths up to 1 000<br><br>Add 0,02 to the preceding tolerance for each 1 000 increase in length beyond 1 000.<br><br>Maximum tolerance: 0,15 | |

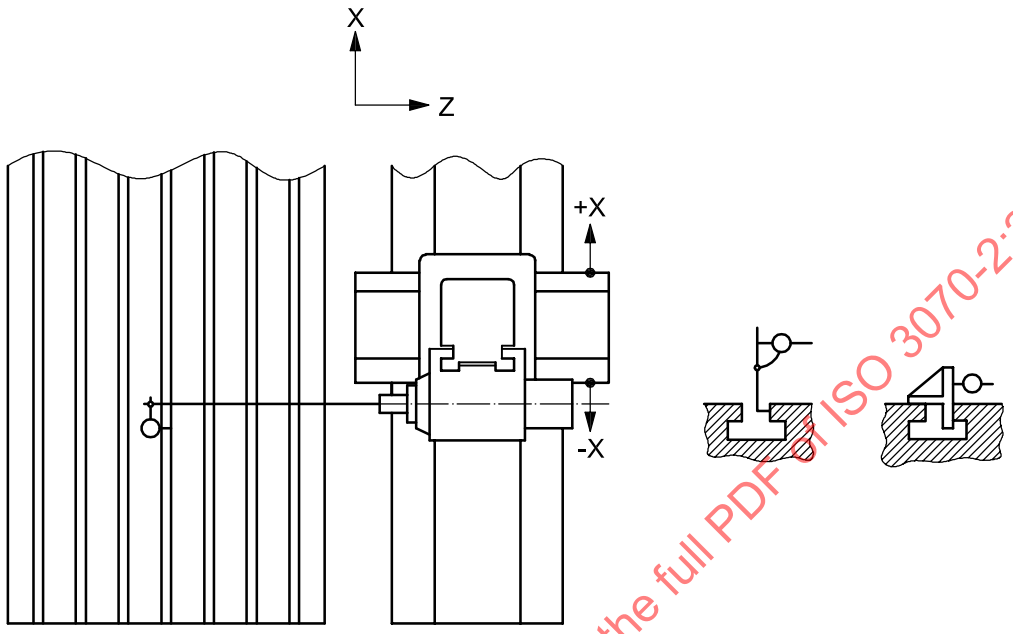
**Measuring instruments**

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**

| **Object** | **G10** |
|---|---|
| Checking of the parallelism of the median or reference T-slot or any other reference face of the fixed table relative to the column saddle movement (X axis). | |

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| 0,09 for any measuring length up to 1 000<br><br>Add 0,025 to the preceding tolerance for each 1 000 increase in length beyond 1 000<br><br>Maximum tolerance: 0,25 | |

**Measuring instruments**

Linear displacement sensor and cross-square

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

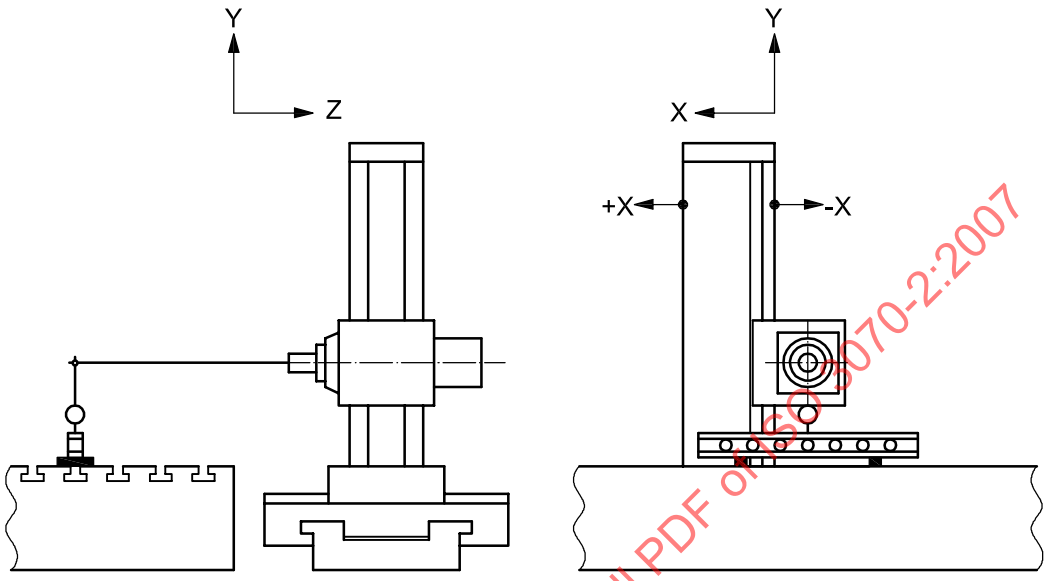
If the spindle can be locked, mount the linear displacement sensor may be mounted on it. If the spindle cannot be locked, mount the linear displacement sensor on the spindle head.

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

**Object** **G11**

Checking of the parallelism of the fixed table surface relative to the column saddle movement (X axis).

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| 0,04 for any measuring length up to 1 000<br><br>Add 0,025 to the preceding tolerance for each 1 000 increase in length beyond 1 000<br><br>Maximum tolerance: 0,30 | |

**Measuring instruments**

Linear displacement sensor, straightedge and gauge blocks or optical method

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

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

Set the straightedge on the fixed table in the X-axis direction parallel to the table surface and traverse column saddle and note the variation in readings.

Without using the straightedge, it is also possible to make direct measurements of the table surface using a linear displacement sensor and gauge block.

