INTERNATIONAL STANDARD

ISO 2433

Third edition
1999-12-15

Machine tools — Test conditions for external cylindrical and universal grinding machines with a movable table — Testing of the accuracy

Machine-outils — Conditions d'essai des machines à rectifier les surfaces de révolution extérieures et à rectifier universelles à table mobile — Contrôle de la précision

Reference number
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Foreword

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

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

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

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

International Standard ISO 2433 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 the second edition (ISO 2433:1984), which has been technically revised.

Annex A of this International Standard is for information only.

Machine tools — Test conditions for external cylindrical and universal grinding machines with a movable table — Testing of the accuracy

1 Scope

This International Standard describes, with reference to ISO 230-1 and ISO 230-2, geometric tests, machining tests and tests for accuracy and repeatability of positioning axes on general purpose and normal-accuracy external cylindrical and universal grinding machines with a movable table. It also specifies the applicable tolerances corresponding to the above-mentioned tests.

This International Standard applies to machines with a swing diameter of up to 800 mm and a distance between centres of up to 4 000 mm.

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

This International Standard provides the terminology used for the principal components of the machine and the designation of the axes with reference to ISO 841.

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

2 Normative references

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

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

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

3 Description, terminology, and designation of axes

3.1 Description of machines

3.1.1 Generalities

This International Standard deals with both external cylindrical grinding machines and universal grinding machines with movable tables. Although the constructions of both machines are very similar, the machine functions are different.

The universal grinding machine can grind external and internal, cylindrical and conical surfaces. Whereas the external cylindrical grinding machine can grind only the external cylindrical surfaces and, in some cases, the external conical surfaces.

Both machines have two principal linear movements of the table (Z-axis) and the wheelhead (X-axis) on the bed. These movements are generally at right angles. In some machines, these two movements cross with an oblique angle and are called angular-slide cylindrical grinding machines.

The main components of external cylindrical and universal grinding machines are described below:

3.1.2 Bed

The bed has separate slideways for the table and grinding wheelhead which are generally at 90° to each other.

3.1.3 Table saddle

The table saddle supports the table and moves on the bed slideway (Z-axis).

3.1.4 Table

The workhead, tailstock and, when necessary, steady rests are mounted on the table. The workpiece is supported between the workhead spindle and tailstock spindle. The table can swivel on the table saddle in the case of a universal grinding machine; but in the case of the external cylindrical grinding machine, swivelling is not an essential function. When there is no need for swivelling, the table and table saddle may be constructed as one unit.

3.1.5 Workhead

The workhead rotates the workpiece which is mounted on the workholding chuck or supported between centres. In the case of the universal grinding machine, the workhead may swivel. The workhead may be of a fixed type on the external cylindrical grinding machines.

3.1.6 Tailstock

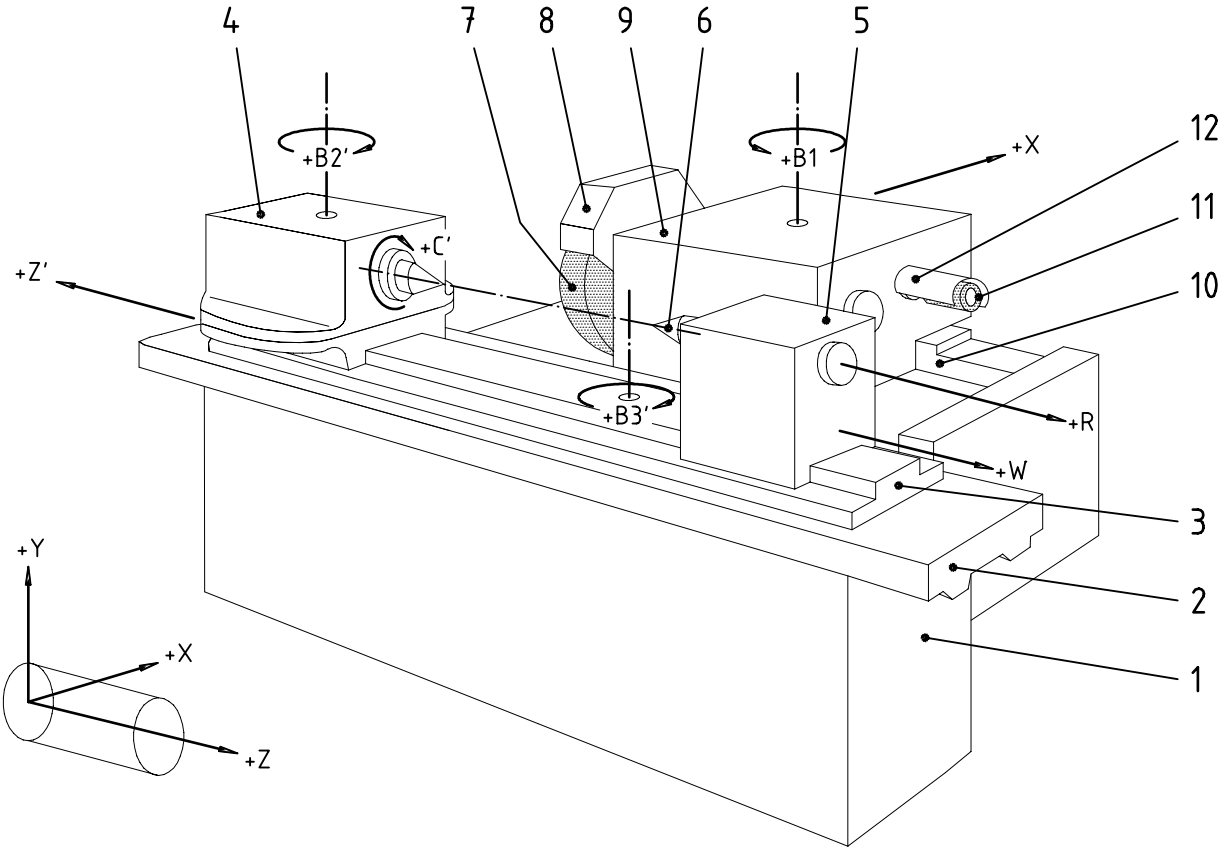
The tailstock can move on the tabletop for adjusting the distance between centres. The tailstock quill movement is used for fine adjusting (work loading).

3.1.7 Wheelhead

The wheelhead is mounted on the wheelhead saddle and may swivel. The grinding wheel is mounted on the wheelhead spindle. In the case of the universal grinding machine, the internal grinding spindle is integral, or attachable, to the wheelhead. The axis of the wheel spindle is in the zero position of swivelling, parallel to the table movement.

3.2 Terminology and designation of axes

For simplicity, only one example of a universal grinding machine is shown in Figure 1.



NOTE Axis B1 is used for convenience

Figure 1 — Universal grinding machine

Table 1 — Terminology

Reference	English	French
1	Bed	Banc
2	Table saddle	Selle
3	Table, swivelling	Table pivotante
4	Workhead	Poupée porte-pièce
5	Tailstock	Contre-poupée
6	Tailstock quill	Fourreau contre-poupée
7	Grinding wheel	Meule
8	Wheel guard	Carter de protection
9	Wheelhead	Poupée porte-meule
10	Wheelhead saddle	Selle de poupée porte-meule
11	Internal grinding wheel	Meule intérieure
12	Wheel guard for internal grinding wheel	Dispositif de protection pour meule intérieure

4 Preliminary remarks

4.1 Measuring units

In this International Standard, all linear dimensions, deviations and corresponding tolerances are expressed in millimetres; angular dimensions are expressed in degrees, and angular deviations and the corresponding tolerances are primarily expressed in ratios, but in some cases, microradians or arcseconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind:

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

4.2 Reference to ISO 230-1

To apply this International Standard, reference shall be made to ISO 230-1, especially for the installation of the machine before testing, warming up of the spindle and other moving components, description of measuring methods and recommended accuracy of testing equipment.

In the “Observations” box of the tests described in clauses 5, 6 and 7, the instructions are followed by a reference to the corresponding clause in ISO 230-1 in cases where the test concerned is in compliance with the specifications of that part of ISO 230.

4.3 Testing sequence

The sequence in which the tests are presented in this International Standard does not define the practical order of testing. In order to make the mounting of instruments or gauging easier, tests may be performed in any order.

4.4 Tests to be performed

When testing a machine, it is not always necessary or possible to carry out all the tests described in this International Standard. When the tests are required for acceptance purposes, it is up to the user to choose, in agreement with the supplier/manufacturer, those tests relating to the components and/or the properties of the machine which are of interest. These tests are to be clearly stated when ordering a machine. Mere reference to this International Standard for the acceptance tests, without specifying the tests to be carried out, and without agreement on the relevant expenses, cannot be considered as binding for any contracting party.

4.5 Measuring instruments

The measuring instruments indicated in the tests described in clauses 5, 6 and 7 are examples only. Other instruments measuring the same quantities and having at least the same accuracy may be used. Dial gauges shall have a resolution of 0,001 mm or better.

