International Standard

ISO 2407

Fourth edition
2024-08

Test conditions for internal cylindrical grinding machines with horizontal spindle — Testing of accuracy

Conditions d'essai des machines à rectifier les surfaces de révolution intérieures à broche horizontale — Contrôle de l'exactitude

Reference number
ISO 2407:2024(en)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

This fourth edition cancels and replaces the third edition (ISO 2407:1997), which has been technically revised. It also incorporates the Amendment ISO 2407:1997/Amd 1:2016. The main changes are as follows:

— references to ISO 230 series have been updated;

— tests for optional B1-axis have been added;

— a new Annex A has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Test conditions for internal cylindrical grinding machines with horizontal spindle — Testing of accuracy

1 Scope

This document specifies, with reference to ISO 230-1, ISO 230-2 and ISO 230-7, geometric tests, positioning tests and machining tests on general purpose and normal accuracy internal cylindrical grinding machines with horizontal spindle, whether they are or are not fitted with a facing wheelhead slide. This document also specifies the applicable tolerances corresponding to the above-mentioned tests.

This document deals only with the verification of the accuracy; it applies neither to the testing of the machine operation (vibrations, abnormal noise, stick-slip motion of components, etc.), nor to the checking of its characteristics (such as speeds, feeds), which are generally checked before the testing of the accuracy.

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 230-1:2012, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions*

ISO 230-2:2014, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning of numerically controlled axes*

ISO 230-7:2015, *Test code for machine tools — Part 7: Geometric accuracy of axes of rotation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 230-1, ISO 230-2 and ISO 230-7 apply.

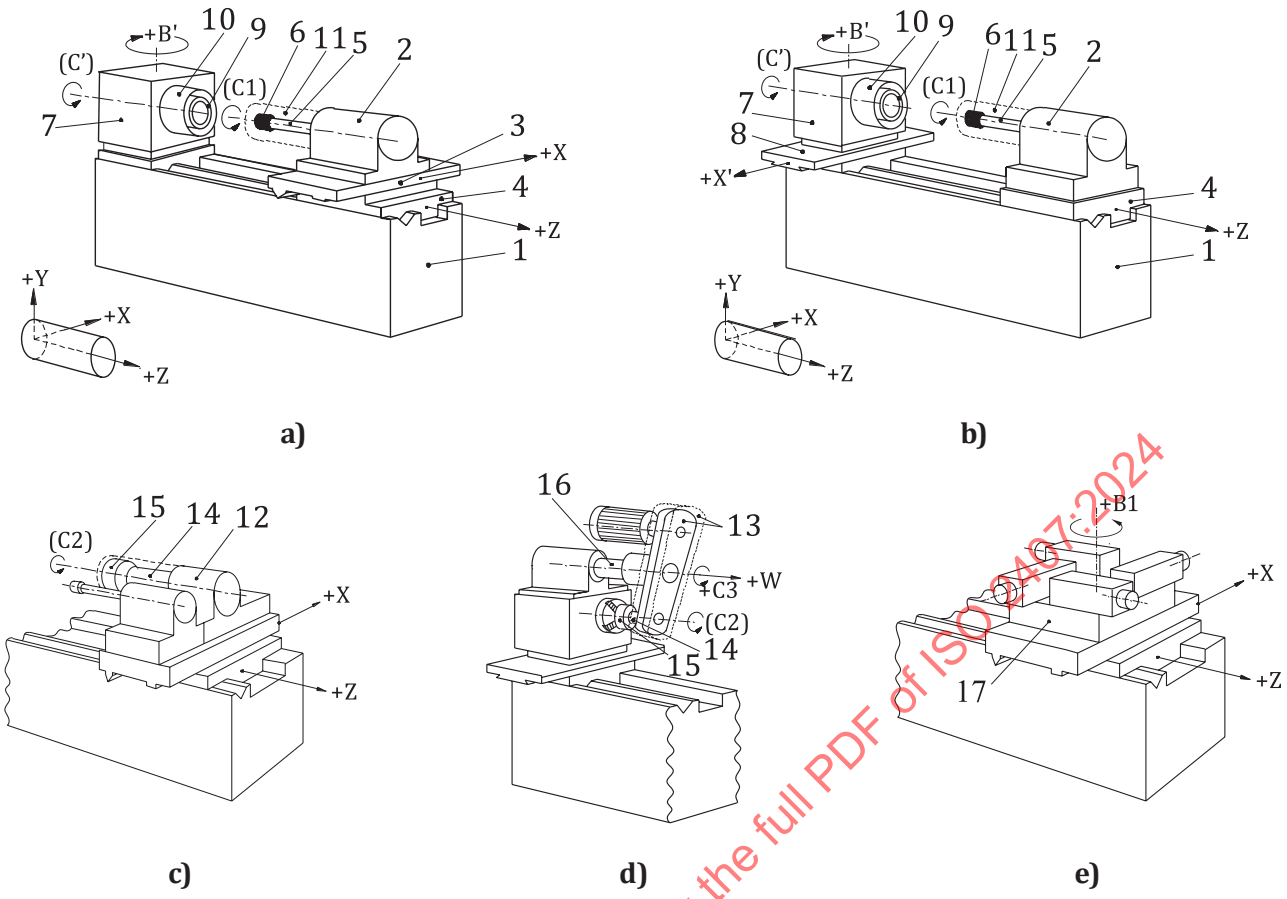
ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Machine configurations

The common characteristic of all internal cylindrical grinding machines with horizontal spindle is that they have at least one horizontal workhead and one wheelhead on the bed and the spindles are facing each other. The workhead can swivel around a vertical axis (B'-axis) for grinding conical surfaces.



Key

1 bed
2 wheelhead
3 wheelhead cross slide (X-axis)
4 wheelhead carriage (Z-axis)
5 wheel spindle [(C1)-axis]
6 internal grinding wheel
7 workhead (swivelling) [including B'-axis and (C')-axis]
8 workhead cross slide (X'-axis)
9 workholding spindle
10 workpiece guard
11 wheel guard
12 facing wheelhead
13 swivel arm (with drive and guard) (C3-axis)
14 facing spindle [(C2)-axis]
15 facing wheel
16 facing wheel quill (W-axis)
17 B1-axis

Figure 1 — Machine configurations

Depending upon the machine design, one of the two heads (workhead or wheelhead) can move along the X-axis. The wheelhead usually can move along the Z-axis [see Figures 1 a) and b)].