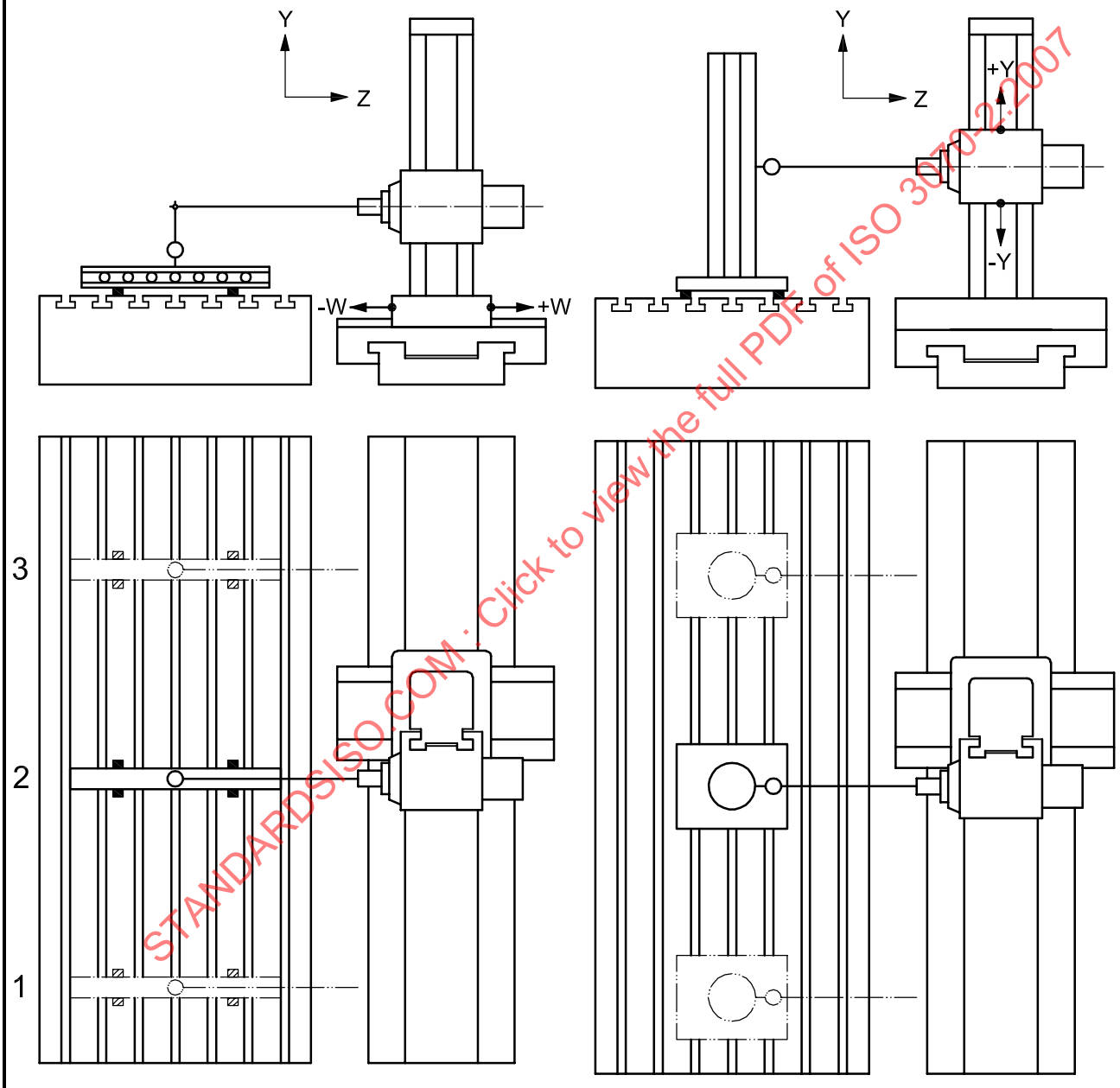
**Object** **G12**

a) Checking of the parallelism of the surface of the fixed table relative to the column movement (W axis).

Alternatively, when the column does not have W-axis motion:

b) Checking of the squareness of the surface of the fixed table relative to the spindle head movement (Y axis).

**Diagram**




**a)** **or** **b)**

**Key**

1 near position
2 middle position
3 end position

| Tolerance | Measured deviation |
|---|---|
| a) 0,065 for any measuring length of 1 000 | a) |
| b) 0,1 for any measuring length of 1 000 | b) |

**Measuring instruments**

a) Linear displacement sensor and straightedge or optical method;

b) Cylindrical square or precision square and linear displacement sensor or optical method.

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

This test shall be carried out for three positions (middle and both extreme positions) of the column saddle along the bed.

**a) 5.422.22**

Set the straightedge on the fixed table in the W-axis direction parallel to the table surface and traverse the column through the measuring length, noting the variation in readings.

Without using a straightedge, it is also possible to make a direct measurement of the table surface using a linear displacement sensor and gauge block.

**b) 5.522.2**

Place a cylindrical square on the fixed table and attach a linear displacement sensor to the spindle such that its stylus touches the cylindrical square in the direction of the spindle axis.

Lock the column when taking measurement. Move the spindle head through the measuring length and note the variation in readings.

