
**Test conditions for numerically
controlled turning machines and
turning centres —**

**Part 1:
Geometric tests for machines with
horizontal workholding spindle(s)**

*Conditions d'essai des tours à commande numérique et des centres de
tournage —*

Partie 1: Essais géométriques pour les machines à broche horizontale



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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.

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 documents 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

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.

This second edition cancels and replaces the first edition (ISO 13041-1:2004), which has been technically revised.

The main changes compared to the previous edition are as follows:

- in 5.2, straightness measurements in all axes of motions have been added (tests G3, G4 and G5);
- in 5.3, squareness errors between axes of motion have been added (tests G7, G8 and G9);
- a test for error motion of axis of rotation of workholding and tool spindles has been added in Annex A;
- terms in non-ISO languages have been added in Annex B.

In addition to text written in the official ISO languages (English, French or Russian), this document gives text in German, Italian, Japanese and Persian. This text is published under the responsibility of the member body/National Committee for Germany (DIN), Italy (UNI), Japan (JISC) and Iran (ISRI) and is given for information only. Only the text given in the official languages can be considered as ISO text.

A list of all parts in the ISO 13041 series can be found on the ISO website.

Introduction

The objective of the ISO 13041 series is to provide information as wide and comprehensive as possible on geometric, positional, contouring, thermal and machining tests which can be carried out for comparison, acceptance, maintenance or any other purpose.

The ISO 13041 series specifies, with reference to the ISO 230-1 and ISO 230-7, tests for turning centres and numerically controlled turning machines with/without tailstocks standing alone or integrated in flexible manufacturing systems. The ISO 13041 series also establishes the tolerances or maximum acceptable values for the test results corresponding to general-purpose and normal-accuracy turning centres and numerically controlled turning machines.

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Test conditions for numerically controlled turning machines and turning centres —

Part 1:

Geometric tests for machines with horizontal workholding spindle(s)

1 Scope

This document specifies, with reference to ISO 230-1, the geometric tests on normal accuracy numerically controlled (NC) turning machines and turning centres with horizontal work spindles as defined in 3.1 and 3.2. It also specifies the applicable tolerances corresponding to the above-mentioned tests.

Where applicable, this document also applies to horizontal spindle turret and single spindle automatic lathes.

This document explains different concepts or configurations and common features of NC turning machines and turning centres. It also provides a terminology and designation of controlled axes.

This document 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 are checks generally carried out before testing the accuracy.

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

numerically controlled turning machine

NC turning machine

turning machine that operates under numerical control or computerized numerical control

3.2

turning centre

NC turning machine (3.1) equipped with power-driven tool(s) and the capacity to orientate the workholding spindle around its axis

Note 1 to entry: This machine may include additional features such as automatic tool changing from a magazine

3.3

tool turret

multiple tool-holding system capable of positioning the cutting tool to execute machining operation

4 Preliminary remarks

4.1 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 may be used for clarification purposes. [Formula \(1\)](#) should be used for the conversion of the units of angular deviations or tolerances.

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

4.2 Reference to ISO 230

To apply this document, reference shall be made to ISO 230-1:2012, ISO 230-7:2015, when required, 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.

Where the test concerned is in compliance with the specifications of ISO 230-1 and/or ISO 230-7, a reference to the corresponding clause of ISO 230-1, respectively ISO 230-7, is shown before the instructions in the "Observations" block of the tests described below. Tolerances are given for each test (see G1 to G30).

4.3 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, 6.1.1 and 6.1.2).

4.4 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 gauging easier, tests may be performed in any order.

4.5 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, the relevant tests relating to the components and/or the properties of the machine. These tests are to be clearly stated when ordering a machine. A simple 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.

4.6 Measuring instruments

Measuring instruments indicated in the tests described below are only examples. Other instruments capable of measuring the same quantities and having the same, or a smaller, measurement uncertainty may be used.

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 metrological standard, such as a laser beam, special optics, 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 be 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 a special dedicated artefact.

Valuable information for measuring instruments are available in ISO/TR 230-11.

4.7 Diagrams

In this document, for reasons of simplicity, the diagrams associated with geometric tests illustrate only one type of machine.

4.8 Linear motions

For simplicity, all the machine examples shown in the Figures and Tables use the axis designation of a letter and a number (e.g. X1, X2) as defined in ISO 841:2001, 6.1. In all examples, the use of the letters U, V, or W can be substituted.

4.9 Tool turret and tool spindle(s)

As defined in 3.2, turning centres have not only stationary tools but also power-driven rotary tools, which means that the turret should also have power drive mechanisms. When the number of tools expected to be used exceeds the capacity of the turret, an automatic change of tools in the turret, or a change of turret, may be provided.

[Figure 3](#) shows typical types of tool turrets and tool spindles.

4.10 Machine classifications

The machine tools considered in this document are divided into two basic configurations (see [Table 1](#), [Figure 1](#) and [Figure 2](#)):

- Type A: Machine tools with tailstock;
- Type B: Machine tools without tailstock.

Type A-Machine tools can be generally classified into two further groups:

- Group A-1: With one turret;
- Group A-2: With two turrets.

NOTE There are machines with multiple turrets. Test described in this document apply to all turrets.

Type B-Machine tools can be generally classified into four further groups:

- Group B-1: With one workhead (headstock);
- Group B-2: With two co-axial interfacing heads;
- Group B-3: With a co-axial rotating head;
- Group B-4: With two parallel heads.