4.6 Machining tests

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

4.7 Minimum tolerance for geometric tests

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

5 Geometric tests

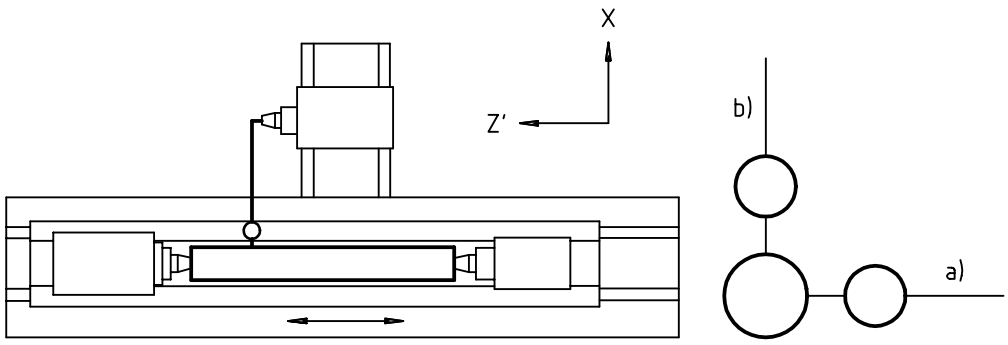
5.1 Linear axes of motion

Object **G1**

a) Checking of straightness of the table-saddle movement (Z-axis) in the horizontal ZX-plane.

b) Checking of parallelism of the axis between the centres of the workhead spindle and the tailstock quill and the table-saddle movement (Z-axis) in the vertical YZ-plane.

Diagram



Tolerance	**Measured deviation**
a) 0,01 for a measuring length of up to 1 000 Add 0,005 for each additional 1 000 or part thereof	a)
b) 0,02 for a measuring length of up to 1 000 Add 0,005 for each additional 1 000 or part thereof	b)

Measuring instruments

a) Dial gauge and test mandrel between centres or straightedge, or optical method, or taut wire and microscope or laser method.

b) Dial gauge and test mandrel between centres.

Observations and references to ISO 230-1 5.212 (Figure 11), 5.232.11, 5.232.12, 5.232.13, 5.232.14 and 5.422.3

Test mandrel of sufficient length shall be used as the reference.

Workhead and table, when of the swivelling type, shall be set at zero position of swivelling. Tailstock quill retracted.

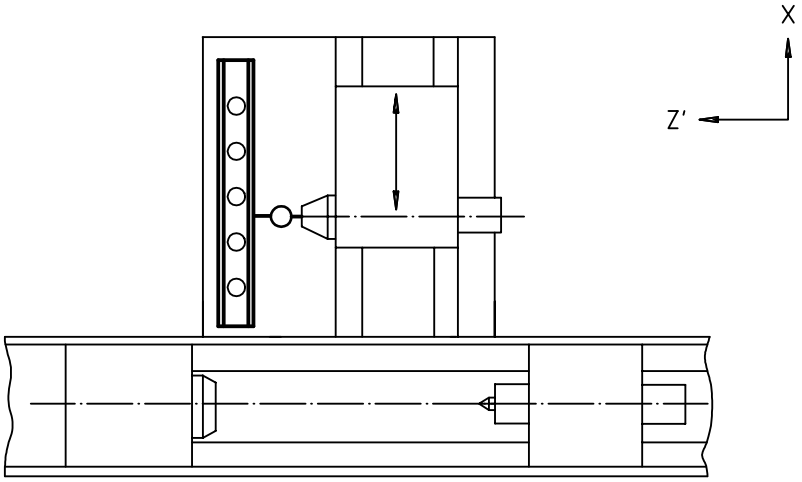
Move the table and take measurements at a number of equally spaced positions.

Determination of straightness deviation shall be in accordance with ISO 230-1:1996, 5.212.1 but the maximum difference of the readings may be substituted as the straightness deviation.

Object **G2**

Checking of straightness of the wheelhead-saddle movement (X-axis) in the horizontal ZX-plane.

Diagram



Tolerance	**Measured deviation**
0,02 for full travel	

Measuring instruments

Straightedge and dial gauge or optical methods

Observations and references to ISO 230-1 5.232.11, 5.232.13 and 5.232.14

Place a straightedge on the fixed part of the machine using gauge blocks near the wheel-spindle nose so that its reference face is parallel[a] to the X-axis movement in the horizontal ZX-plane.

Set a dial gauge on the wheelhead near its spindle. The stylus shall touch the reference face of the straightedge.

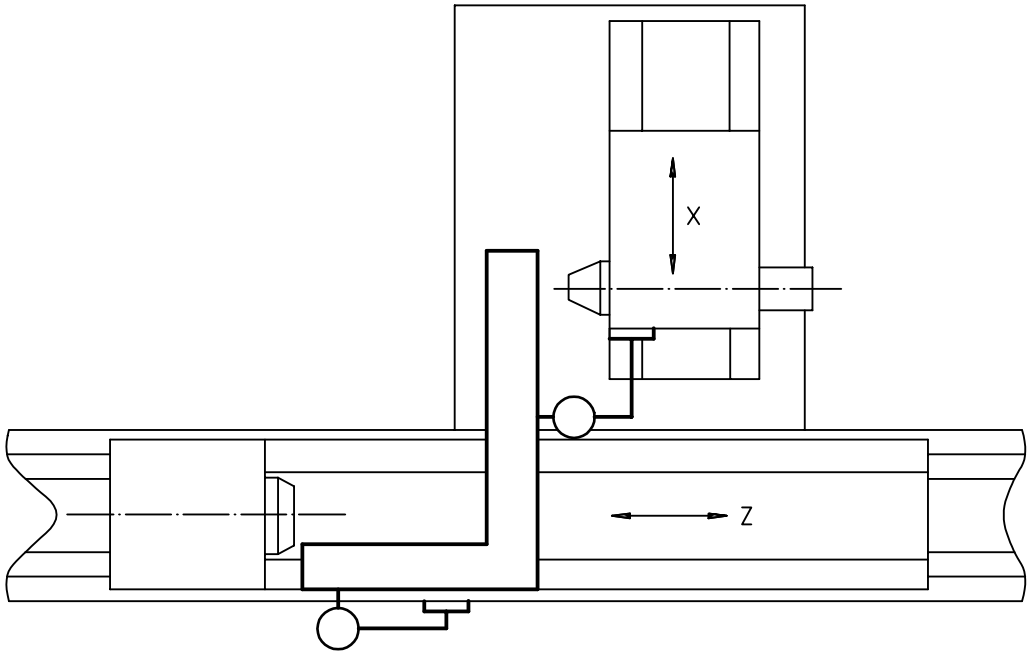
Move the wheelhead and take measurements at a number of positions equally spaced. The maximum difference of the readings is the straightness deviation.

[a] Parallel means that the dial gauge readings at both ends are the same. In this case, the maximum difference of the readings gives the straightness deviation.

Object **G3**

Checking of squareness of the wheelhead-saddle movement (X-axis) to the table-saddle movement (Z-axis), where applicable.

Diagram



Tolerance	**Measured deviation**
0,02 for a measuring length of 300	

Measuring instruments

Square and dial gauge

Observations and references to ISO 230-1 5.522.4

Adjust one arm of the square to be parallel to the table movement (Z-axis). Set a dial gauge on the wheelhead and touch the other arm of the square during the transverse movement (X-axis).

5.2 Workhead

Object **G4**

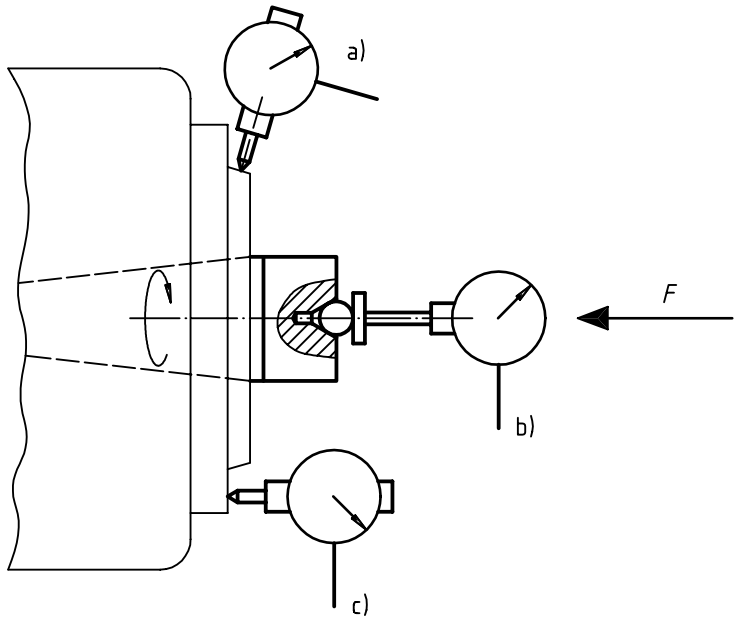
Checking of the workhead live spindle:

a) run-out of the external register diameter;

b) periodic axial slip;

c) camming of the register face (including periodic axial slip).