In some cases, these machines are equipped with a facing wheel. This can be accomplished by means of the second wheelhead as shown in Figure 1 c) or by an additional swivelling wheelhead attachment. This attachment is usually mounted on the workhead with a linear motion (W-axis) parallel to Z-axis and a swivelling motion (C3-axis) around the W-axis [see Figure 1 d)].

In some cases, these machines are equipped with a B1-axis that is mounted on the wheelhead cross slide (X-axis) and allows a fast tool change (2 to 4 axes). In some machine tools, B1-axis is a contouring rotary axis [see Figure 1 e)].

5 Preliminary remarks

5.1 Measuring units

In this document, 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 but in some cases microradians or arcseconds are used for clarification purposes. The equivalence of Formula (1) should always be kept in mind:

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

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

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

In the "Observations" block of the tests described in Clauses 6 and 7, the instructions are followed by a reference to the corresponding clauses of ISO 230-1, ISO 230-2 or ISO 230-7, in cases where the test concerned complies with the specifications of that part of the ISO 230 series.

5.3 Machine levelling

Prior to conducting tests on a machine tool, the machine tool should be levelled according to the recommendations of the supplier/manufacturer (see ISO 230-1:2012, 6.1).

5.4 Temperature conditions

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

5.5 Testing sequence

The sequence in which the tests are presented in this document in no way defines the practical order of testing. In order to make the mounting of instruments or measuring easier, tests may be performed in any order.

5.6 Tests to be performed

When testing a machine, it is not always necessary or possible to carry out all the tests described in this document. 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 shall be clearly stated when ordering a machine. Mere reference to this document for the acceptance tests, without specifying the tests to be carried out and without agreement on the relevant expenses, cannot be considered as binding for any contracting party.

5.7 Measuring instruments

Measuring instruments indicated in the tests described in Clauses 6 and 7 are examples only. Other instruments capable of measuring the same quantities and having the same, or a smaller, measurement uncertainty can be used. Reference shall be made to ISO 230-1:2012, Clause 5, which indicates the relationship between the measurement uncertainties and the tolerances.

When a "dial gauge" is referred to, it can mean not only dial test indicators (DTI), but any type of linear displacement sensor, such as analogue or digital dial gauges, linear variable differential transformer (LVDTs), linear scale displacement gauges, or non-contact sensors, when applicable to the test concerned.

Similarly, when a "straightedge" is referred to, it can mean any type of straightness reference artefact, such as a granite or ceramic or steel or cast-iron straightedge, one arm of a square, one generating line on a

cylindrical square, any straight path on a reference cube, or a special, dedicated artefact manufactured to fit in the T-slots or other references.

In the same way, when a "square" is mentioned, it can mean any type of squareness reference artefact, such as a granite or ceramic or steel or cast-iron square, a cylindrical square, a reference cube, or, again, a special, dedicated artefact.

When a "precision level" is referred to, it can mean any type of level such as bubble tube, digital and analogue electronic levels.

Valuable information on measuring instruments is available in ISO/TR 230-11.

5.8 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 manufacturer/supplier and the user, with due consideration to the machine tool intended use, e.g. if the intended use of the machine tool is with or without software compensation for geometric errors. When the software compensation is used, this shall be stated in the test report. It shall be noted that when software compensation is used, some machine tool axes cannot be locked for test purposes.

Valuable information on numerical compensation of geometric errors is available in ISO/TR 16907.

5.9 Machining tests

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

5.10 Minimum tolerance

By mutual agreement, the manufacturer/supplier and the user can establish the tolerance for a measuring length different from that given in the tests described in Clauses 6 and 7. However, it shall be considered that the minimum value of tolerance is 0,005 mm unless otherwise specified.

When establishing the minimum tolerance, the measurement uncertainty associated with the test and the recommended instrument, shall be taken into account; see 5.7.

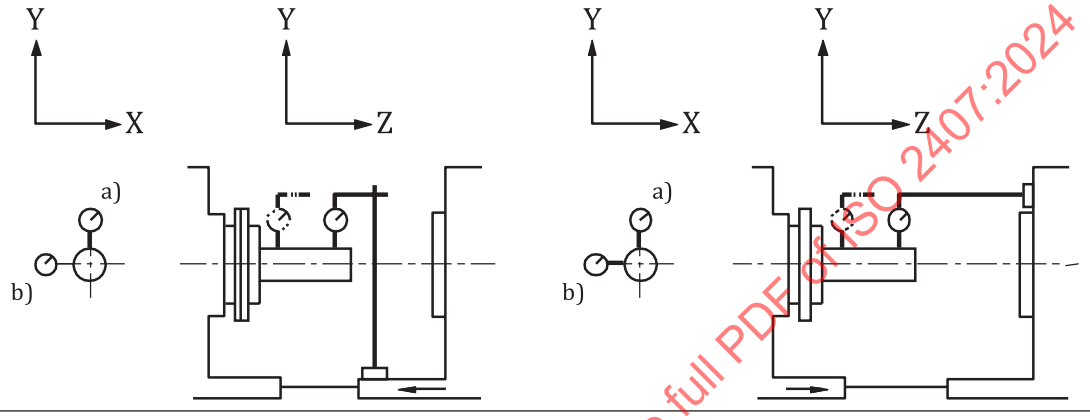
5.11 Diagrams

For reasons of simplicity, the diagrams in Clauses 6 and 7 illustrate only one type of machine.

Where applicable, the diagram box provides, for each test a), b) and c) identified in the object box, a schematic representation of a possible test setup, including the identification of the relevant coordinate plane (e.g. XY, YZ, ZX).

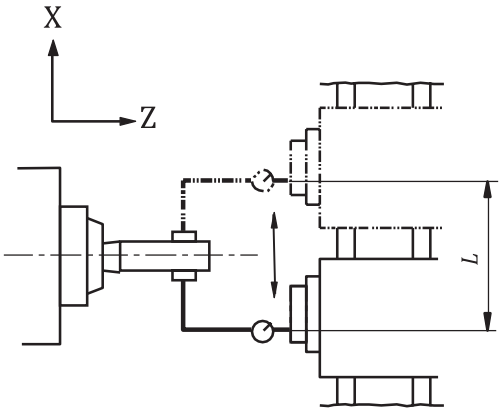
6 Geometric tests

6.1 Linear axes motions

Object	**G1**
Checking of straightness of the wheelhead (or workhead) slide motion along the Z-axis: a) in the vertical plane, E_{YZ}; b) in the horizontal plane, E_{XZ}.	
Diagram  	
Tolerance a) 0,015 for a measuring length of 250 b) 0,008 for a measuring length of 250	
Measurement results a) b)	
Measuring instruments Dial gauge and test mandrel or straightedge, or optical instruments	
Observations and reference to ISO 230-1:2012, 8.2 When a test mandrel is used, the dial gauge support shall be placed on the fixed part of the wheelhead and the test mandrel in the workholding spindle. When a straightedge is used, the dial gauge support shall be placed on a fixed part of the wheelhead, the stylus touching a straightedge laid approximately parallel to the Z-axis motion. When a straightedge is mounted on the workhead, its sag shall be taken into account. When a straightedge is used for long axes, it can be mounted on a fixed part of the machine (e.g. bed). In this case, differential straightness measurements shall be conducted, one with wheelhead motion and the other with workhead motion, without moving the straightedge between the two sets of measurements.	