Table 1 — Examples of turning centre configurations

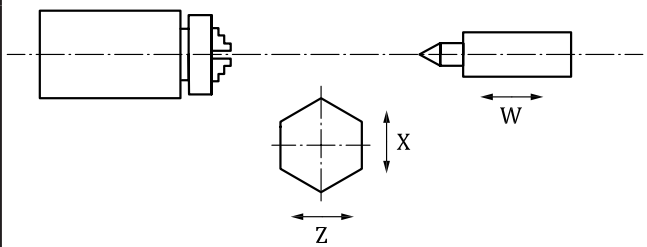
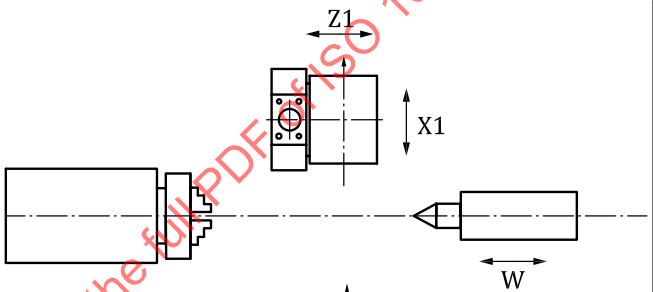
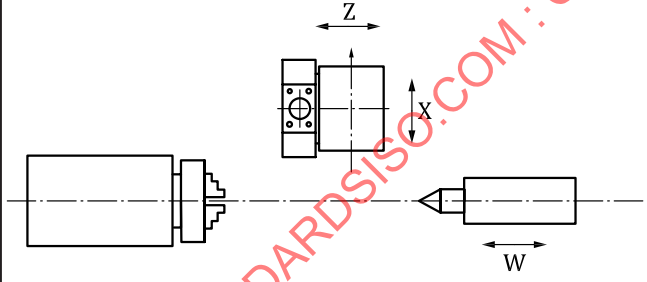
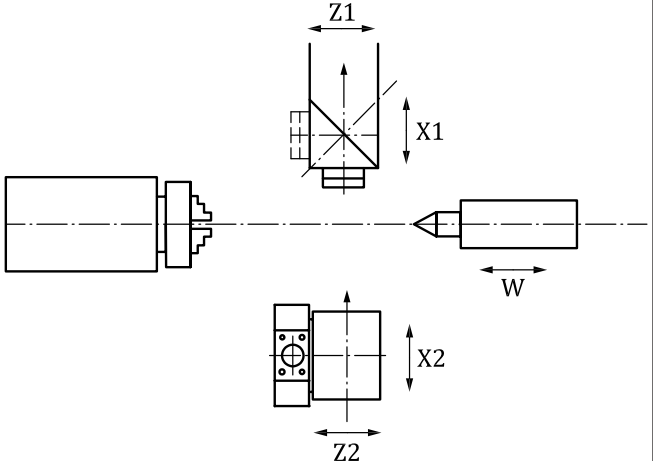
Type A - With tailstock	
Group A-1: With one tool turret	Group A-2: With two tool turrets
Tool turret type: With tool turret type a): 	Tool turret type: NOTE The two tool turrets can be different. With two tool turrets type b): 
With tool turret type b): 	With tool turret type b) and tools turret type f): 

Table 1 (continued)