Diagram



Tolerance	**Measured deviation**
a) 0,005 b) 0,005 c) 0,01	a) b) c)

Measuring instruments

Dial gauge

Observations and references to ISO 230-1

a) 5.612.2

In the case of a tapered spindle nose, the stylus of the dial gauge shall be set normal to the surface to be checked.

b) and c) 5.621.2, 5.622.1, 5.622.2 and 5.632

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

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

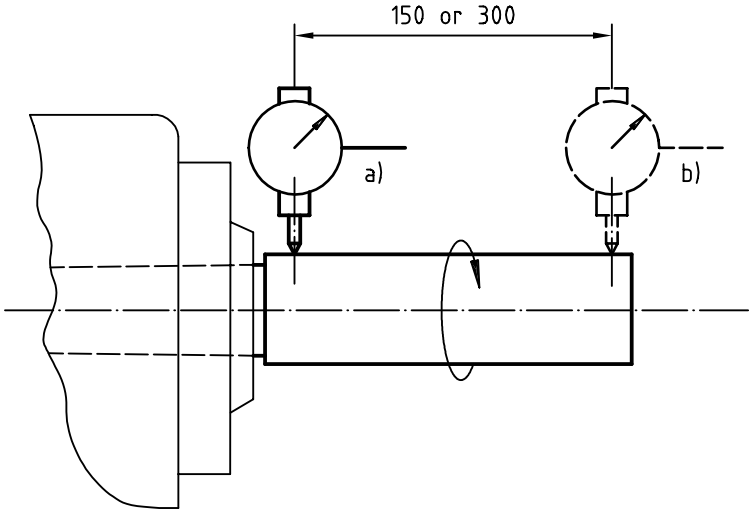
Object **G5**

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

a) near the spindle nose;

b) at a distance of 150 mm or 300 mm.

Diagram



Tolerance	**Measured deviation**
a) 0,005 b) 0,015 for a distance of 300 0,010 for a distance of 150	a) b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.612.3

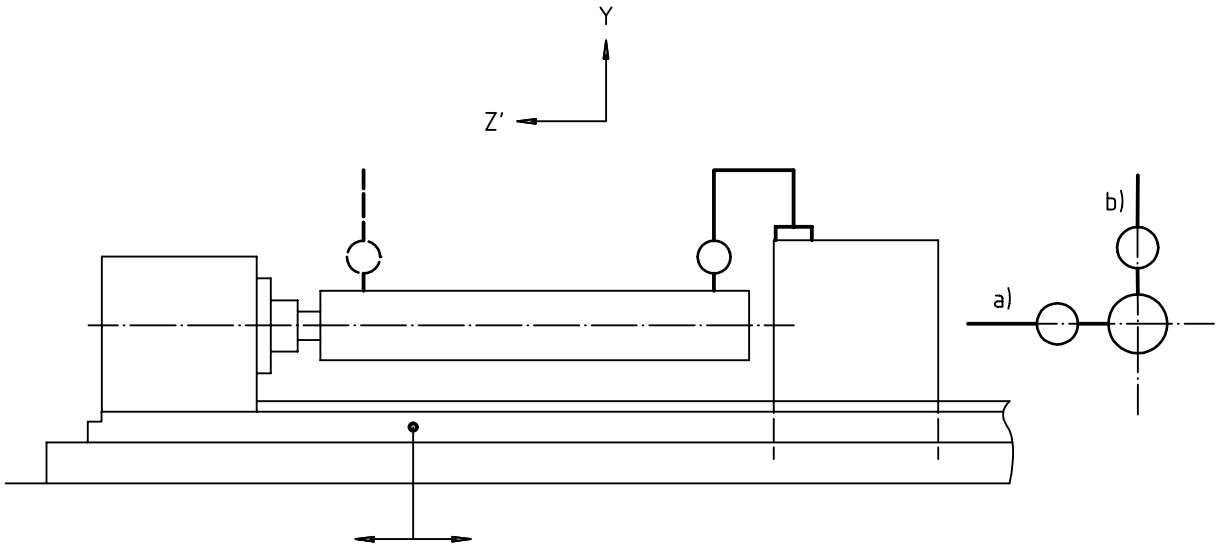
Object **G6**

Checking of parallelism of the axis of rotation of the workhead spindle to the table movement (Z-axis):

a) the horizontal ZX-plane;

b) in the vertical YZ-plane.

Diagram



Tolerance	**Measured deviation**
For a) and b)	
0,012 for a measuring length of 300 (end of test mandrel directed towards wheel and upwards)	a)
0,008 for a measuring length of 150 (end of test mandrel directed towards wheel and upwards)	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

The table setting established for test G1 shall not be modified.

5.3 Tailstock

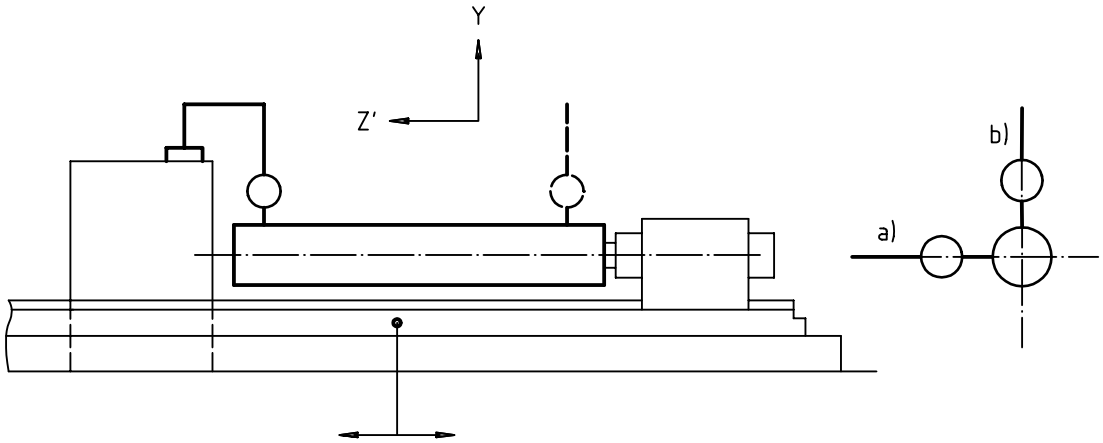
Object **G7**

Checking of parallelism of the axis of taper bore of the tailstock to the table movement (Z-axis):

a) in the horizontal ZX-plane;

b) in the vertical YZ-plane.

Diagram



Tolerance	**Measured deviation**
a) 0,015 for a measuring length of 300 (end of test mandrel directed towards wheel) 0,01 for a measuring length of 150 (end of test mandrel directed towards wheel)	a)
b) 0,015 for a measuring length of 300 (end of test mandrel directed upwards) 0,01 for a measuring length of 150 (end of test mandrel directed upwards)	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

Table setting established for test G1 shall not be modified.

Tailstock quill retracted.

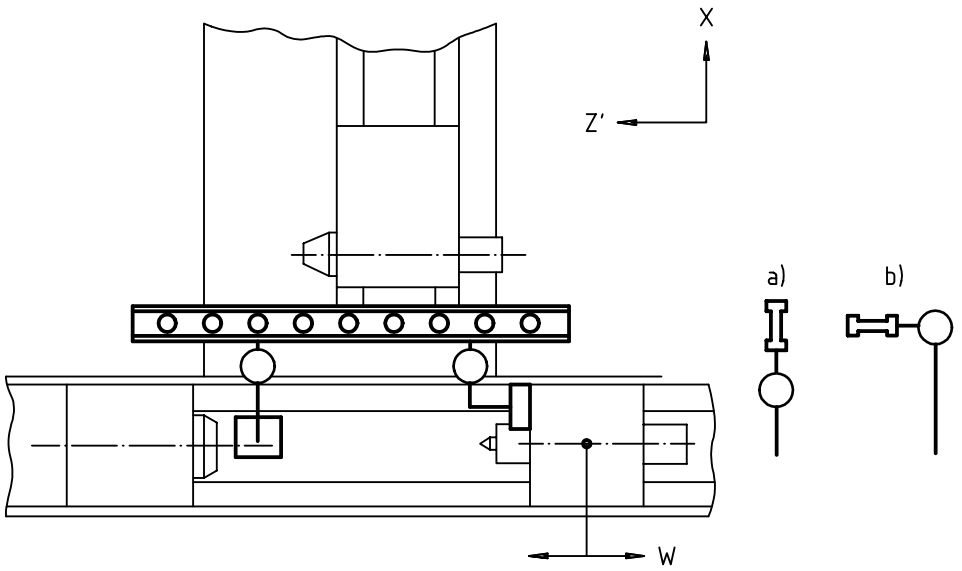
Object **G8**

Checking of parallelism of the movement of the tailstock on the table (W-axis) to the table movement (Z-axis):

a) in the horizontal ZX-plane;

b) in the vertical YZ-plane.

Diagram



Tolerance	**Measured deviation**
a) 0,01 for a measuring length of up to 1 000 Add 0,005 for each 1 000 or part thereof	a)
b) 0,015 for a measuring length of up to 1 000 Add 0,005 for each 1 000 or part thereof	b)

Measuring instruments

Straightedge and dial gauges

Observations and references to ISO 230-1 5.422.2

The table setting established for test G1 shall not be modified.

Place a straightedge on the fixed part of the machine parallel to the table movement (Z-axis) using a dial gauge mounted on the table.

Mount a dial gauge on the tailstock and adjust the stylus to touch the straightedge.

Move the tailstock and clamp it, where applicable, and then read the dial gauge.

Take the maximum difference of the dial-gauge readings.