Object	**G2**
Checking of squareness of the motion of the wheelhead cross slide or workhead cross slide (X-axis) to the Z-axis motion, $E_{B(0Z)X}$.	

Diagram



Key

L distance between the two points touched

Tolerance

0,020/300 (0,066/1 000)

where 300 is the distance between the two points touched, L.

Measurement results

Measuring instruments

Test mandrel and dial gauge support or optical instruments

Observations and references to ISO 230-1:2012, 10.3.2 and 10.3.3

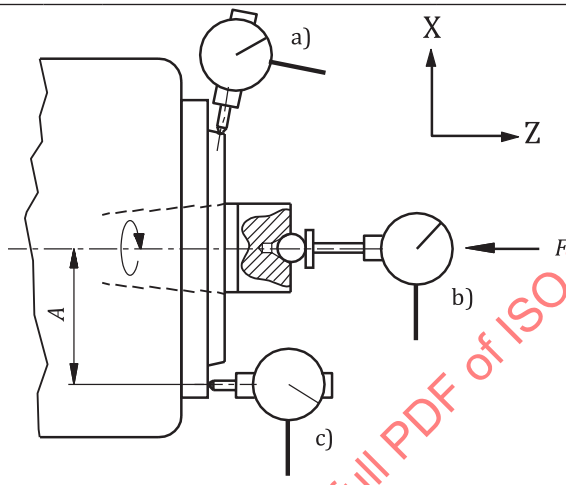
Set a test mandrel on the workholding spindle and adjust the workhead (B'-axis) so that the spindle axis is parallel to the Z-axis motion.

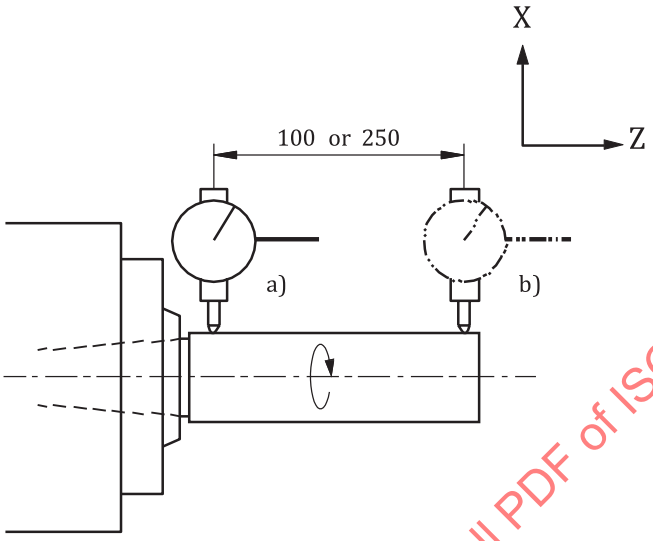
Fix the dial gauge support on the test mandrel, with the stylus of the dial gauge touching a point of the wheel spindle.

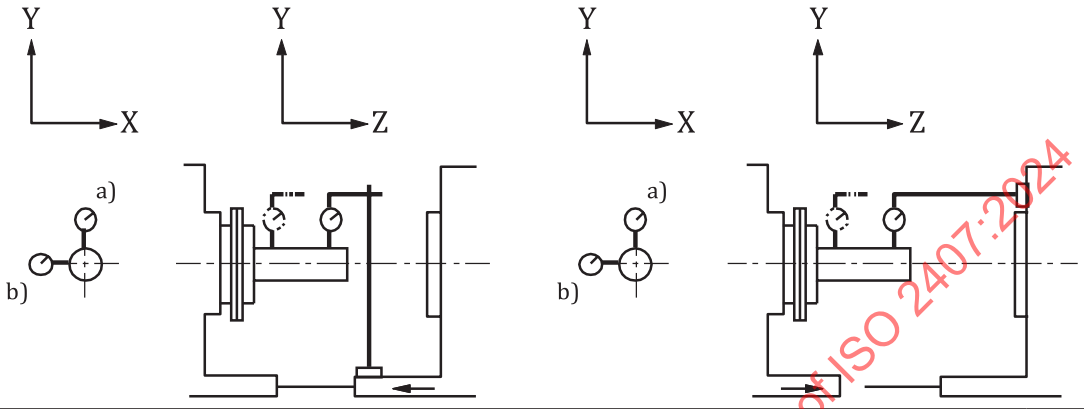
Turn the workholding spindle through 180° and move the X-axis until the stylus again touches the same point.

The difference in the readings of the dial gauge divided by the distance, L, between the two points touched is the squareness error to be reported.

6.2 Workholding spindle

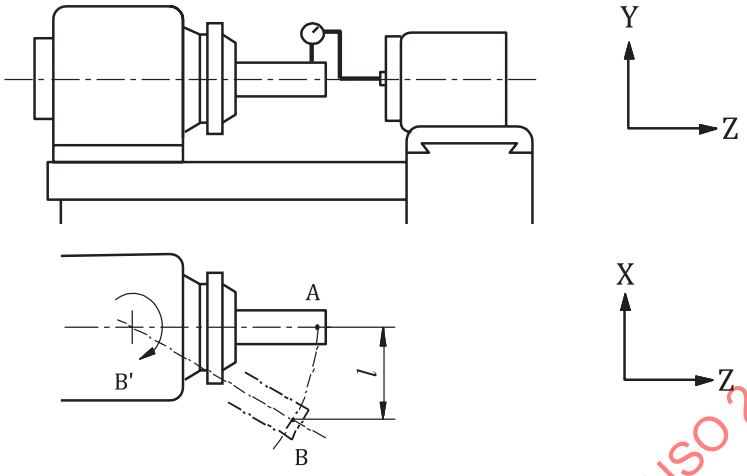
Object	**G3**
Checking of the workholding spindle rotation: a) run-out of the external centring surface; b) axial error motion, $E_{Z(C')}$; c) face run-out of the front resting surface.	
Diagram  **Key** *A* distance from the spindle axis *F* axial force	
Tolerance a) 0,005 b) 0,005 c) 0,010	
Measurement results a) b) c)	
Measuring instruments Dial gauge for a) and c) and dial gauge with flat-ended stylus tip for b)	
Observations and, for a) and c), reference to ISO 230-1:2012, 12.5; for b), reference to ISO 230-7:2015, 5.4.4 For a), in the case of a tapered spindle nose, the stylus of the dial gauge shall be set normal to the surface to be checked. For b), the value and the direction of the axial force, *F*, to be applied shall be specified by the supplier/manufacturer. Where preloaded thrust bearings are used, no force needs to be applied. For c), the distance, *A*, of the dial gauge from the spindle axis shall be as large as possible. See also test AR1 in Annex A.	