## 7.4 Boring spindle

**Object** **G13**

Checking of the boring spindle:

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

   1) at the mouth of taper,

   2) at a distance of 300 from spindle nose;

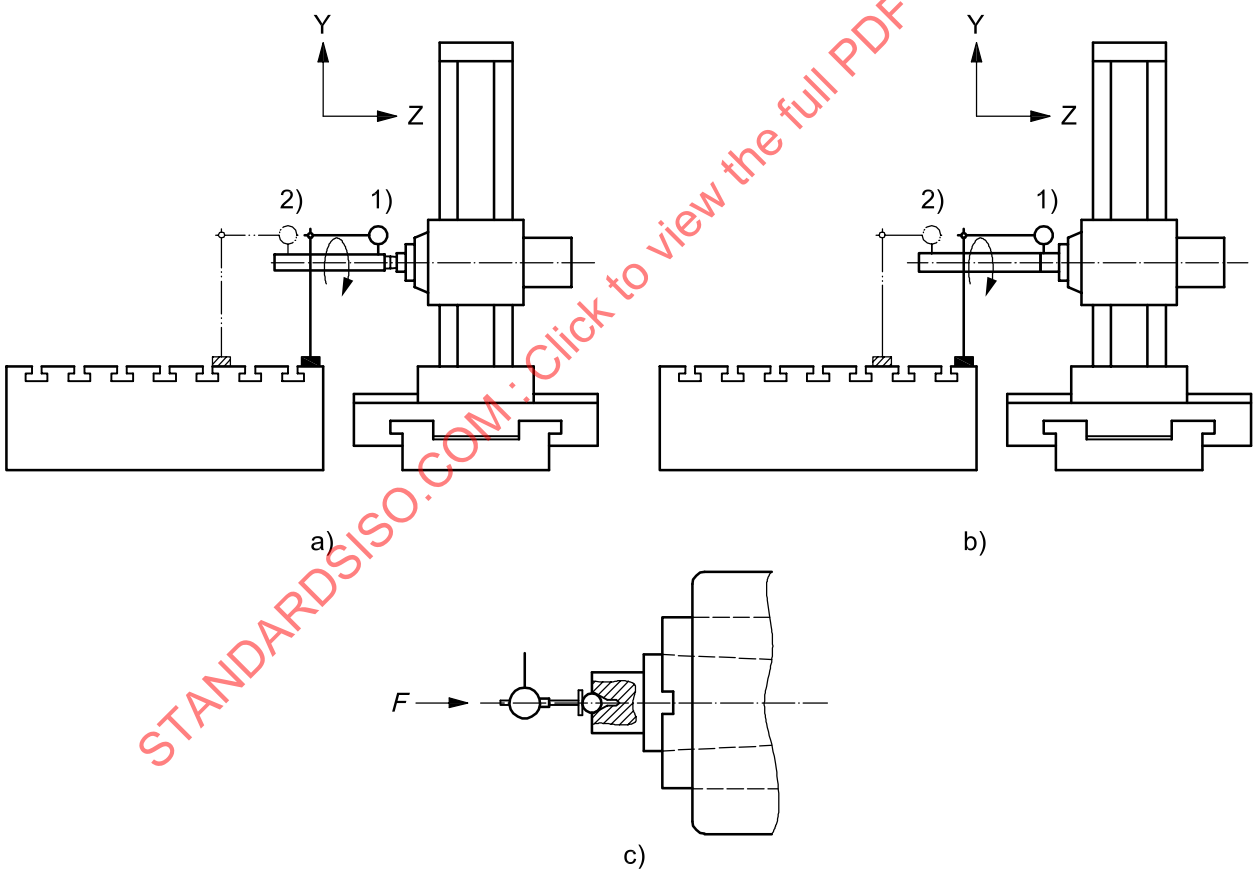
b) run-out of the external diameter

   1) with the spindle retracted,

   2) with the spindle extended by 300;

c) periodic axial slip, with the spindle retracted.

**Diagram**



| **Tolerance** | | | | **Measured deviation** |
|---|---|---|---|---|
| | | $D \leqslant 125$ | $D > 125$ | a) |
| a) and b) | 1) | 0,01 | 0,015 | 1) |
| | 2) | 0,02 | 0,03 | 2) |
| c) | | 0,01 | 0,015 | b) |
| where $D$ is the diameter of the boring spindle. | | | | 1) |
| | | | | 2) |
| | | | | 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** | **G14**

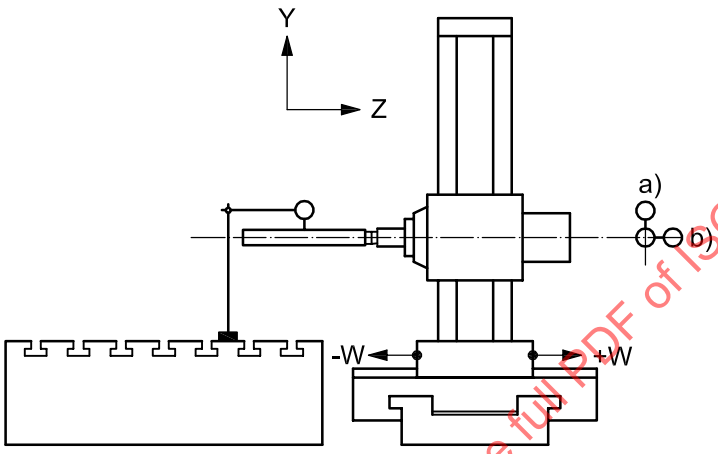
Checking of the parallelism of the boring spindle axis relative to the column movement (W axis)

a) in the YZ plane (vertical),

b) in the ZX plane (horizontal).

NOTE In the case where the column has W-axis motion.