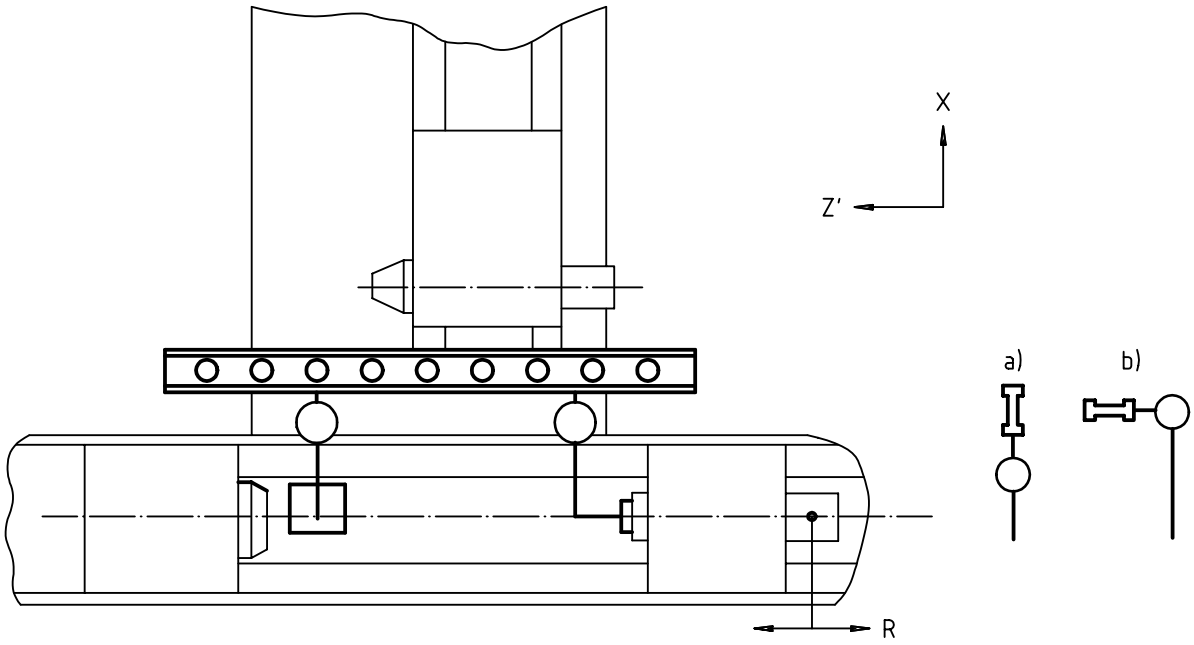
Object **G9**

Checking of parallelism of the movement of the tailstock quill (R-axis) to the table movement (Z-axis):

a) in the horizontal ZX-plane;

b) in the vertical YZ-plane.

Diagram



Tolerance	**Measured deviation**
For a) and b) 0,008 for a measuring length of 100	a) b)

Measuring instruments

Straightedge and dial gauges

Observations and references to ISO 230-1 5.422.2

The table setting established for test G1 shall not be modified.

Place a straightedge on the fixed part of the machine parallel to the table movement (Z-axis), the same as for test G8.

Mount a dial gauge on the tailstock quill and adjust the stylus to touch the straightedge.

Move the quill and clamp it, where applicable, and then read the dial gauge.

Take the maximum difference of the dial-gauge readings.

5.4 Wheelhead

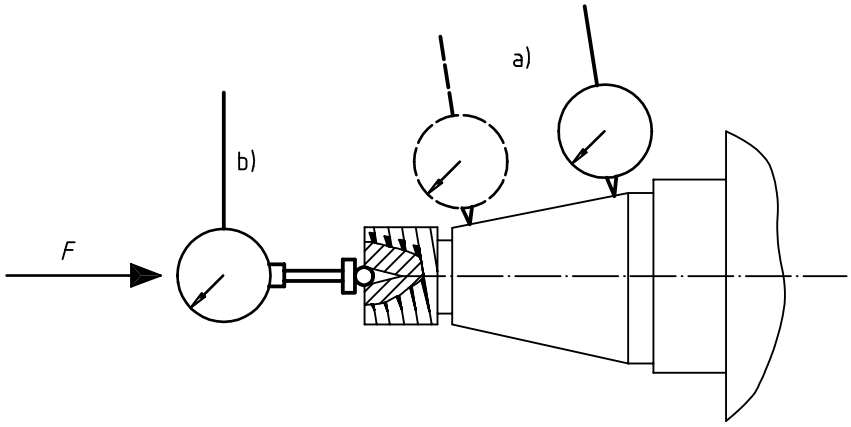
Object **G10**

Checking of the grinding-wheel spindle:

a) run-out (wheel mounting diameter);

b) periodic axial slip.

Diagram



Tolerance	**Measured deviation**
a) 0,005 for the two sections touched	a)
b) 0,01	b)

Measuring instruments

Dial gauge

Observations and references to ISO 230-1

a) 5.612.2

In the case of a tapered spindle nose, the stylus of the dial gauge shall be set normal to the surface to be checked.

The measurement of the run-out shall be carried out at the two ends of the taper.

b) 5.622.1 and 5.622.2

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

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

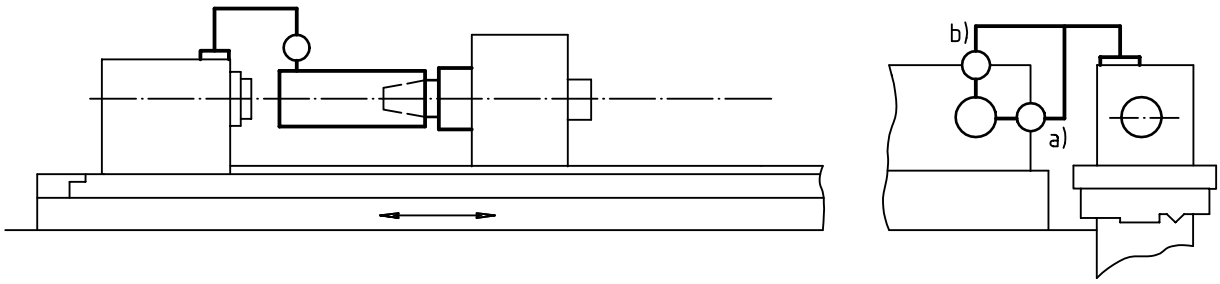
Object **G11**

Checking of parallelism of the grinding-wheel spindle axis to the table movement (Z-axis):

a) in the horizontal ZX-plane;

b) in the vertical YZ-plane.

Diagram



Tolerance	**Measured deviation**
a) 0,03 for a measuring length of 300 0,02 for a measuring length of 150	a)
b) 0,03 for a measuring length of 300 0,02 for a measuring length of 150 (end of test mandrel directed upwards except where grinding wheels can be mounted on both ends of spindle)	b)

Measuring instruments

Special test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

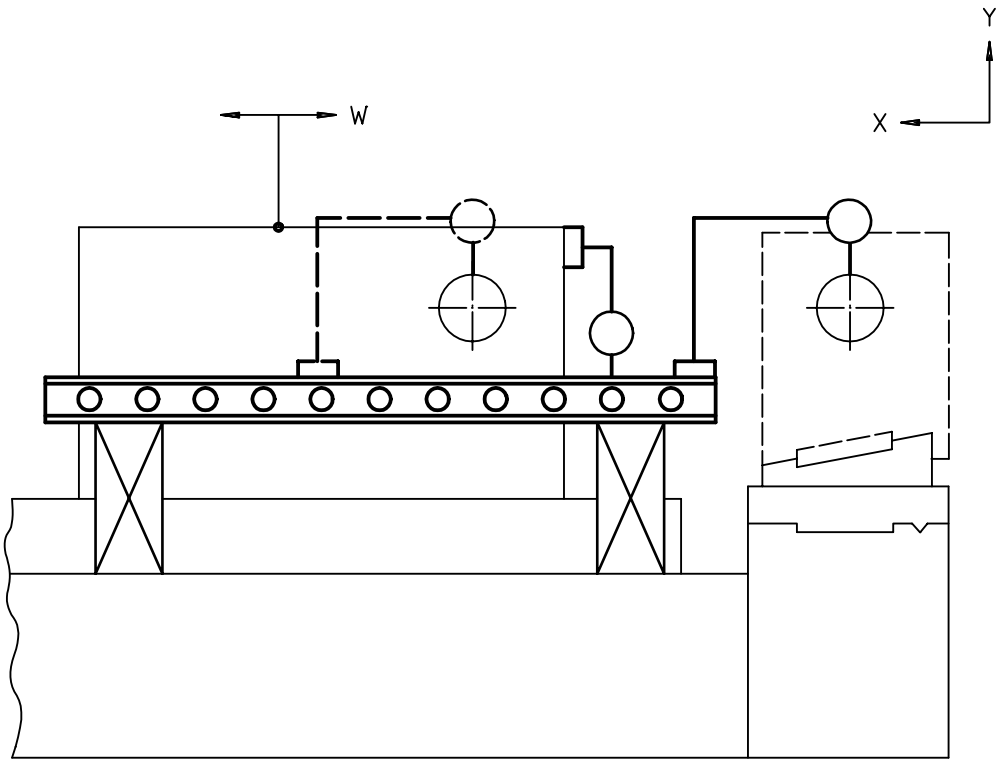
Mount a special test mandrel on the wheel spindle. Set a dial gauge on the table or workhead.

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

Object **G12**

Checking of the equidistance (equal in height) of the workhead spindle and wheel spindle from the reference plane (plane defined by X- and Z-axis movements).

Diagram



Tolerance	**Measured deviation**
0,4	

Measuring instruments

Test mandrels, dial gauge, gauge blocks and straightedge

Observations and references to ISO 230-1 5.432.1

Test mandrels of the same diameter shall be inserted into the workhead spindle and the wheel-spindle nose.