Object	**G4**
Checking of run-out of the internal taper of the workholding spindle: a) near the spindle nose; b) at a distance of 100 or 250.	
Diagram  	
Tolerance a) 0,005 b) 0,010 for a measuring distance of 100 0,015 for a measuring distance of 250	
Measurement results Measured distance: a) b)	
Measuring instruments Test mandrel and dial gauge	
Observations and reference to ISO 230-1:2012, 12.5 In the case of an internal taper, the test shall be made with the aid of a test mandrel.	

Object	**G5**
Checking of parallelism of the workholding spindle axis, (C'), to the Z-axis motion of the wheelhead (or of the workhead): a) in the vertical plane, $E_{A(0Z)(C')}$; b) in the horizontal plane, $E_{B(0Z)(C')}$.	
Diagram  	
Tolerance a) 0,008/100, 0,020/250 (0,080/1 000); test mandrel end directed upwards b) 0,003/100, 0,008/250 (0,032/1 000)	
Measurement results a) b)	
Measuring instruments Test mandrel and dial gauge or optical instruments	
Observations and reference to ISO 230-1:2012, 12.5 The checking shall be done first at one angular position of the workholding spindle and then repeated after rotating the spindle through 180°. Mean values shall be taken at each measuring point in order to evaluate the parallelism error.	

Object	**G6**
Checking of parallelism of the workhead swivelling plane to the X-axis.	

Diagram



Key

l difference in X-axis positions between measuring points A and B (highest points on the test mandrel)

Tolerance

0,010/100 (0,100/1 000)

Measurement results

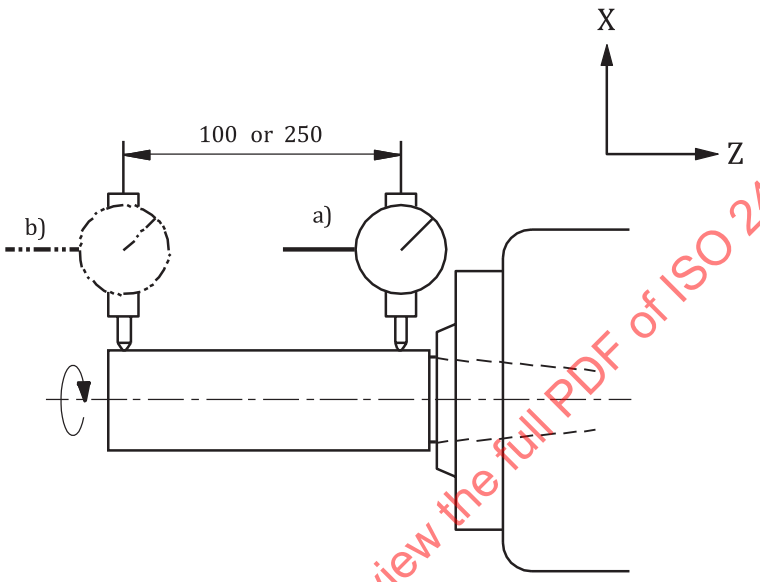
Measuring instruments

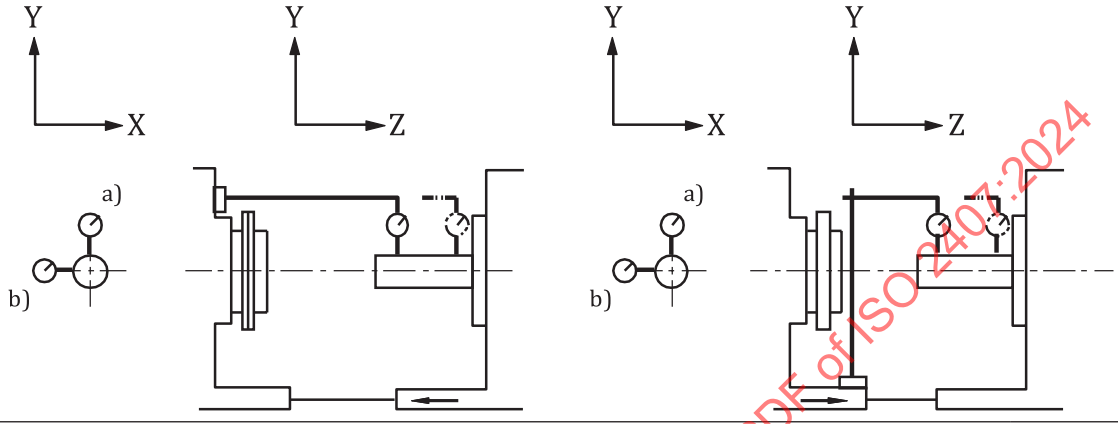
Test mandrel and dial gauge

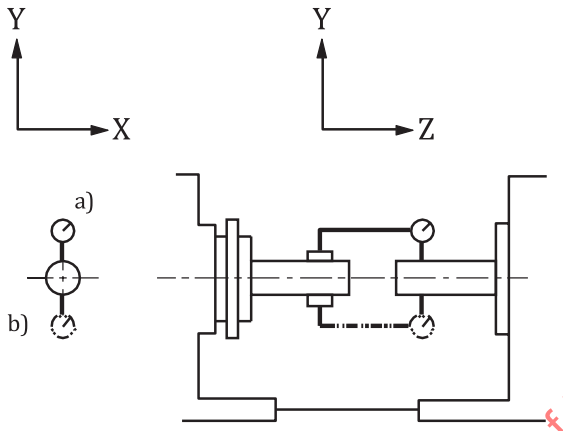
Observations and reference to ISO 230-1:2012, 12.3.3.2

A reading shall be taken when the workhead is locked in position A. Swivel the workhead towards its external position B and touch the stylus of the dial gauge to the same point of the test mandrel as in position A, moving the cross slide and the Z-axis. The difference between the readings at positions A and B, divided by the distance, *l*, is the value to be reported.