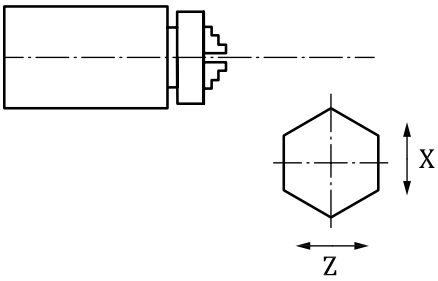
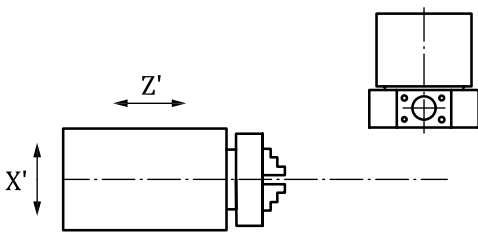
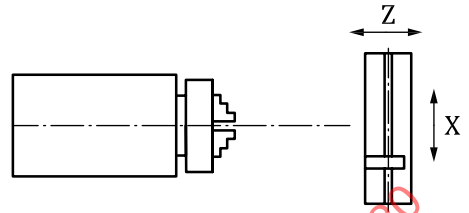
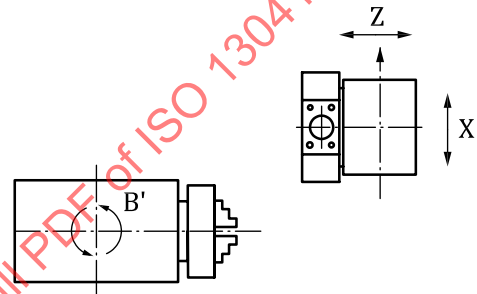
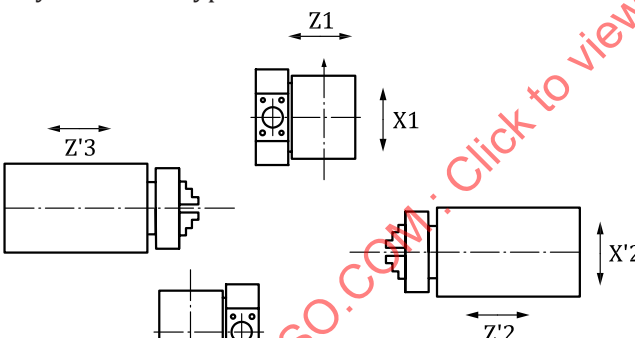
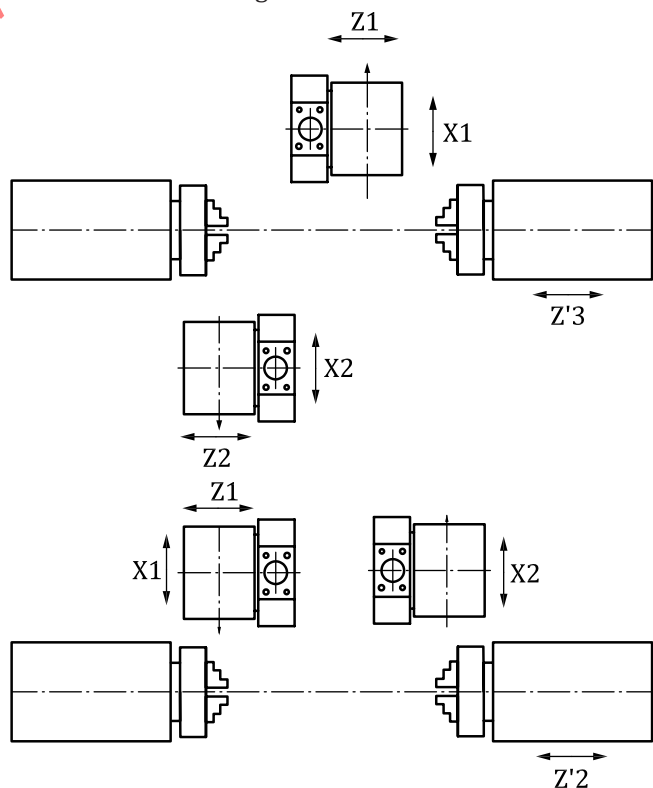
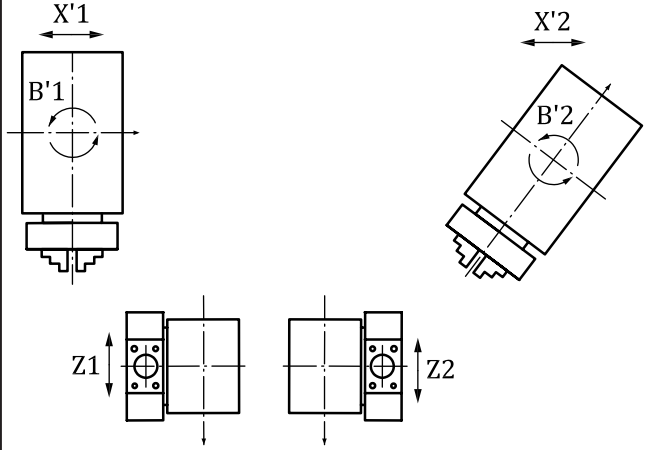
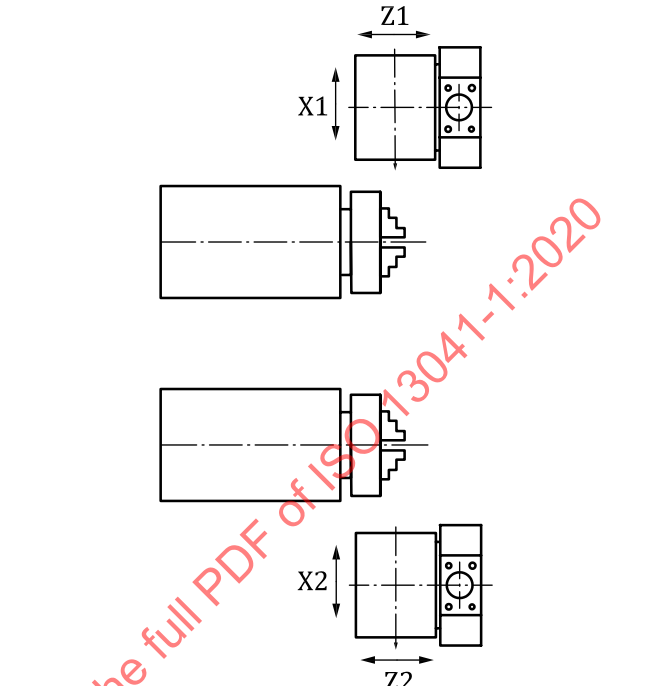
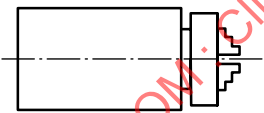
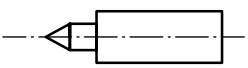
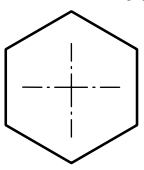
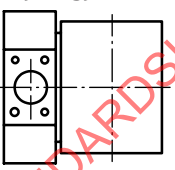
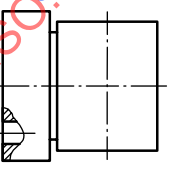
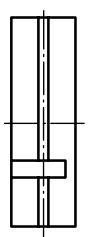
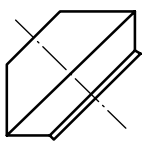
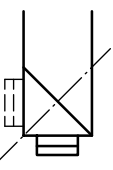
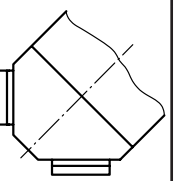
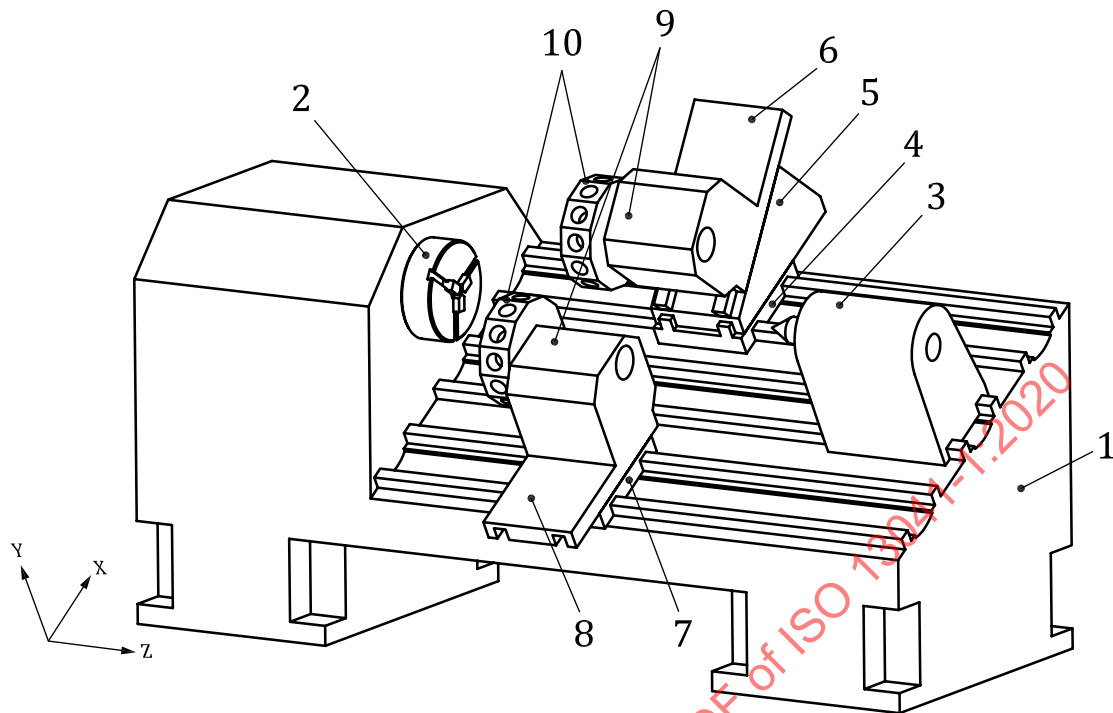
Type B – Without tailstock	
Group B-1: With one workholding spindle head	
With tool turret type a):  With tool turret type b): 	With tool turret type d):  With B'-axis rotary head: 
Group B-2: With two co-axial workholding spindle heads	
Any tool turret type: 	Both heads can be aligned: 