Place a straightedge on the fixed part of the machine using gauge blocks near the wheel-spindle nose so that its reference face is parallel to X- and Z-axis movements.

Position the table so that the workhead-spindle nose is near the straightedge.

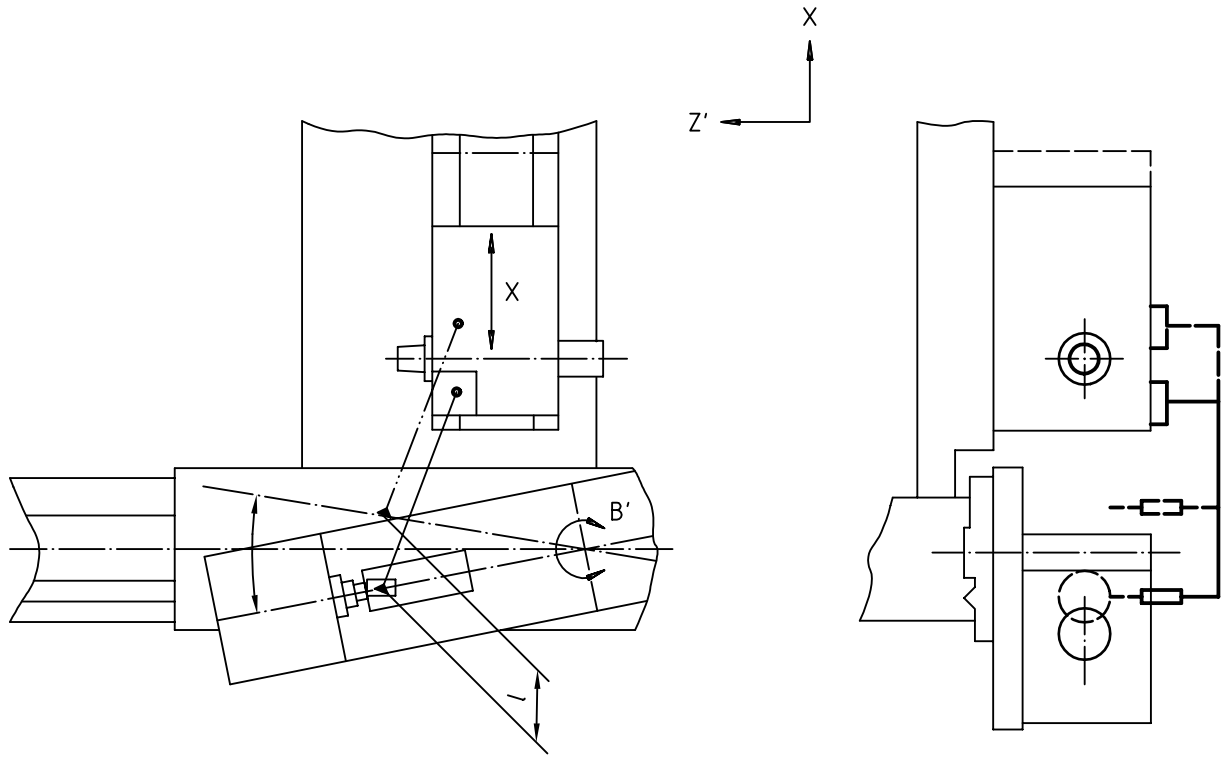
Measure the respective distances of the test mandrels to the straightedge and compare the difference with tolerance.

5.5 Swivel motions (Tests apply for swivelling component only)

Object **G13**

Checking of parallelism of the mounting and swivelling plane of the table to the ZX-plane.

Diagram



Tolerance	**Measured deviation**
0,05 over entire travel	

Measuring instruments

Test mandrels, dial gauge, and rigid support

Observations and references to ISO 230-1 5.432.1 and 5.432.2

Mount a test mandrel on the workhead spindle.

Fix a dial gauge with rigid support on the wheelhead. The stylus should touch the test mandrel.

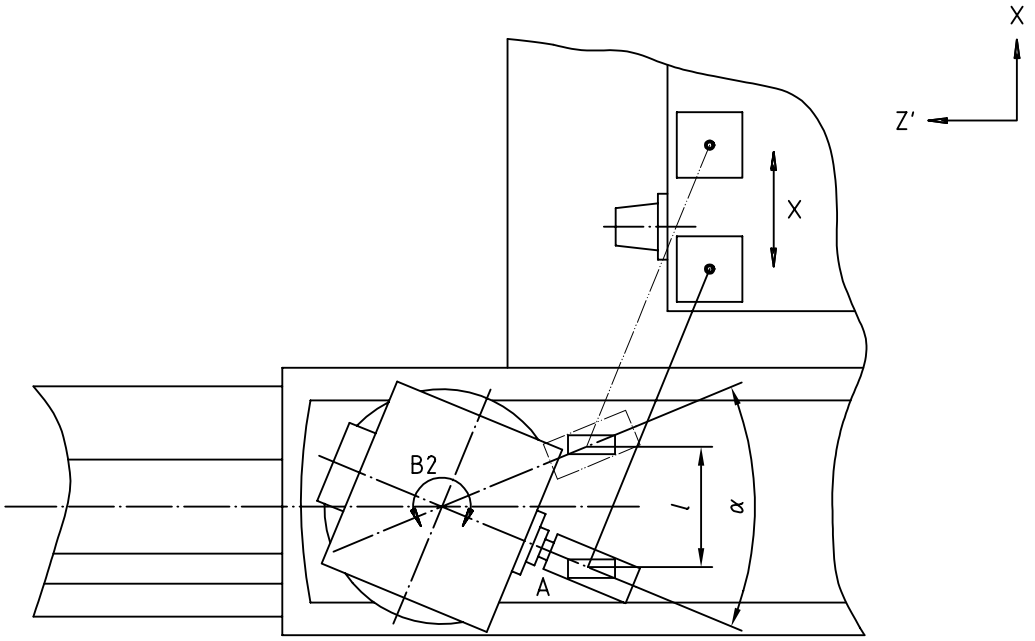
First, clamp the table in its centre position and read the dial gauge. Then swivel the table to the extreme positions. The dial gauge should be displaced to touch the same location of the test mandrel by means of X- and Z-movements only (the dial-gauge support should always remain fixed to the top of the wheelhead in the same position). Read the dial gauge after clamping the table.

Take maximum differences of the dial-gauge readings.

Object **G14**

Checking of parallelism of the mounting and swivelling plane of the workhead to the ZX-plane.

Diagram



Tolerance	**Measured deviation**
0,02 for l = 200	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.432.1 and 5.432.2

Mount a test mandrel on the workhead spindle.

Set a dial gauge on the rigid support fixed on the wheelhead.

Swivel the workhead through α^{o} (max. 45^{o}), touch the dial gauge to the test mandrel at position A and read the dial gauge.

Swivel back to the opposite side through α^{o} and take readings at the same position A of the test mandrel using the wheelhead movement (X-axis motion).

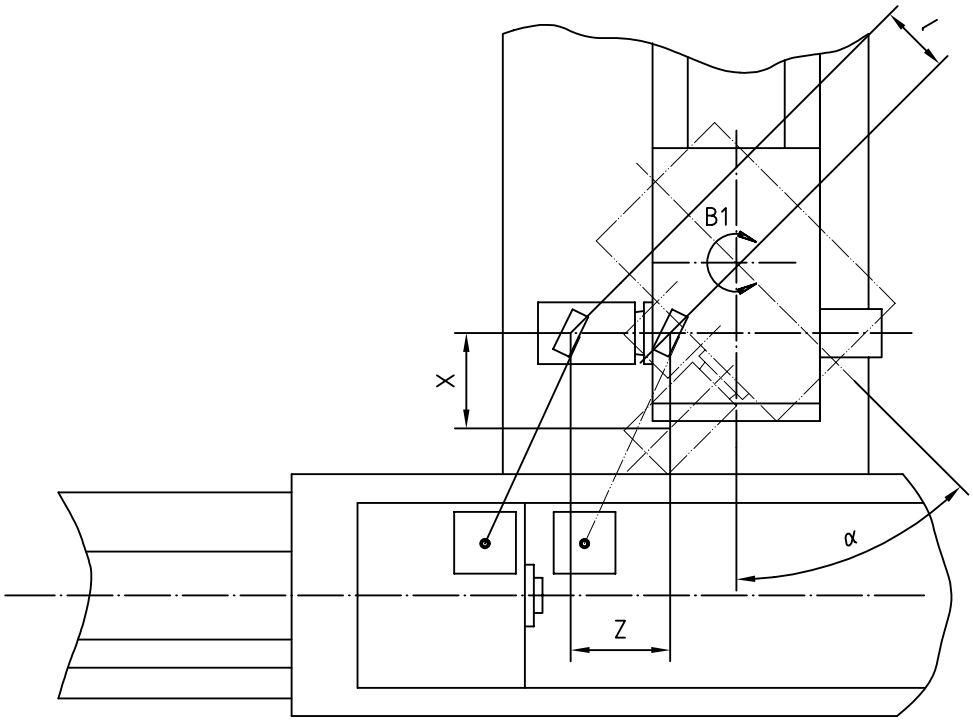
The dial gauge should be displaced to touch the same location of the test mandrel by means of X- and Z-movements only (the dial-gauge support should always remain fixed to the top of the wheelhead in the same position).