**Diagram**




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

**Measuring instruments**

Linear displacement sensor and, possibly, test mandrel, and surface plate

**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.

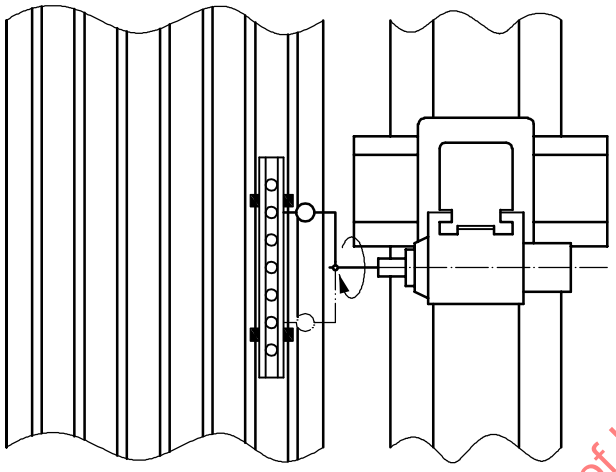
The column saddle may be locked in mid-travel.

The 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** | **G15** |
|---|---|
| Checking of the squareness of the boring spindle axis relative to the column saddle movement (X axis). | |

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| 0,03/1 000<br>(1 000 is the distance between the two measuring points touched.) | |

**Measuring instruments**

Linear displacement sensor/support and, possibly, straightedge

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

The column and column saddle shall be locked in mid-travel. The spindle head shall be locked in the low position on the column, and the spindle and, possibly, the ram shall be retracted.

Set the straightedge horizontally on the fixed table, parallel to the column saddle movement (*parallel* means that the reading of the linear displacement sensor touching the square at both ends of the movement is the same value).

Set the linear displacement sensor on the spindle and place the stylus of the linear displacement sensor normally against the reference face of the straightedge. Record the reading.

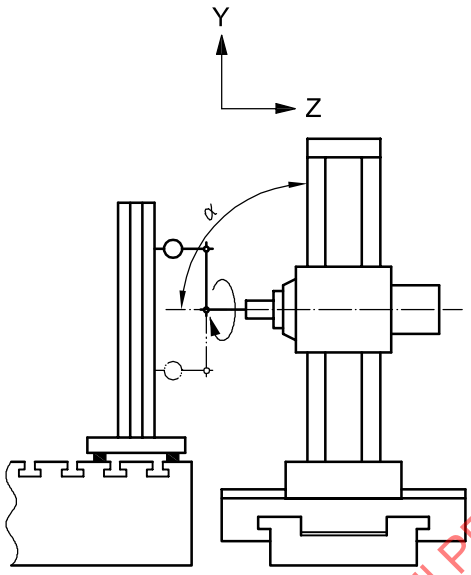
Turn the boring spindle until the stylus touches the reference face of the straightedge again. Record the reading again.

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

**Object** **G16**

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

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| 0,03/1 000 with $\alpha \leqslant 90°$<br><br>(1 000 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 cylindrical square shall be set on the fixed table, parallel to the spindle head movement (Y axis) (*parallel* means that the reading of the linear displacement sensor touching the square at both ends of the movement is the same value).

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

Set a linear displacement sensor on the spindle and touch the stylus of the linear displacement sensor normally against the cylindrical square. Record the reading.

Turn the boring spindle with the attached linear displacement sensor and touch the cylindrical square again. Record the reading again.

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

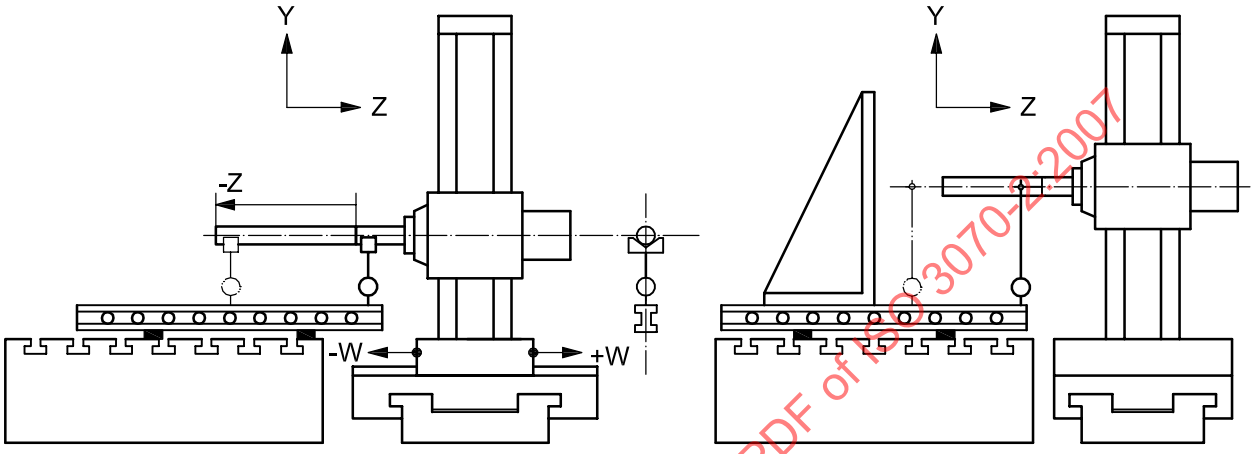
**Object** **G17**

Checking of the orientation of the boring spindle sliding movement (Z axis):

a) (when column saddle is provided) parallelism to the column movement (W axis);

b) (when column is placed directly on the bed) squareness to the spindle head movement (Y axis).

**Diagram**




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

**Measuring instruments**

Straightedge, square, gauge block and linear displacement sensor

**Observations and references to ISO 230-1:1996** **5.232.1, 5.422.22 and 5.522.4**

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

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.

b) Align the straightedge so that the vertical plane of a square laid on this straightedge is parallel to the spindle head movement (Y axis), then check the same with a).