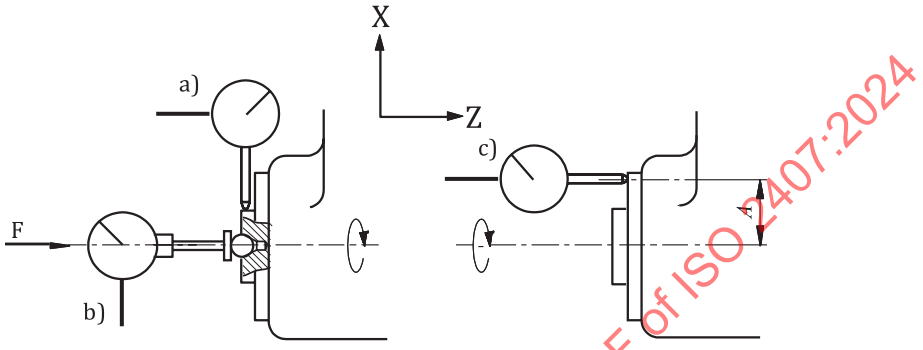
6.3 Wheel spindle

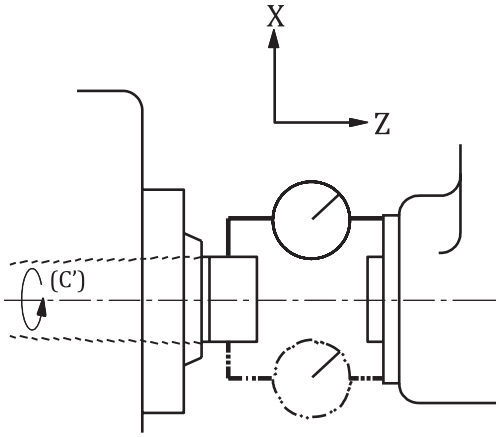
Object	**G7**
Checking of run-out of internal taper of the wheel spindle (wheel mounting diameter): a) near the spindle nose; b) at a distance of 100 or 250. This test is applicable to all available wheel spindles.	
Diagram  	
Tolerance a) 0,005 b) 0,010 for a measuring distance of 100 0,015 for a measuring distance of 250	
Measurement results Measured distance: a) b)	
Measuring instruments Test mandrel according to the type of spindle nose and dial gauge	
Observations and reference to ISO 230-1:2012, 12.5.3 In the case of an internal taper, the test shall be made with the aid of a test mandrel. See also test AR2 in Annex A.	

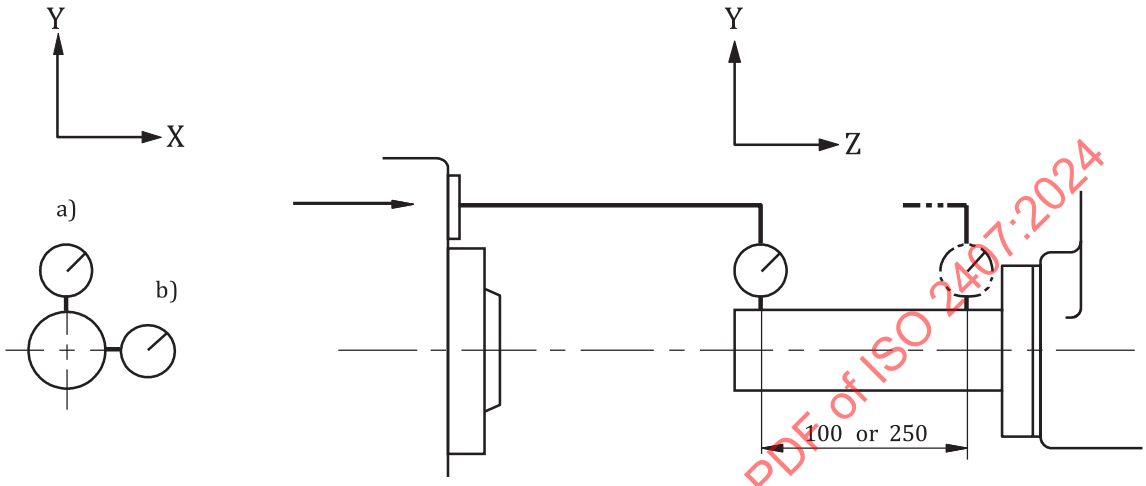
Object	**G8**
Checking of parallelism of the wheel spindle axis, (C1), to the Z-axis motion of the wheelhead (or of the workhead): a) in the vertical plane, $E_{A(0Z)(C1)}$; b) in the horizontal plane, $E_{B(0Z)(C1)}$. This test is applicable to all available wheel spindles.	
Diagram  	
Tolerance a) 0,007/100, 0,020/300 (0,065/1 000); test mandrel end directed upwards b) 0,004/100, 0,010/300 (0,035/1 000)	
Measurement results a) b)	
Measuring instruments Test mandrel and dial gauge or optical instruments	
Observations and reference to ISO 230-1:2012, 10.1.3 The checking shall be done first at one angular position of the wheel spindle, (C1), and then repeated after rotating the spindle through 180°. Mean values shall be taken at each measuring point in order to evaluate the parallelism error.	

Object	**G9**
Checking of the equidistance (difference in height) of the workholding spindle axis, (C'), and the wheel spindle axis, (C1), in the vertical plane. This test is applicable to all available wheel spindles.	
Diagram 	
Tolerance 0,025	
Measurement results	
Measuring instruments Test mandrel, dial gauge and dial gauge support, or optical instruments	
Observations and reference to ISO 230-1:2012, 12.3.3 The test shall be carried out in the vertical plane after having obtained alignment in the horizontal plane. Specific care shall be devoted to minimize the compliance of the dial gauge support.	