The difference between the two readings in relation with the distance between two measured positions is the measured deviation.

Object **G15**

Checking of parallelism of the mounting and swivelling plane of the wheelhead to the ZX-plane.

Diagram



Tolerance	**Measured deviation**
0,05 for l = 200	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.432.1 and 5.432.2

Mount a test mandrel on the wheelhead spindle.

Set a dial gauge with rigid support on the workhead.

Swivel the wheelhead to zero position and adjust the stylus of the dial gauge to touch the test mandrel.

Swivel the wheelhead to the α^{o} (max. 45^{o}) position and check at the same position of the test mandrel using X- and Z-axis movements.

The dial gauge should be displaced to touch the same location of the test mandrel by means of X- and Z-movements only (the dial-gauge support should always remain fixed to the top of the workhead in the same position).

The difference between the two readings in relation with the distance between the two measured positions is the measured deviation.

5.6 Internal grinding spindle

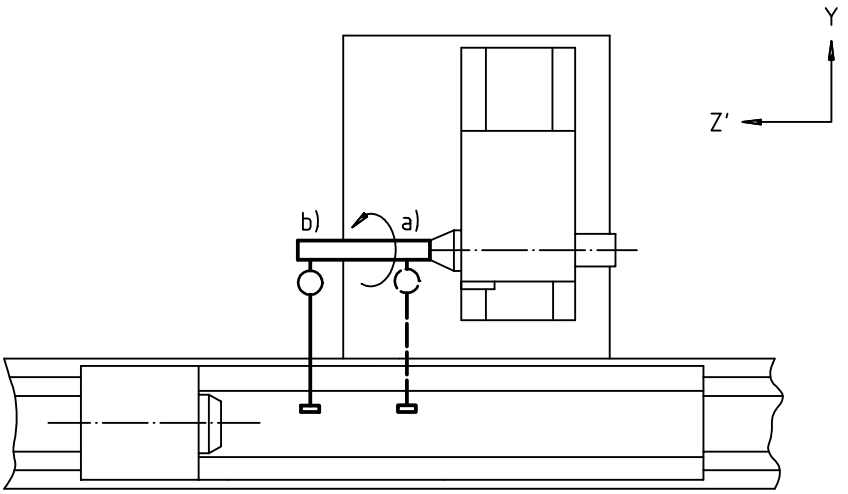
Object **G16**

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

a) at the outlet of taper;

b) at a distance of 150 mm.

Diagram



Tolerance	**Measured deviation**
a) 0,005	a)
b) 0,01	b)

Measuring instruments

Test mandrel according to the type of spindle nose and dial gauge

Observations and references to ISO 230-1 5.612.3

In the case of an internal cylindrical centring register, the test shall be performed on the register with direct touching of the dial gauge and without using a test mandrel. In this case, the value a) will be taken as the tolerance.

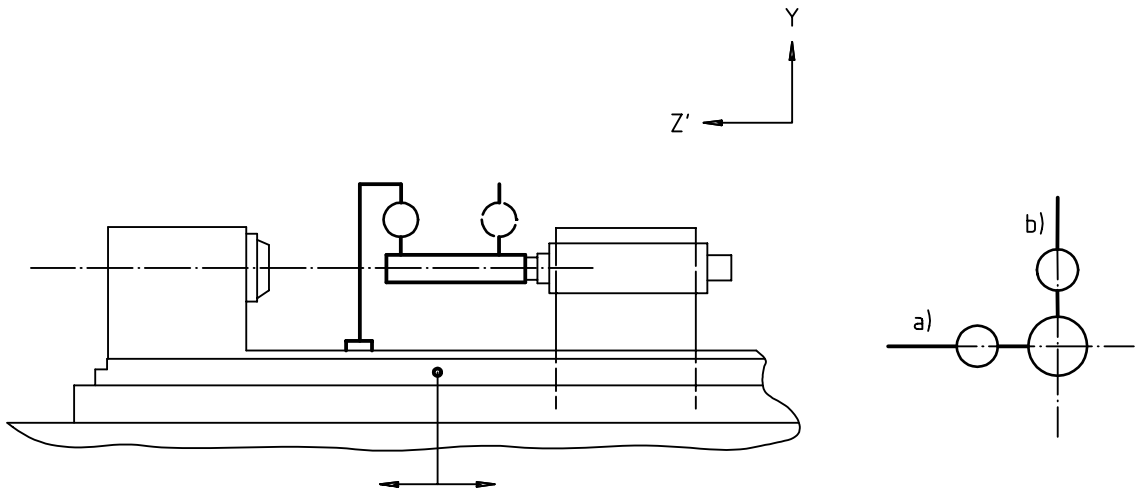
Object **G17**

Checking of parallelism of the axis of the internal grinding spindle to the table movement (Z-axis):

a) in the horizontal plane;

b) in the vertical plane.

Diagram



Tolerance	**Measured deviation**
a) 0,03 for a measuring length of 300 0,02 for a measuring length of 150	a)
b) 0,03 for a measuring length of 300 (test-mandrel end directed upwards) 0,02 for a measuring length of 150	b)

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1 5.412.1 and 5.422.3

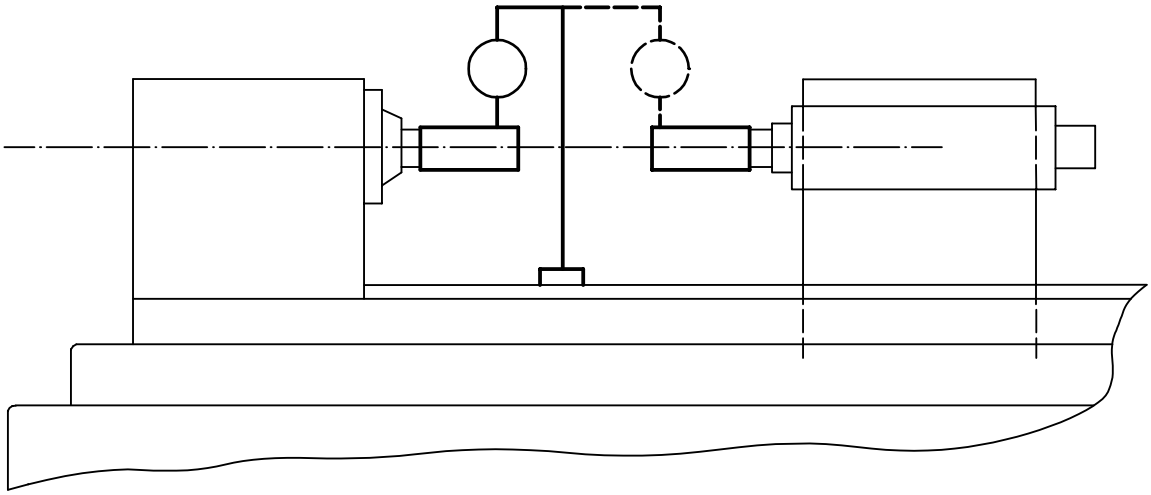
Checking shall be carried out at each mean position of rotation of the grinding spindle in the horizontal and vertical plane.

Alternatively, check first at a position of spindle rotation and then rotate the spindle by 180^{o} and check again. Take mean values at each measuring point and evaluate the deviations.

Object **G18**

Checking of the equidistance (equal in height) of the internal grinding spindle and workhead spindle from the reference plane (plane composed of X- and Z-axis movements).

Diagram



Tolerance	**Measured deviation**
0,02	

Measuring instruments

Test mandrels, dial gauge, gauge blocks and straightedge

Observations and references to ISO 230-1 5.432.1

Test mandrels of the same diameter shall be mounted onto the workhead spindle and the internal grinding spindle.

Place a straightedge on the fixed part of the machine using gauge blocks near to the internal grinding spindle nose so that its reference face is parallel to X- and Z-axis movements.

Position the table so that the workhead-spindle nose is near to the straightedge.

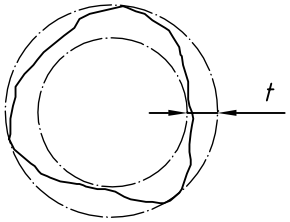
Measure the respective distances of the test mandrels to the straightedge and compare their differences with the tolerance.

6 Machining tests

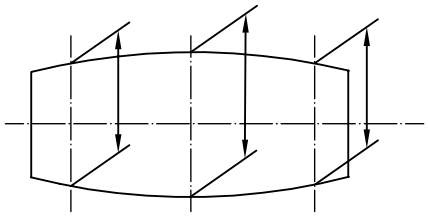
Object **M1**

Checking of

a) circularity

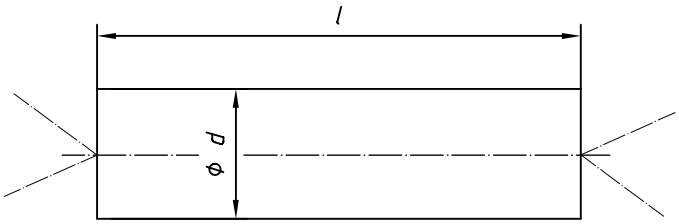


b) consistency of diameter, variation of diameter measured at both ends and in the middle of the test piece



by grinding of cylindrical test piece mounted between centres.