Table 1 (continued)

Group B-3: With two co-axial rotating workholding spindle heads	Group B-4: With two parallel workholding spindle heads
Workhead at machining position: 	 Axes of motion may be by the work heads. Y-axis motion can be optional.
Symbols used: Workhead  Tailstock  Tool turret types a) to g), see also Figure 3.        a)b)c)d)e)f)g)	

**Key****English**

- 1 bed
- 2 main workholding spindle, C'-axis
- 3 tail stock, W-axis
- 4 carriage 1, Z-axis
- 5 tool turret slide 1, X-axis
- 6 slide, P-axis
- 7 carriage 2, Z2-axis
- 8 tool turret slide 2, X2-axis
- 9 tool turret head 1 and 2
- 10 indexing turret 1 and 2

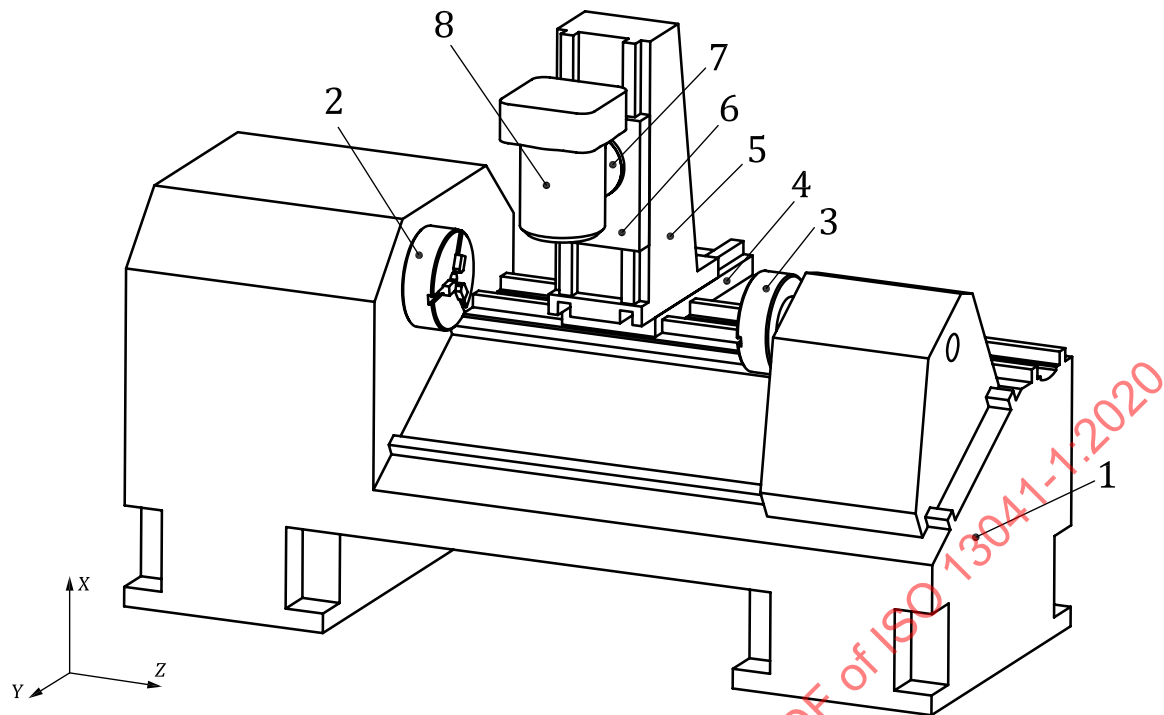
French

- banc
- broche porte-pièce, axe C'
- contre-poupée, axe W
- chariot 1, axe Z
- chariot de tourelle 1, axe X
- chariot, axe P
- chariot 2, axe Z2
- chariot de tourelle 2, axe X2
- poupée porte-tourelle 1 et 2
- tourelle à indexage 1 et 2

NOTE 1 P-axis in item 6 and X-axis in item 5 together generate the Y-axis movement.

NOTE 2 For languages other than official ISO languages, see [Table B.1](#).

Figure 1 — Example of a horizontal spindle turning centre with two tool turrets and tail stock



Key

English	French
1 bed	banc
2 main workholding spindle, C'-axis	broche porte-pièce principal, axe C'
3 sub workholding spindle, C'2-axis	sous-broche porte-pièce, axe C'2
4 carriage, Z-axis	chariot, axe Z
5 column, Y-axis	colonne, axe Y
6 carriage, X-axis	chariot, axe X
7 rotational B-axis	chariot, axe Y
8 tool spindle head	tête de la broche porte-outil

NOTE For languages other than official ISO languages, see [Table B.2](#).