## 7.5 Milling spindle

**Object** **G18**

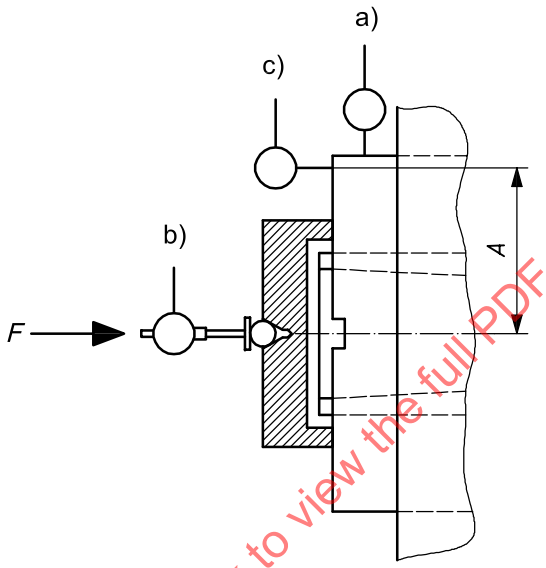
Checking of the milling spindle nose:

a) run-out;

b) periodical 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**

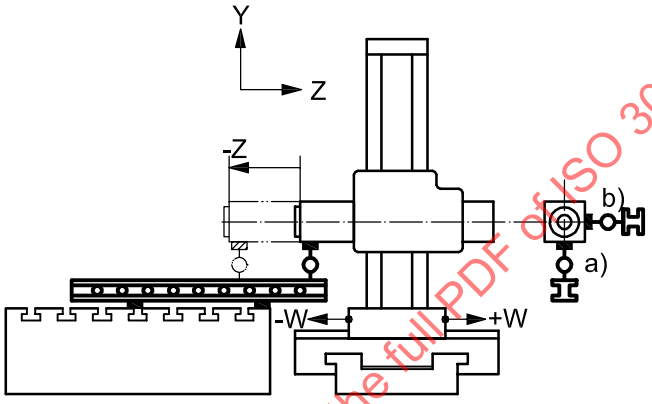
The distance, $A$, of the linear displacement sensor c) from the spindle axis shall be as large as possible.

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

## 7.6 Ram

| **Object** | **G19** |
|---|---|
| Checking of the parallelism of the ram movement (Z axis) relative to the column movement (W axis)<br><br>a) in the YZ plane (vertical plane),<br><br>b) in the ZX plane (horizontal plane).<br><br>NOTE In the case where the column has W-axis motion. | |

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| a) and b)<br><br>0,03 for a measuring length of 500 | a)<br><br>b) |

**Measuring instruments**

Straightedge, linear displacement sensor and adjustable blocks

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

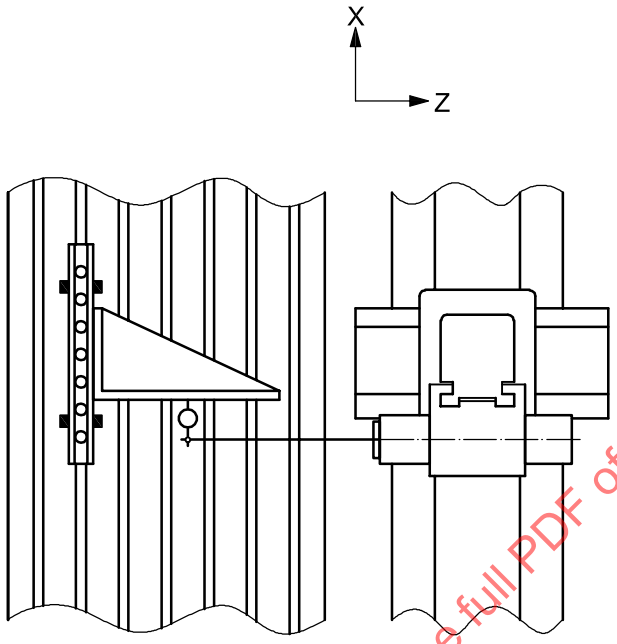
Set a straightedge on the fixed table parallel to the column movement (W axis) for a) a vertical measurement and for b) a horizontal measurement (*parallel* means that the readings of the linear displacement sensor touching the straightedge at both ends of the movement are the same value).

The 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 | G20 |
|---|---|
| Checking of the squareness of the ram movement (Z axis) relative to the column saddle movement (X 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**

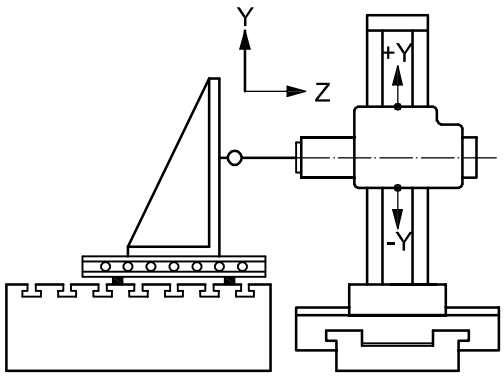
The column shall be locked in mid-travel.

Set a straightedge on the fixed table parallel to the column saddle movement and then place a square on the straightedge.

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

| **Object** | **G21** |
|---|---|
| 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**

The column shall be locked in mid-travel.

Set a straightedge on the fixed table parallel to the ram movement, then place a square on the straightedge.