6.4 Facing wheelhead

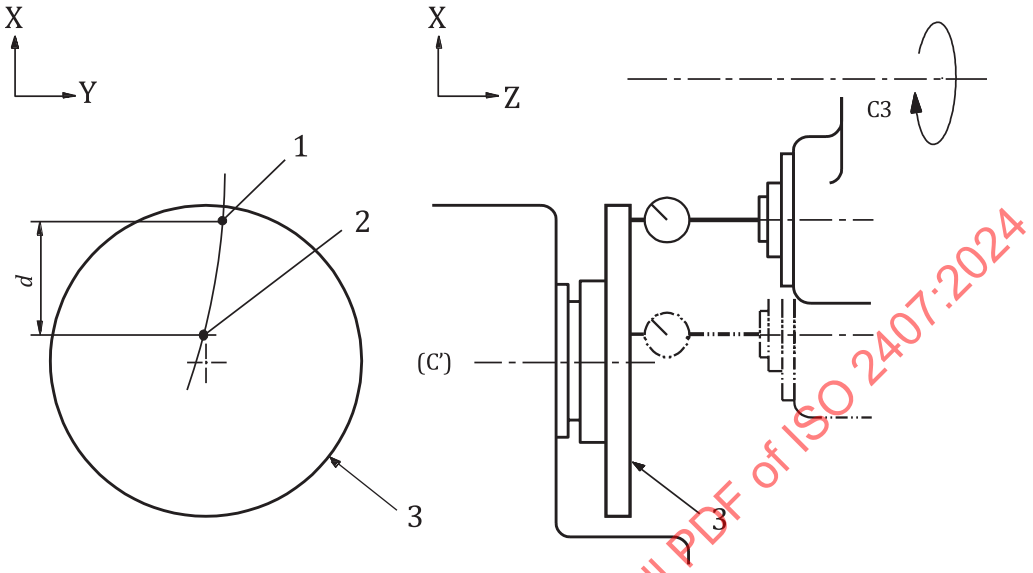
Object	**G10**
Checking of the facing spindle: a) run-out of the external centring surface; b) axial error motion, $E_{Z(C2)}$; c) face run-out of the front resting surface.	
Diagram  **Key** *A* distance from the spindle axis *F* axial force	
Tolerance a) 0,005 b) 0,005 c) 0,010	
Measurement results a) b) c)	
Measuring instruments Dial gauge for a) and c) and dial gauge with flat-ended stylus tip for b)	
Observations and, for a) and c), reference to ISO 230-1:2012, 12.5, for b), reference to ISO 230-7:2015, 5.4.4 For a), in the case of a tapered spindle nose, the stylus of the dial gauge shall be set normal to the surface to be checked. For b), the value and the direction of the axial force, *F*, to be applied shall be specified by the supplier/manufacturer. Where preloaded thrust bearings are used, no force needs to be applied. For c), the distance, *A*, of the dial gauge from the spindle axis shall be as large as possible. See also test AR2 in Annex A.	

Object	**G11**
Checking of perpendicularity of the flange face of the facing spindle, (C2), to the workholding spindle axis, (C').	
Diagram  	
Tolerance 0,020 over 300 where 300 is the distance between the two points touched.	
Measurement results	
Measuring instruments Dial gauge and dial gauge support	
Observations and references to ISO 230-1:2012, 12.4.1 and 12.4.8 The dial gauge is rotated through 360° and the largest variation in the readings is the squareness error to be reported.	

Object	**G12**
Checking of parallelism of the facing spindle axis, (C2), to the Z-axis motion (of the wheelhead or of the workhead): a) in the vertical plane, $E_{A(0Z)(C2)}$; b) in the horizontal plane, $E_{B(0Z)(C2)}$.	
Diagram  	
Tolerance a) 0,008/100, 0,020/250 (0,080/1 000); test mandrel end directed upwards b) 0,003/100, 0,008/250 (0,032/1 000)	
Measurement results a) b)	
Measuring instruments Dial gauge and test mandrel	
Observations and reference to ISO 230-1:2012, 10.1.3 The checking shall be done first at one angular position of the facing spindle, (C2), and then repeated after rotating the spindle through 180°. Mean values shall be taken at each measuring point in order to evaluate the parallelism error.	

Object	**G13**
Checking of parallelism of the swivel arm axis, C3, to the workholding spindle axis, (C'), in the ZX plane. This test is only applicable for the machine tool configuration depicted in Figure 1 d).	

Diagram



Key

1, 2	measurement points
3	flat disc
d	measurement distance projected on the X-axis
C3	swivelling arm axis
(C')	workholding spindle axis

Tolerance

0,035/1 000

Measurement results Measured distance *d*:

Measuring instruments

Dial gauge and flat disc or straightedge

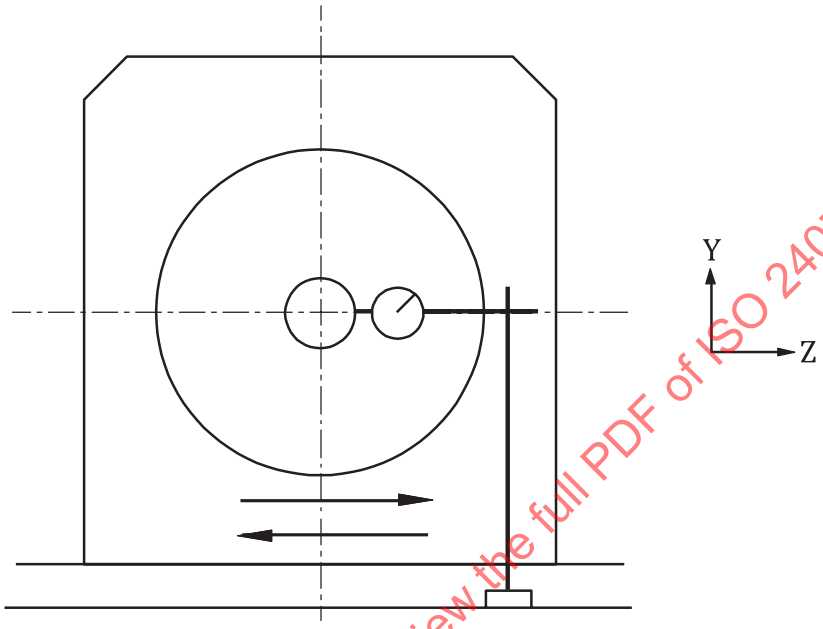
Observations and references to ISO 230-1:2012, 10.1.5.1

The dial gauge is rigidly mounted on the facing spindle and it is brought to contact the disc. The (C')-axis is rotated by 180° and the perpendicularity of the disc surface with respect to the (C')-axis is adjusted, or the lack of perpendicularity is considered in the measurement.

A reading of the dial gauge is taken at point 1 then the C3-axis is swivelled and a new reading is taken at point 2.

The difference between the two readings divided by the distance, *d*, between the measurement points 1 and 2, projected on the X-axis, is the parallelism error to be reported.