Diagram and sizes of test pieces



DC[a]	l	d_{min}
DC ⩽ 315	160	16
315 < DC ⩽ 630	315	32
630 < DC ⩽ 1 500	630	63
1 500 < DC ⩽ 3 000	1 000	100
3 000 < DC	1 500	150

[a] DC is the distance between centres

Cutting conditions

Grinding without arbor support over the whole length of the test piece

Tolerance

a) 0,003 for $l \leqslant 630$
0,005 for $l > 630$

b) for l = 160: 0,003
for l = 315: 0,005
for l = 630: 0,008
for l = 1 000: 0,010
for l = 1 500: 0,015

Measuring instruments

a) Roundness-measuring machine

b) Micrometer or coordinate measuring machine (CMM)

Observations and references to ISO 230-1 4.1 and 4.2

The test for circularity should be made at several positions of the test piece and the greatest value of the deviation should be reported.

The measurement for consistency of diameter shall be carried out in a single axial plane.

NOTE Any taper should be such that the major diameter is near the workhead.

Object **M2**

Checking of circularity by grinding of a cylindrical test piece mounted on a work-holding chuck.

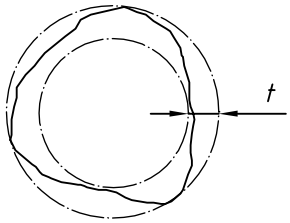
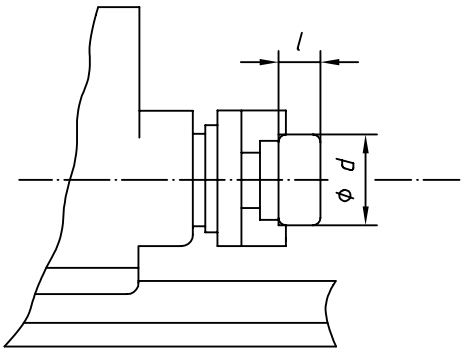


Diagram and sizes of test pieces



DC [a] ⩽ 1 500	DC > 1 500
l = 0,5 d	l = 0,25 to 0,5 d
d_{min} = 40	d_{min} = 100
d_{max} = 100	d_{max} = 400
[a] DC is the distance between centres	

Tolerance

For DC ⩽ 1 500: 0,003

For DC > 1 500: 0,004 for a 100 mm diameter piece

Measuring instruments

Roundness-measuring machine

Observations and references to ISO 230-1 4.1 and 4.2

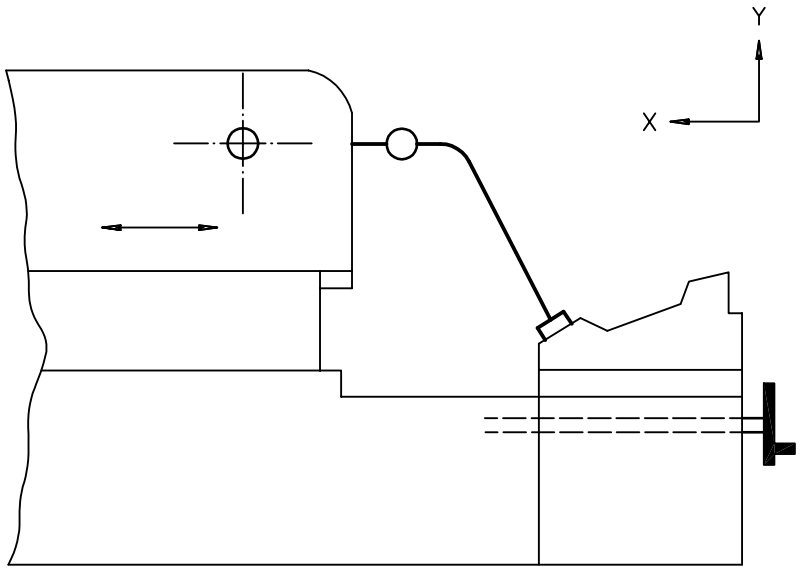
Tests for circularity should be made at several positions of the test piece, and the greatest value of the deviations should be reported.

7 Accuracy and repeatability of positioning

7.1 Positioning of manual or automatic (but not numerically controlled) linear axes

Object	**P1**
Checking of repeatability of the finish approach of the wheelhead positioning.	

Diagram



Tolerance	**Measured deviation**
For $D \leqslant 500$: 0,003 For $D > 500$: 0,005 where D is the maximum diameter admissible for grinding	

Measuring instruments

Dial gauge

Observations and references to ISO 230-1

Carry out five consecutive tests for the wheelhead positioning, the movement being obtained by a fast approach followed by a slow approach.

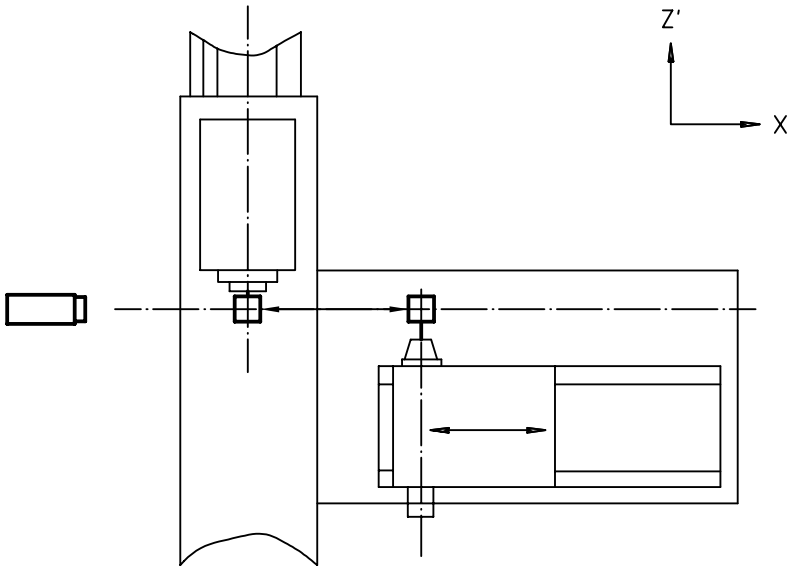
The range of five readings shall be recorded and compared with the tolerance.

7.2 Positioning of numerically controlled linear axes

Object **P2**

Checking of unidirectional accuracy and repeatability of positioning of the X-axis movement of the wheelhead by numerical control.

Diagram



Tolerance		Measuring length		**Measured deviation**
		⩽ 500	⩽ 1 000	
Unidirectional accuracy of positioning	A↑ and A↓	0,016	0,020	
Unidirectional repeatability of positioning	R↑ and R↓	0,006	0,008	
Unidirectional systematic deviation of position	E↑ and E↓	0,008	0,013	
Reversal value	B	0,010	0,013	

Measuring instruments

Linear scale or laser measurement equipment

Observations and reference to ISO 230-2

Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be placed on the table parallel to the X-axis and the scale reader should be mounted on the tool position.

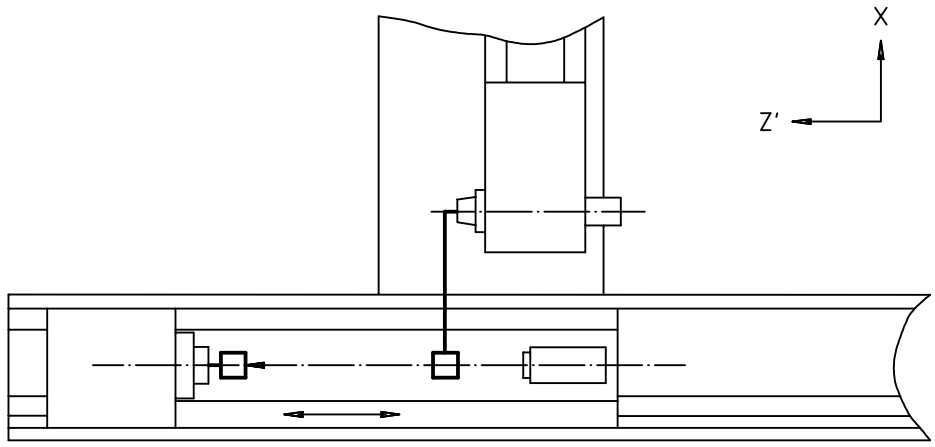
When laser equipment is used, the reflector shall be mounted on the tool position and the interferometer shall be mounted on the table or workhead.

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

Object **P3**

Checking of accuracy and repeatability of positioning of the Z-axis movement of the table by numerical control.

Diagram



Tolerance		Measuring length ⩽ 500	⩽ 1 000	⩽ 2 000	**Measured deviation**
Axes up to 2 000 mm					
Bidirectional accuracy of positioning	A	0,025	0,032	0,040	
Unidirectional accuracy of positioning	A↑ and A↓	0,015	0,019	0,024	
Bidirectional repeatability of positioning	R	—	—	—	
Unidirectional repeatability of positioning	R↑ and R↓	0,008	0,010	0,013	
Bidirectional systematic deviation of positioning	E	0,016	0,020	0,025	
Unidirectional systematic deviation of positioning	E↑ and E↓	0,008	0,010	0,013	
Range of the mean bidirectional positional deviation	M	0,008	0,010	0,013	
Reversal value	B	0,010	0,013	0,016	
Axes exceeding 2 000 mm					
Bidirectional systematic deviation of positioning	E	0,032 + 0,008 for each excess 1 000 mm			
Unidirectional systematic deviation of positioning	E↑ and E↓	0,025 + 0,005 for each excess 1 000 mm			
Range of the mean bidirectional positional deviation	M	0,025 + 0,005 for each excess 1 000 mm			
Reversal value	B	0,016 + 0,003 for each excess 1 000 mm			

Measuring instruments

Linear scale or laser measurement equipment

Observations and reference to ISO 230-2

Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be placed on the table parallel to the Z-axis and the scale reader should be mounted on the tool position.