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

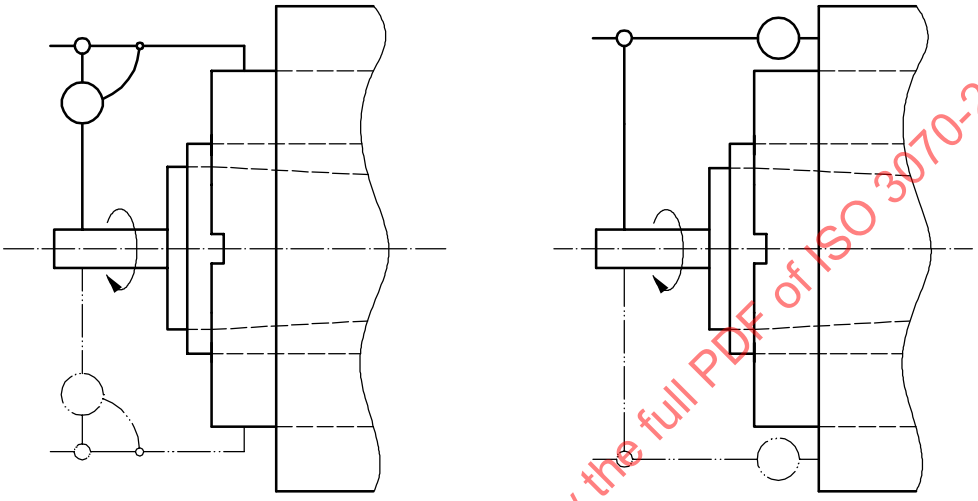
**Object** **G22**

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<br>b) 0,02/500<br>(500 is the distance between the two measuring points touched.) | a)<br>b) |

**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**

## 7.7 Integral facing head

**Object** **G23**

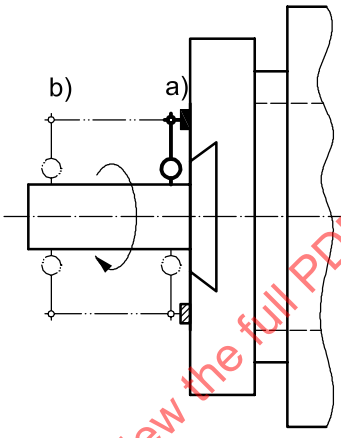
Checking of the coaxiality of the boring spindle rotating axis and of the facing head axis:

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** | | | **Measured deviation** |
|---|---|---|---|
| | $D \leqslant 125$ | $D > 125$ | a) |
| a) | 0,02 | 0,03 | b) |
| b) | 0,03 | 0,04 | |

where $D$ is the diameter of the boring spindle.

**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, at 300 mm.

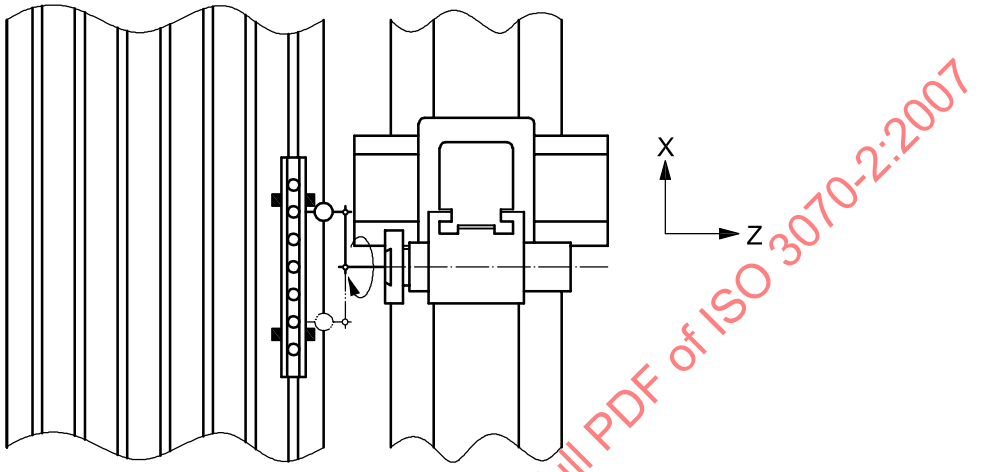
For each operation, determine half the difference of the extreme readings to obtain the coaxiality deviation.

**Object** **G24**

Checking of the squareness of the facing head rotation axis relative to the column saddle 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** |
|---|---|
| 0,03/1 000<br>(1 000 is the distance between the two measuring points touched.) | |

**Measuring instruments**

Linear displacement sensor/rigid support and straight edge

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

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

Set a straightedge on the fixed table parallel to the column saddle movement in the horizontal plane.

Set a linear displacement sensor on a rigid arm fixed to the facing head and the stylus of linear displacement sensor against the straightedge. Record the reading.

Turn the facing head until the stylus touches the straightedge again. Record the reading again.

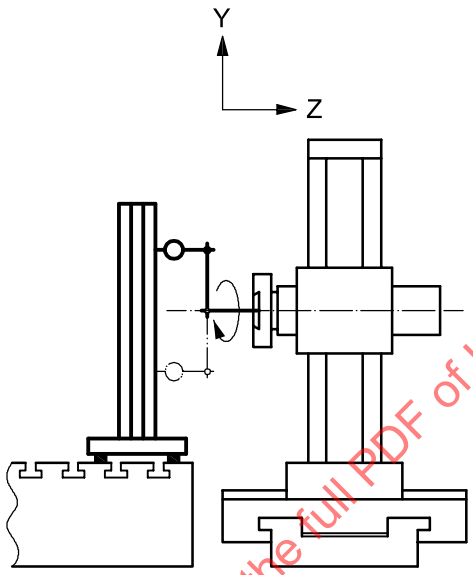
The difference between the two readings divided by the distance between the two measuring points defines the squareness deviation.