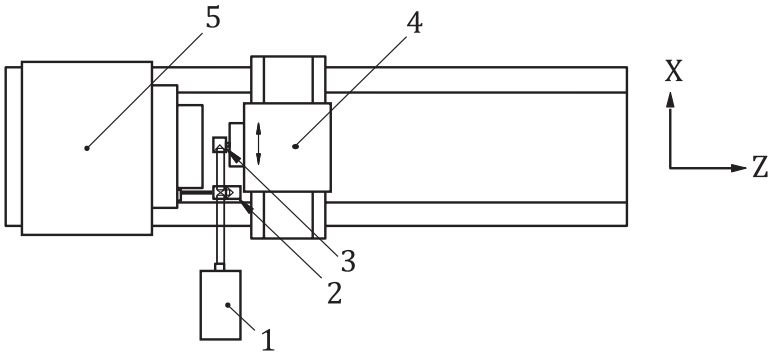
7 Positioning tests

Object	**P1**
Checking of the repeatability of the finishing approach of the wheelhead cross slide (or the workhead cross slide).	
Diagram 	
Tolerance 0,002	
Measurement results	
Measuring instruments Dial gauge	
Observations Carry out five consecutive tests for the wheelhead cross slide positioning (or workhead slide positioning), the motion being obtained by a quick approach followed by a slow approach. The range of individual positioning measurements is the measurement result to be reported.	

Object | **P2**

Checking of the accuracy and repeatability of the X-axis motion of the wheelhead cross slide, E_{XX}.

Diagram



Key

1 laser head 2 interferometer 3 retro-reflector 4 wheelhead carriage 5 workhead

Tolerance For axes up to 1 000		**Measuring length** ≤500	≤1 000	**Measurement results: Measured length**
Unidirectional positioning accuracy of X-axis[a]	$E_{XX,A\uparrow}$; $E_{XX,A\downarrow}$	0,016	0,020	
Unidirectional positioning repeatability of X-axis[a]	$E_{XX,R\uparrow}$; $E_{XX,R\downarrow}$	0,006	0,008	
Mean reversal value of X-axis	$E_{XX,\bar{B}}$	0,010	0,013	
Unidirectional systematic positioning error of X-axis[a]	$E_{XX,E\uparrow}$; $E_{XX,E\downarrow}$	0,008	0,013	

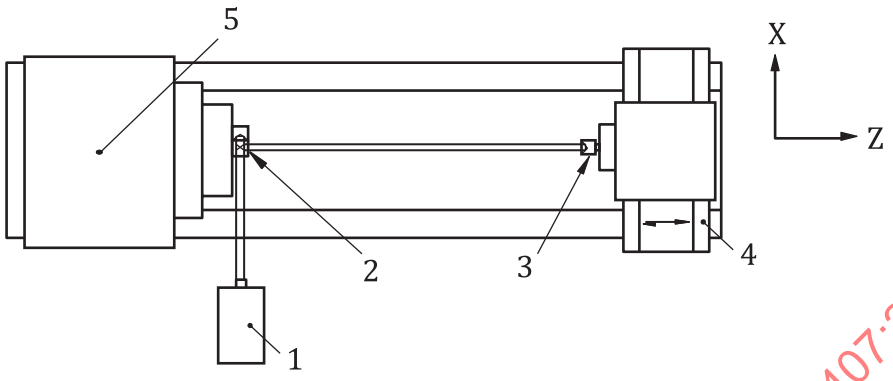
[a] Possible basis for machine acceptance.

Measuring instruments

Laser measuring equipment or linear scale

Observations and references to ISO 230-1:2012, 3.4.3 and ISO 230-2:2014, Clause 3, 5.3.2 and 5.3.3

Relative measurement between the tool position and work-piece position is desired. When a linear scale is used, it shall be set on the table parallel to the X-axis, the scale reader being on the tool position. When laser equipment is used, the reflector should be set on the spindle head and the interferometer on the workhead. Concerning the test conditions, test program and presentation of results, ISO 230-2:2014, Clauses 3, 4 and 7 and 8.2.4 shall be referred to. The starting point of measurement shall be stated.

Object					**P3**
Checking of the accuracy and repeatability of the Z-axis motion of the wheelhead carriage, E_{ZZ}.					
Diagram  **Key** 1 laser head 2 interferometer 3 retro-reflector 4 wheelhead carriage 5 workhead					
Tolerance For axes up to 2 000		**Measuring length** ≤500	≤1 000	≤2 000	**Measurement results: Measured length**
Bi-directional positioning accuracy of Z-axis [a]	$E_{ZZ,A}$	0,025	0,032	0,040	
Unidirectional positioning accuracy of Z-axis[a]	$E_{ZZ,A\uparrow}$; $E_{ZZ,A\downarrow}$	0,015	0,019	0,024	
Unidirectional positioning repeatability of Z-axis[a]	$E_{ZZ,R\uparrow}$; $E_{ZZ,R\downarrow}$	0,008	0,010	0,013	
Mean reversal value of Z-axis	$E_{ZZ,\bar{B}}$	0,010	0,013	0,016	
Bi-directional systematic positioning error of Z-axis[a]	$E_{ZZ,E}$	0,016	0,020	0,025	
Unidirectional systematic positioning error of Z-axis[a]	$E_{ZZ,E\uparrow}$; $E_{ZZ,E\downarrow}$	0,008	0,010	0,013	
Mean bi-directional positioning error of Z-axis [a]	$E_{ZZ,M}$	0,010	0,013	0,016	
For axes exceeding 2 000					
Bi-directional systematic positioning error of Z-axis[a]	$E_{ZZ,E}$	0,032 + 0,008 for each additional 1 000			
Mean bi-directional positioning error of Z-axis[a]	$E_{ZZ,M}$	0,025 + 0,005 for each additional 1 000			
[a] Possible basis for machine acceptance.					
Measuring instruments Laser measuring equipment or linear scale					

Observations and references to ISO 230-1:2012, 3.4.3; ISO 230-2:2014, Clause 3, 5.3.2 and 5.3.3

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

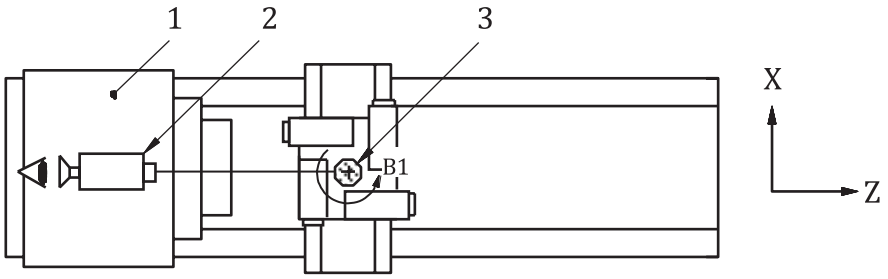
For axes exceeding 2 000, one or more segments of 2 000 with 5 runs forward and backward each is recommended. Tolerances for axis lengths ≤2 000 shall be applied.