Figure 2 — Example of a horizontal spindle turning centre with double workholding spindles, tool spindle and B-axis

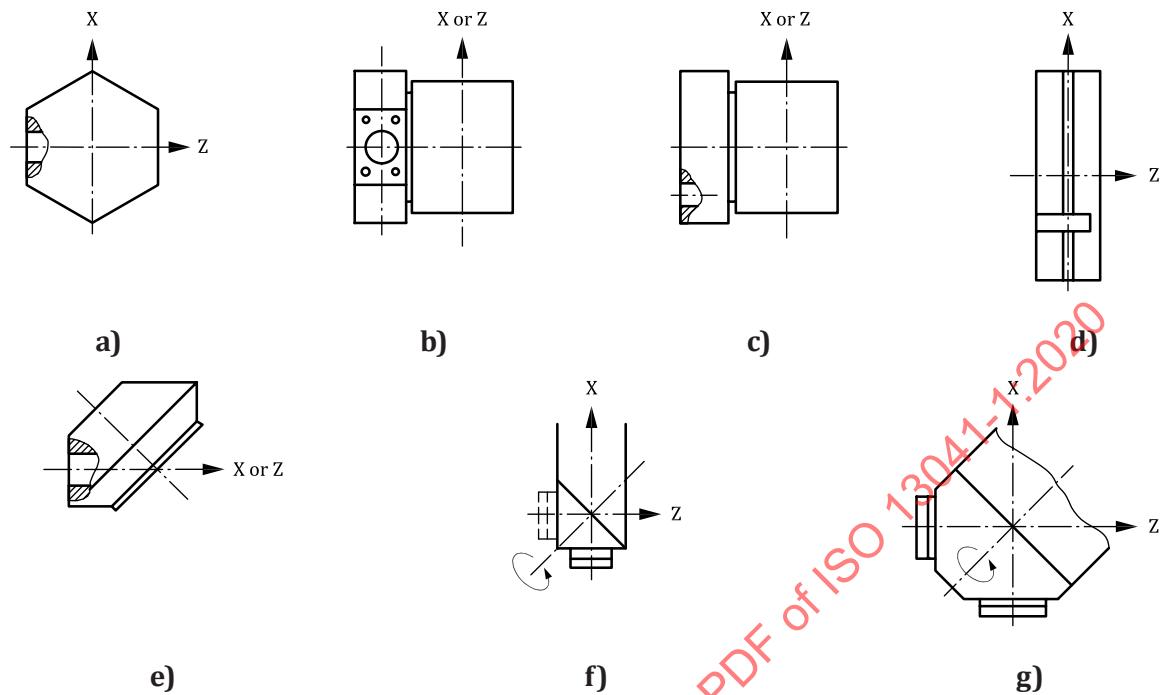


Figure 3 — Examples of tool turret and tool spindle configurations

Figure 3 shows the following types:

- a) horizontal turret: Turret rotation axis is in the Y-direction. This turret type can have either stationary or power-driven tools or a combination of both;
- b) wheel type turret for radial tools: Turret rotation axis is in the X- or Z-direction. This turret type can have stationary tools only, power-driven tools only or both stationary and power-driven tools;
- c) wheel type turret for axial tools: The tools are set axially to the axis of rotation of the turret. Combinations of b) and c) are possible;
- d) linear turret;
- e) oblique turret: The tools can be used in the X- or Z-direction only;
- f) single tool spindle with single tool head: By swivelling the head the tool spindle can be in both X- and Z-axis direction. A tool changer and a tool magazine are needed;
- g) oblique dual spindle tool head: One spindle is provided for stationary tools and the second for power-driven tools.

4.11 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 an agreement between the user and the supplier/manufacturer. When the software compensation is used, axes shall not be locked for test purposes.

4.12 Tolerances

When the tolerance for a geometric test is established for a measuring length different from that given in this document (see ISO 230-1:2012, Clause 4), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

In principles, angular tolerances are given as a distance over 1 000 mm. The angle converted for a typical measuring length is presented in parentheses; for example: 0,060/1 000 (0,015/250).

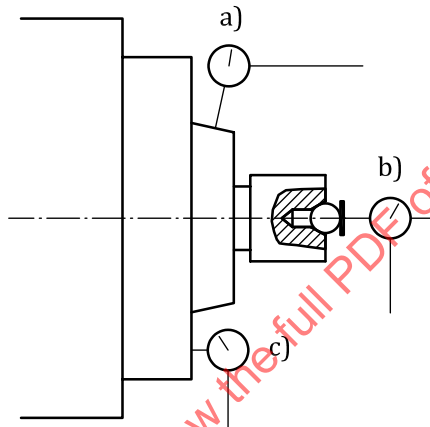
4.13 Axes not under test

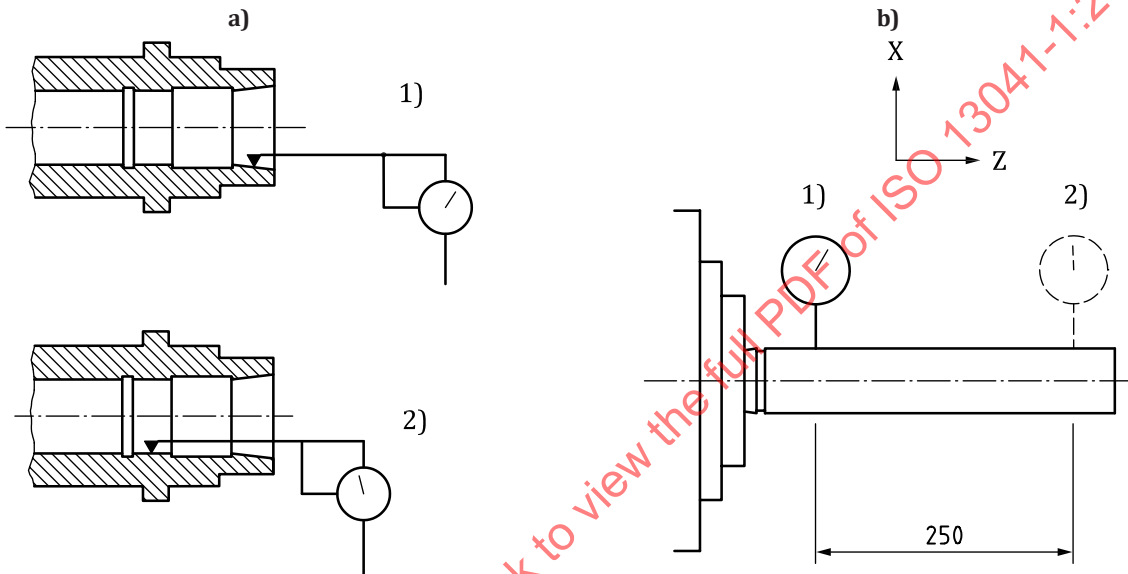
During the execution of some geometric tests on one axis of motion, the position of the other axes, not under test, may affect the results. Therefore, the position of these axes as well as offsets on the tool side and on the workpiece side are to be stated in the test report.