**Object** **G25**

Checking of the squareness of the facing head rotation axis relative 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** | **Measured deviation** |
|---|---|
| 0,03/1 000<br>(1 000 is the distance between the two measuring points touched.) | |

**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.

The column shall be locked in mid-travel.

Set a cylindrical square on the fixed table parallel to the spindle head movement (Y axis) (*parallel* means that the readings of the linear displacement sensor touching the square at both ends of the movement are the same value.)

Set a linear displacement sensor on the facing head and set its stylus against the cylindrical square. Record the reading.

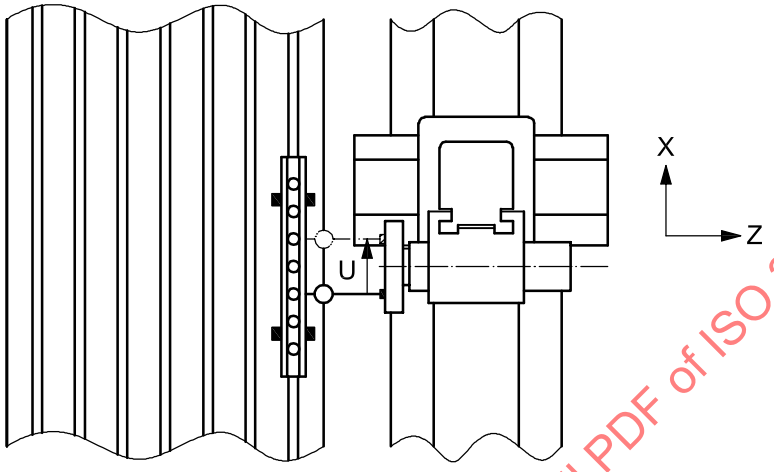
Turn the facing head with linear displacement sensor so that it touches the cylindrical square again. Record the reading again.

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

## 7.8 Radial facing slide movement (U axis)

| **Object** | **G26** |
|---|---|
| Checking of the parallelism of the radial facing slide movement (U axis) in the horizontal plane relative to the column saddle movement (X axis). | |

**Diagram**




| **Tolerance** | **Measured deviation** |
|---|---|
| 0,025 for a measuring length of 300 | |

**Measuring instruments**

Straightedge, linear displacement sensor/support and gauge blocks

**Observations and references to ISO 230-1:1996** **5.422.5 and 5.422.2**

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

Move the radial facing slide, and record the difference of the readings.

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

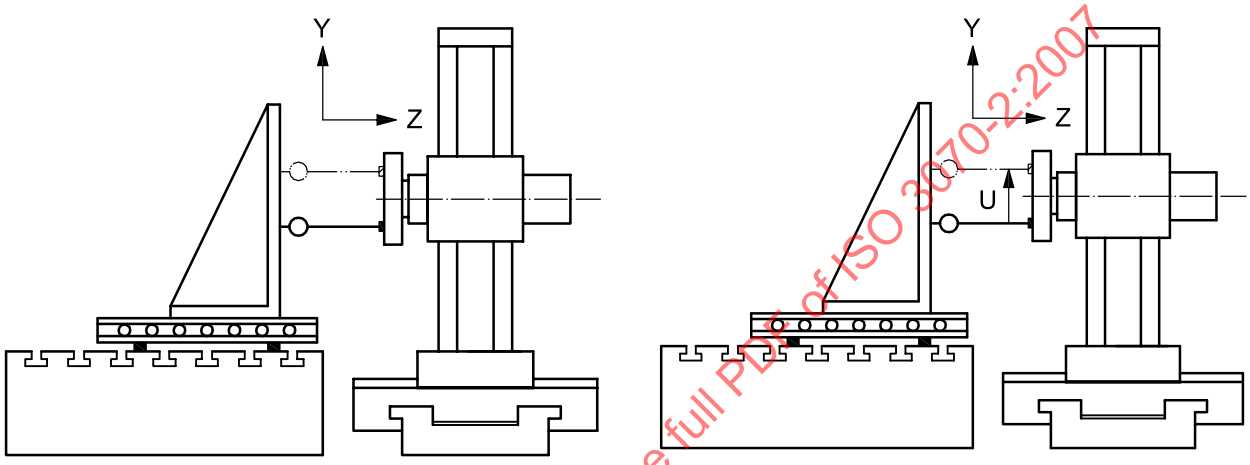
**Object** **G27**

a) Checking of the parallelism of the radial facing slide movement in the vertical plane relative to the spindle head movement (Y axis).

Alternatively, if there is column movement (W axis):

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

**Diagram**




a) or b)

| **Tolerance** | **Measured deviation** |
|---|---|
| 0,025 for a measuring length of 300 | |

**Measuring instruments**

Cylindrical square, straightedge, square, linear displacement sensor/support and gauge blocks

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

**5.422.2**

Set a cylindrical square on the fixed table parallel to the spindle head movement (Y 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°.

**Alternatively, 5.522.4**

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

The stylus of the 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 plate by 180°.