For axes up to 4 000, one measurement over one 2 000 segment is recommended, for axes over 4 000 and up to 8 000, two 2 000 segments are recommended, and so forth.

Test segments shall be equally spaced along the full axis length, with any excess length equally divided at the beginning, in between and at the end of the test segments.

Other number of 2 000 segments, other lengths of segments, as well as the positions of the segments within the working area can be subject to agreement between the manufacturer/supplier and the user. Additionally, one test over the total travel of the axis (once forward and once backward) shall be performed.

Concerning the test conditions, test program and presentation of results, ISO 230-2:2014, Clauses 3, 4 and 7 and 8.2.4 shall be referred to. The starting point of measurement shall be stated.

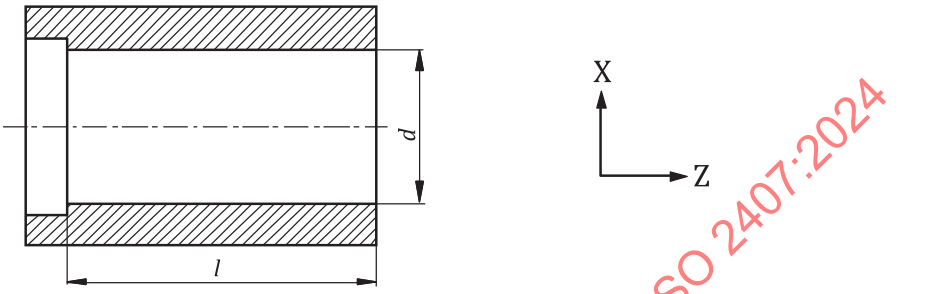
Object				**P4**
Checking of the accuracy and repeatability of the B1-axis of rotation, E_{BB1}.				
Diagram				
				
Key 1 workhead 2 autocollimator 3 polygon				
Tolerance (30° or 45° interval positioning)		**For 360°**		**Measurement results**
		"	µrad	
Bi-directional positioning accuracy of B1-axis [a]	$E_{BB1,A}$	11	55	
Unidirectional positioning repeatability of B1-axis [a]	$E_{BB1,R\uparrow}$; $E_{BB1,R\downarrow}$	6	30	
Bi-directional positioning repeatability of B1-axis	$E_{BB1,R}$	8	40	
Mean reversal value of B1-axis	$E_{BB1,\bar{B}}$	6	30	
Bi-directional systematic positioning error of B1-axis[a]	$E_{BB1,E}$	6	30	
Mean bi-directional positioning error of B1-axis [a]	$E_{BB1,M}$	4	20	
[a] Possible basis for machine acceptance.				
Measuring instruments Laser angle measuring equipment or polygon and autocollimator				
Observations and references to ISO 230-1:2012, 3.4.3 and ISO 230-2:2014, Clause 3, 5.3.4 and 5.3.5 Fix the autocollimator on the workhead side of the machine tool and fix the polygon near the centre of the B1-axis of rotation, in alignment with the autocollimator at the first measuring rotary position. Target positions shall be selected in accordance with ISO 230-2:2014, Table 1. Angular positioning feed speed shall be agreed between the manufacturer/supplier and the user. Concerning the test conditions, test program and presentation of results, ISO 230-2:2014, Clauses 3, 4 and 7 and 8.2.4 shall be referred to.				

8 Machining tests

Object | **M1**

Checking of the accuracy of the bore of a test piece ground by internal grinding:
a) roundness;
b) consistency of diameters.

Diagram



Maximum admissible diameter for grinding[a] D	Test bore diameter d	Test bore length l
$D \leq 40$	15	25
$40 < D \leq 80$	30	50
$80 < D \leq 150$	60	100
$D > 150$	100	150

Key

d test bore diameter
l test bore length
[a] Refer to M2 diagram.

Tolerance

a) 0,003
b) 0,005 for $l = 25$
0,005 for $l = 50$
0,010 for $l = 100$
0,015 for $l = 150$

Measurement results Maximum admissible diameter, D:

a)
b)

Measuring instruments

Bore gauge and roundness measuring machine

Observations and references to ISO 230-1:2012, B.1.1 and B.1.2

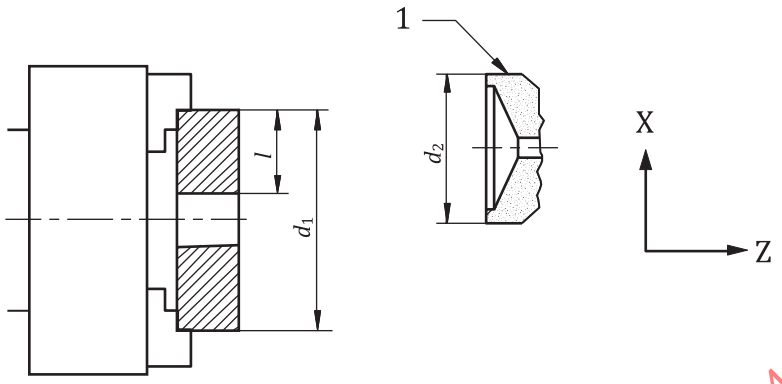
Grinding of the test piece shall be conducted along the whole length, l, without arbor support.

For a), the measurements for roundness shall be made at several positions of the test piece and the greatest measured value shall be recorded.

For b), the variation of diameter shall be measured at both ends and in the middle of the test piece. The measurements shall be carried out in a single axial plane. Any taper should be such that the largest diameter is near the workhead.

Object	**M2**
Checking of the flatness of the ground face of a disk.	

Diagram



Key

1	grinding wheel
d_1	outer diameter of the disk
d_2	outer diameter of the grinding wheel
l	width of ground face

Tolerance

0,010 for d_1 = 300

The ground test piece shall be flat or concave.

Measurement results

Measuring instruments

Straightedge and gauge blocks for surface plate and dial gauge or coordinate measuring machine (CMM)

Observations and references to ISO 230-1:2012, B.1.1 and B.1.2

The test piece shall be mounted on a face plate or chuck.

The workhead spindle axis is set parallel to the Z-axis motion. Facing of a flat surface perpendicular to the workhead spindle.

The outer diameter, d_1, of the disc and the width, l, of the ground face should conform to the following formulae:

$$d_1 = \frac{2}{3} \times D \quad ; \quad l = \frac{2}{3} \times d_2$$

Other d_1 and l values can be agreed between the manufacturer/supplier and the user.