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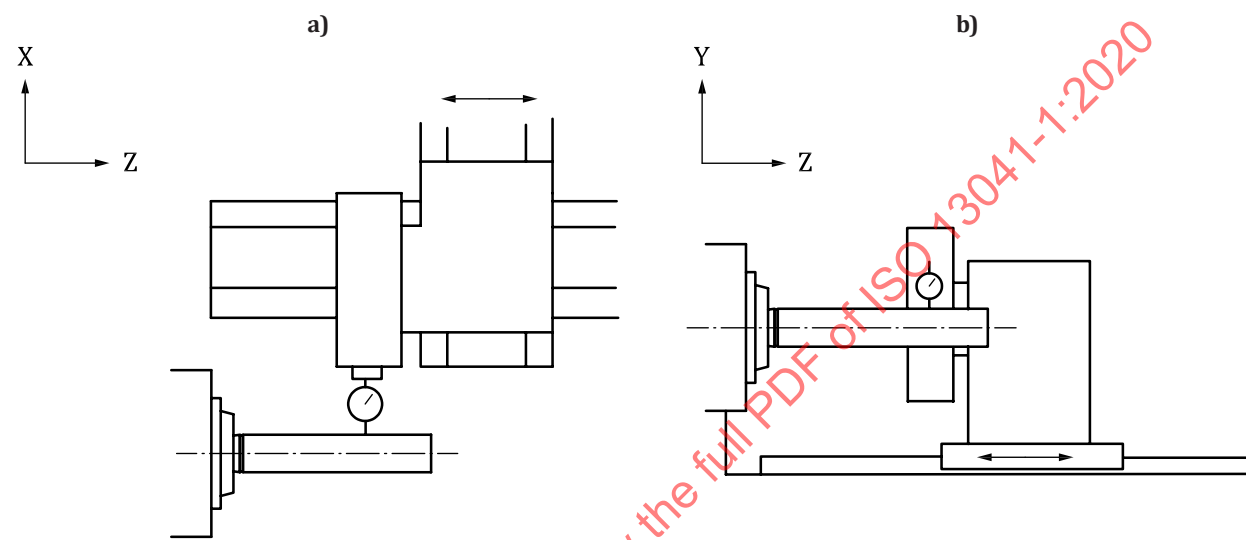
5 Geometric tests

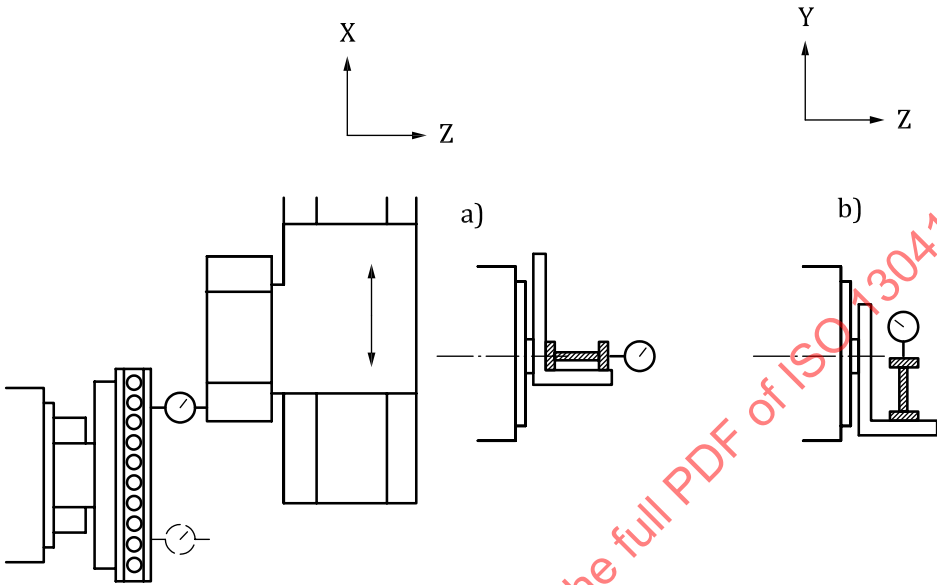
5.1 Workholding spindle

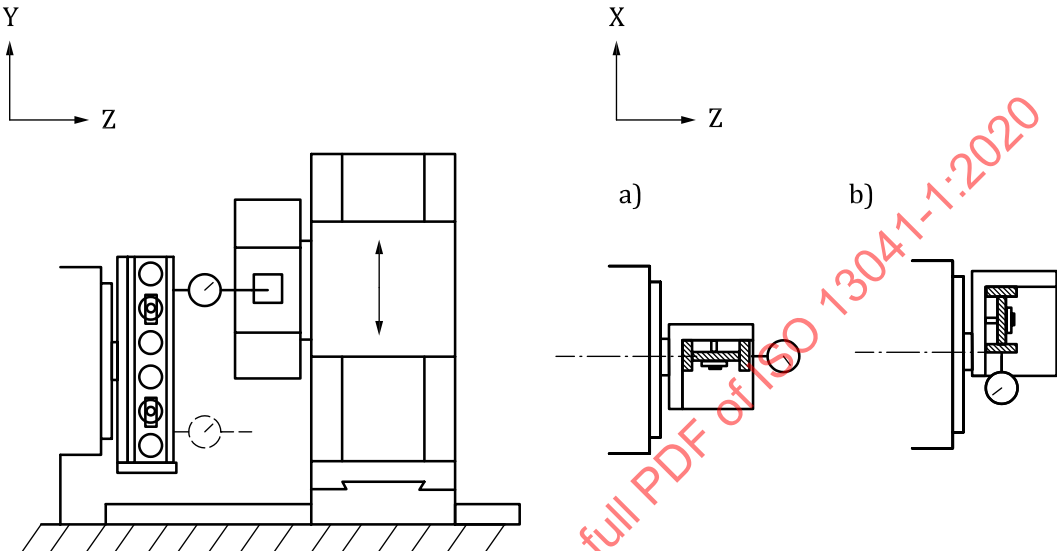
Object				G1	
Checking the workholding spindle nose:					
a) run-out of centring diameter;					
b) axial error motion of the spindle;					
c) run-out of the spindle face.					
Diagram					
					