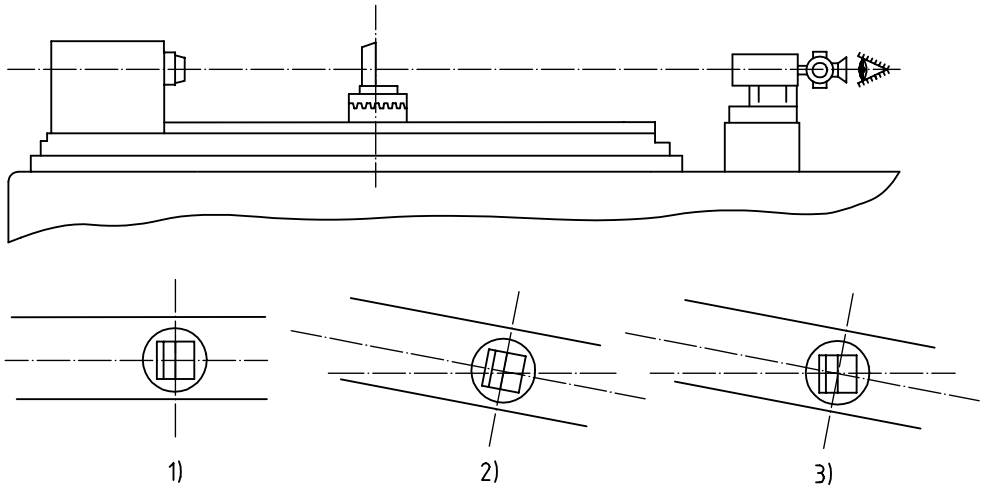
When laser equipment is used, the reflector shall be mounted on the workhead and the interferometer shall be mounted on the tool position or on its extension.

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

Object **P4**

Checking of accuracy and repeatability of positioning of the B3'-axis swivel motion of the table by numerical control.

Diagram



Tolerance		Measurement travel $\leqslant +10^{o}$	**Measured deviation**
Bidirectional accuracy of positioning Unidirectional accuracy of positioning	A A↑ and A↓	25" 20"	
Bidirectional repeatability of positioning Unidirectional repeatability of positioning	R R↑ and R↓	— 10"	
Bidirectional systematic deviation of positioning Unidirectional systematic deviation of positioning Range of the mean bidirectional positional deviation	E E↑ and E↓ M	20" 10" 10"	
Reversal value	B	13"	

Measuring instruments

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

Observations and reference to ISO 230-2

When a master index table is used:

1) set it on the swivelling table so that its rotation axis is parallel and near to the rotation axis of the swivelling table and the mirror face to optical axis of the autocollimator is set on the fixed part of the machine;

2) swivel the table with the master index table through the indexable angle;

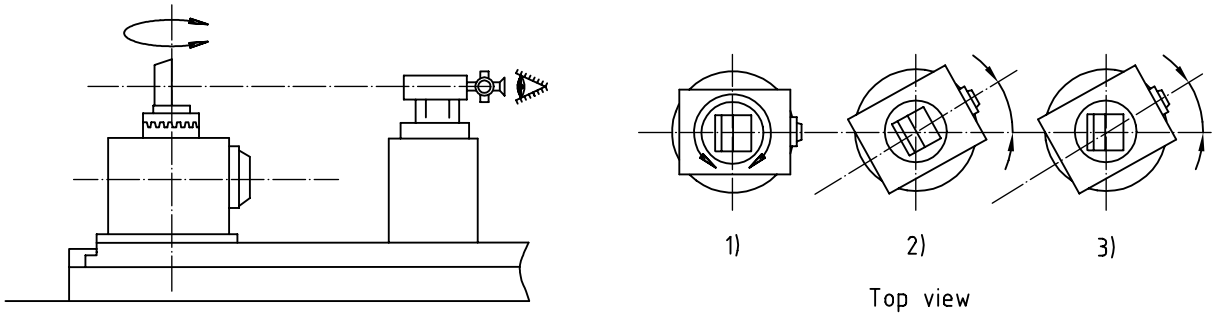
3) then rotate the index table back by the same angle so that the mirror comes back and faces the optical axis. Then check the angular deviation.

ISO 230-2:1997, clauses 3, 4 (especially 4.3.4) and 7, shall be referred to regarding the test conditions, test programme and the presentation of results.

Object **P5**

Checking of accuracy and repeatability of positioning of the B2'-axis swivel motion of the workhead by numerical control.

Diagram



Tolerance		Measurement travel $\leqslant \pm 45^{o}$	**Measured deviation**
Bidirectional accuracy of positioning Unidirectional accuracy of positioning	A A↑ and A↓	25" 20"	
Bidirectional repeatability of positioning Unidirectional repeatability of positioning	R R↑ and R↓	— 10"	
Bidirectional systematic deviation of positioning Unidirectional systematic deviation of positioning Range of the mean bidirectional positional deviation	E E↑ and E↓ M	20" 10" 10"	
Reversal value	B	13"	

Measuring instruments

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

Observations and reference to ISO 230-2

When a master index table is used:

1) set it on the swivelling table so that its rotation axis is parallel and near to the rotation axis of the swivelling table and the mirror face to optical axis of the autocollimator is set on the fixed part of the machine;

2) swivel the table with the master index table through the indexable angle;

3) then rotate the index table back by the same angle so that the mirror comes back and faces the optical axis. Then check the angular deviation.

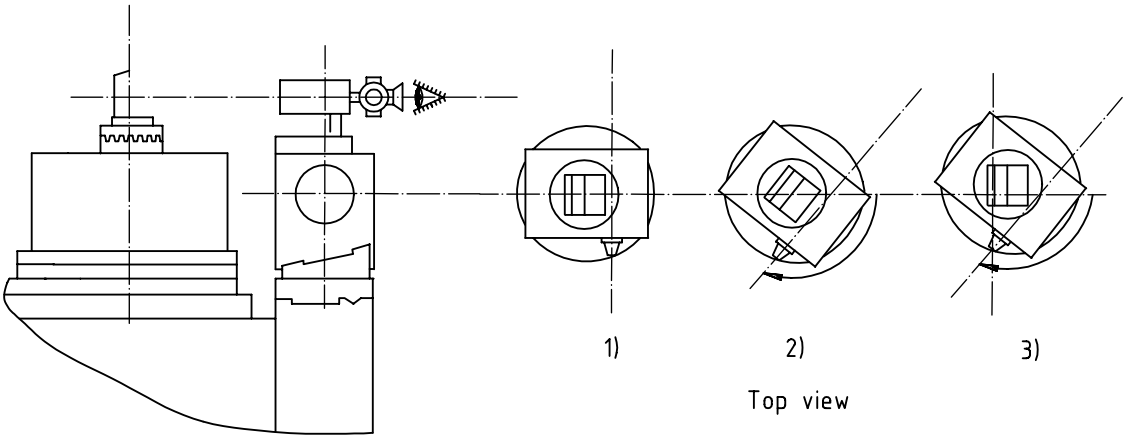
ISO 230-2:1997, clauses 3, 4 (especially 4.3.4) and 7, shall be referred to regarding the test conditions, test programme and the presentation of results.

7.3 Positioning of numerically controlled rotary axes

Object **P6**

Checking of accuracy and repeatability of positioning of the B1-axis swivel motion of the wheelhead by numerical control.

Diagram



Tolerance		Measurement travel $\leqslant \pm 45^{o}$	**Measured deviation**
Bidirectional accuracy of positioning Unidirectional accuracy of positioning	A A↑ and A↓	25" 20"	
Bidirectional repeatability of positioning Unidirectional repeatability of positioning	R R↑ and R↓	— 10"	
Bidirectional systematic deviation of positioning Unidirectional systematic deviation of positioning Range of the mean bidirectional positional deviation	E E↑ and E↓ M	20" 10" 10"	
Reversal value	B	13"	

Measuring instruments

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

Observations and reference to ISO 230-2

When a master index table is used:

a) set it on the swivelling table so that its rotation axis is parallel and near to the rotation axis of the swivelling table and the mirror face to optical axis of the autocollimator is set on the fixed part of the machine;

b) swivel the table with the master index table and indexable angle;

c) then rotate the index table back by the same angle so that the mirror comes back and faces the optical axis. Then check the angular deviation.

ISO 230-2:1997, clauses 3, 4 (especially 4.3.4) and 7, shall be referred to regarding the test conditions, test programme and the presentation of results.

Annex A
(informative)

Equivalent terms in German and Italian

Reference	German	Italian
1	Bett	Banco
2	Tischschlitten	Slitta della tavola
3	Tisch, schwenkbar	Tavola, orientabile
4	Werkstückspindelstock	Testa porta-pezzo
5	Reitstock	Contro-testa
6	Reitstockpinole	Contro-punta
7	Schleifscheibe	Mola
8	Schutzhaube	Riparo della mola
9	Schleifspindelstock	Testa porta-mola
10	Schleifspindelstockschlitten	Slitta della testa porta-mola
11	Innenschleifscheibe	Mola per interni
12	Schutzhaube für Innenschleifsheibe	Riparo della mola per interni

Bibliography

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

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

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