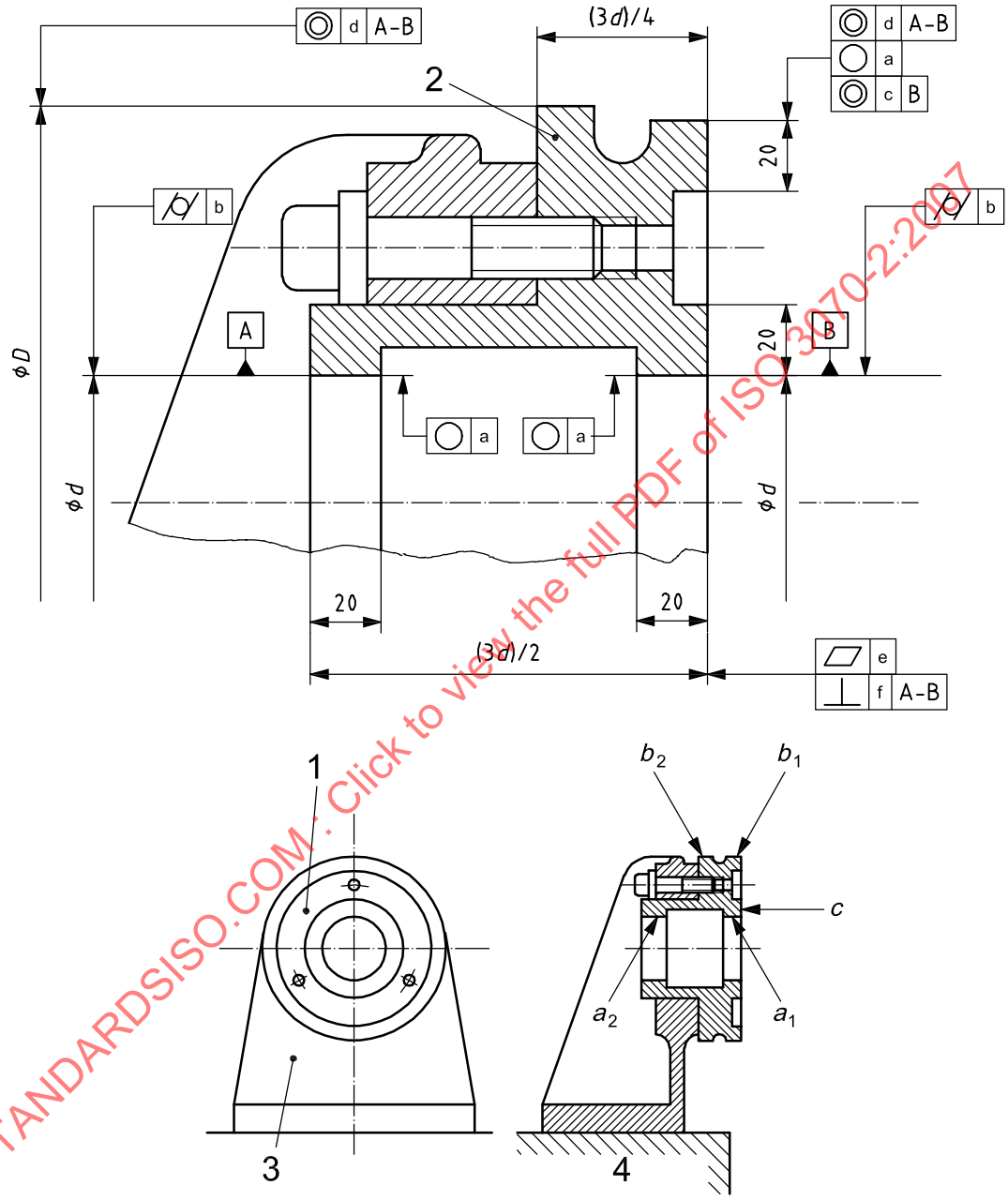
## 8 Machining tests

| Nature of test | M1 |
|---|---|
| Machining of a single test piece including:<br>a) boring of the internal cylindrical holes, $a_1$ and $a_2$;<br>b) turning of the external cylindrical surfaces, $b_1$ and $b_2$;<br>c) facing of the surface, $c$.<br>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. 42.
b See No. 2, p. 42.
c See No. 3, p. 42.
d See No. 4, p. 42.
e See No. 5, p. 42.
f See No. 6, p. 42.

| No. | Check to be made | Tolerance | Measured deviation | Measuring instruments | Observations and references to ISO 230-1:1996 |
|---|---|---|---|---|---|
| 1 | CIRCULARITY [a]<br>of the internal cylindrical holes, $a_1$ and $a_2$, and of the external cylindrical surface, $b_1$ (ISO 1101:2004, 18.3):<br>— machined from the sliding spindle;<br>— machined from column movement. | $a_1$ and $a_2$:<br>$d \leqslant 125$: 0,007 5<br>$d > 125$: 0,01<br>$b_1$:<br>$D \leqslant 300$: 0,01<br>$300 < D \leqslant 600$: 0,015<br>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 5.6.11.3.<br>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.<br>DIRECTIONS FOR MACHINING<br>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.<br>2) Turning of external cylindrical surface $b_1$. Short tool mounted on the facing head with column movement.<br>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.<br>4) Machining of surface $c$ by automatic movement of the radial facing slide or by milling. |
| 2 | CYLINDRICITY [a]<br>of the internal cylindrical holes, $a_1$ and $a_2$ (ISO 1101:2004, 18.4) | $d \leqslant 125$: 0,01<br>$d > 125$: 0,015 | | | |
| 3 | CONCENTRICITY<br>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<br>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<br>of the machined surface (ISO 1101:2004, 18.2) | 0,015 for a diameter of 300 mm | | Straightedge and gauge blocks | |
| 6 | SQUARENESS<br>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 | |

[a] Definitions of circularity and cylindricity tolerances are given in ISO 1101.