Tolerance				Measured error	
	$D \leq 250$	$250 < D \leq 500$	$500 < D \leq 1\,000$		
a)	0,005	0,008	0,012	a)	
b)	0,005	0,005	0,005	b)	
c)	0,008	0,010	0,015	c)	
where D is the diameter permitted over bed.					
Measuring instruments					
Dial gauge,					
Only valid for b): Mechanical device to hold the test sphere					
Observations and references					
a) ISO 230-1:2012, 3.9.7: When the surface is conical, the stylus of the dial gauge shall be normal to the contacting surface.					
b) ISO 230-1:2012, 3.5.5.					
c) ISO 230-1:2012, 12.5.2: Measurements shall be taken on the maximum measurable diameter.					
Measurements shall be performed on all work spindles.					
Spindle shall be operated by NC control.					
NOTE For measurement of spindle error motion, see Annex A , Test AR1.					

Object		G2		
Checking the run-out of the work spindle bore:				
a) by direct contact:				
1) on the front seating cone;				
2) on the back register; or				
b) using a test mandrel:				
1) at the spindle nose;				
2) at a distance of 250 mm from the spindle nose.				
Diagram				
				
Tolerance		Measured error		
a) 1) and 2) 0,008		a 1)		
b) For measuring length of 250 mm or full stroke up to 250 mm		2)		
	$D \leq 250$	$250 < D \leq 500$	$500 < D \leq 1\,000$	b 1)
1)	0,010	0,015	0,020	2)
2)	0,015	0,020	0,025	
where D is diameter permitted over bed.				
Measuring instruments				
Dial gauge and test mandrel				
Observations and references to ISO 230-1:2012, 3.9.7 and 12.5.3				
Measurements should be taken in the ZX and YZ planes. Rotate spindle slowly at least two revolutions at each measuring location when measuring spindle run-out.				
The measurements shall be repeated at least four times, the mandrel being rotated through 90° in relation to the spindle. The run-out to be recorded is the average of the readings.				
Steps should be taken to minimize the effect of the tangential drag upon the stylus of the measuring instrument.				
Measurements shall be performed on all work holding spindles.				
Spindle shall be operated by NC control.				
NOTE For measurement of spindle tilt error motion, see Annex A , Test AR1.				

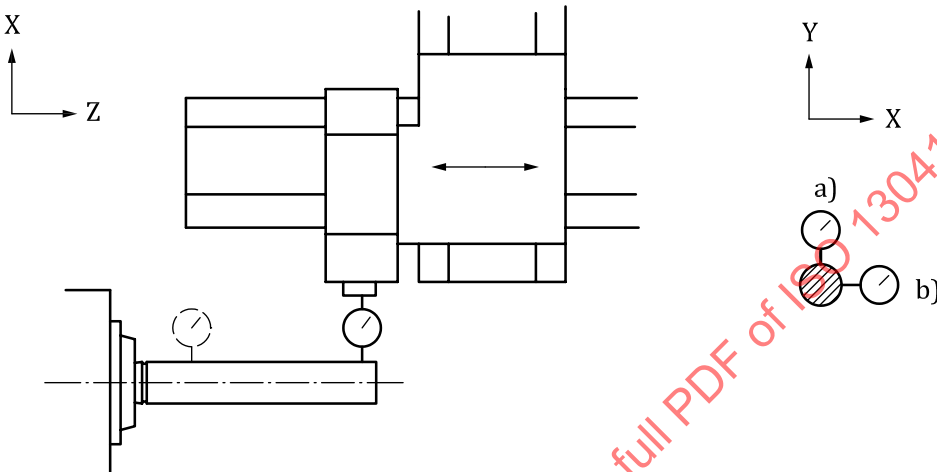
5.2 Straightness of axes of motion

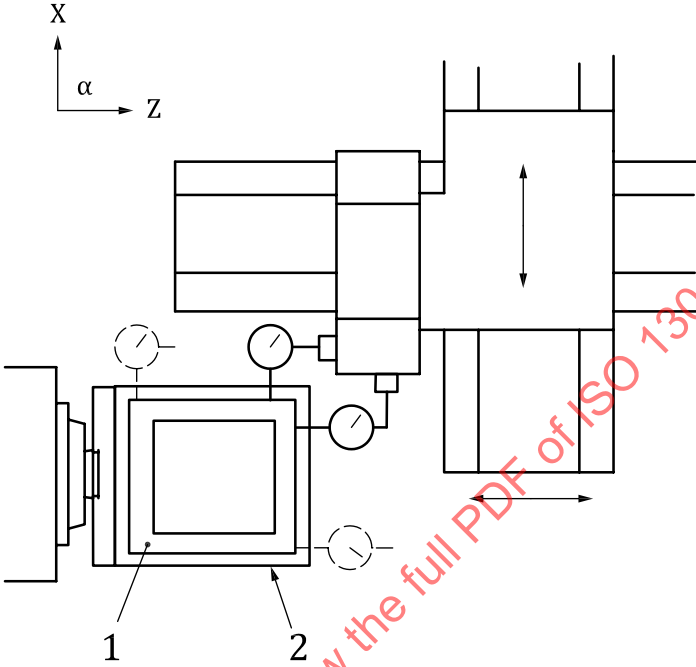
Object		G3
Checking the straightness of the Z-axis motion:		
a) in the ZX plane (E_{XZ});		
b) in the YZ plane (E_{YZ}).		
Diagram		
		
Tolerance		Measured error
$Z \leq 500$ 0,010		For $Z = \dots\dots$
$500 < Z \leq 1\,000$ 0,015		a)
$1\,000 < Z \leq 2\,000$ 0,025		b)
$2\,000 < Z \leq 5\,000$ 0,050		
$5\,000 < Z \leq 10\,000$ 0,080		
Local tolerance 0,007 for a measuring length of 300.		
Measuring instruments		
Test mandrel and dial gauge or optical instruments		
Observations and references to ISO 230-1:2012, 8.2.2.4		
The spindle shall be locked, if possible, when the spindle is used for attaching the mandrel.		
Measurements should be taken at several positions of the Z-axis motion.		
Set-up may be used for G6.		

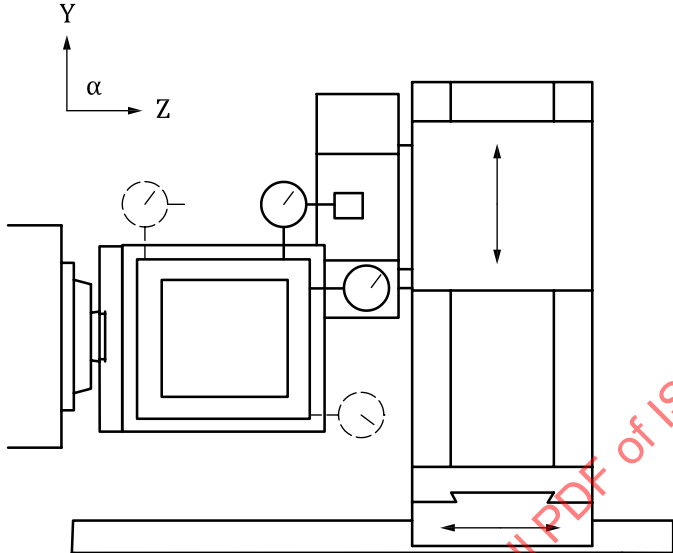
Object Checking the straightness of the X-axis motion: a) in the ZX plane (E_{ZX}); b) in the XY plane (E_{YX}).		G4						
Diagram 								
Tolerance <table border="0" style="width: 100%;"> <tr> <td style="width: 30%;">$X \leq 500$</td><td style="width: 30%; text-align: center;">0,010</td><td style="width: 40%;"></td></tr> <tr> <td>$500 < X \leq 1\,000$</td><td style="text-align: center;">0,015</td><td></td></tr> </table> Tolerances for axes above 1 000 are to be defined by manufacturer/supplier and user. Local tolerance 0,007 for a measuring length of 300.		$X \leq 500$	0,010		$500 < X \leq 1\,000$	0,015		Measured error For $X = \dots\dots$ a) b)
$X \leq 500$	0,010							
$500 < X \leq 1\,000$	0,015							
Measuring instruments Straightedge and dial gauge or optical instruments								
Observations and references to ISO 230-1:2012, 8.2.2.4, 12.1.3.2, 12.1.3.3 and 12.1.3.4 The spindle shall be locked if the spindle is used for attaching the straightedge. Adjust face of the straightedge parallel to the X-axis motion. Measured surface of the straightedge should be at the height of spindle centreline. Measurements should be taken at several positions of the X-axis motion. Offset of indicator from face of toolholder should be noted with the test results. Set-up may be used for G10.								

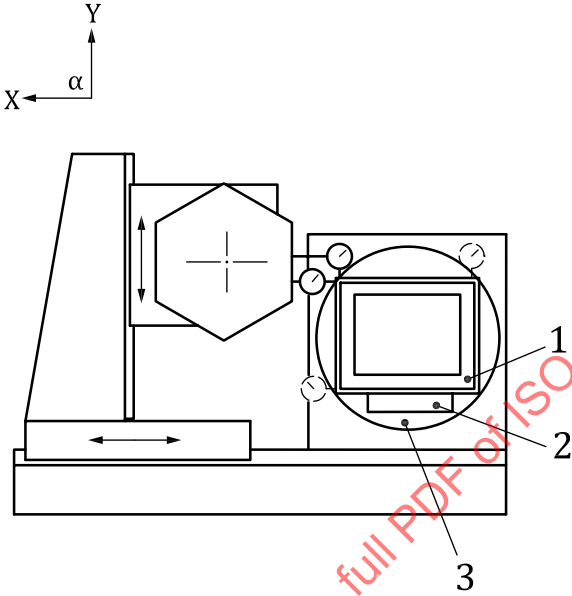
Object Checking the straightness of the Y-axis motion: a) in the YZ plane (E_{ZY}); b) in the XY plane (E_{XY}).	G5				
Diagram  The diagram illustrates the measurement setup for Y-axis straightness. The main side view shows a vertical axis with a dial indicator and a straightedge. The coordinate system has Y pointing up and Z pointing right. Two cross-sectional views, labeled a) and b), show the relationship between the X, Y, and Z axes and the measuring instruments. View a) shows the YZ plane, and view b) shows the XY plane.					
Tolerance <table border="0" style="width: 100%;"> <tr> <td style="width: 30%;">$Y \leq 500$</td> <td style="width: 30%; text-align: center;">0,010</td> </tr> <tr> <td>$500 < Y \leq 1\,000$</td> <td style="text-align: center;">0,015</td> </tr> </table> Tolerances for axes above 1 000 are to be defined by manufacturer/supplier and user. Local tolerance 0,007 for a measuring length of 300.	$Y \leq 500$	0,010	$500 < Y \leq 1\,000$	0,015	Measured error For $Y = \dots\dots$ a) b)
$Y \leq 500$	0,010				
$500 < Y \leq 1\,000$	0,015				
Measuring instruments Straightedge and dial gauge or optical instruments Observations and references to ISO 230-1:2012, 8.2.2.4, 12.1.3.2, 12.1.3.3 and 12.1.3.4 The spindle shall be locked if the spindle is used for attaching straightedge. Adjust face of the straightedge parallel to the Y-axis motion. Measured surface of the straightedge should be at the height of spindle centreline. Measurements should be taken at several positions along the Y-axis motion. Set-up may be used for G11.					

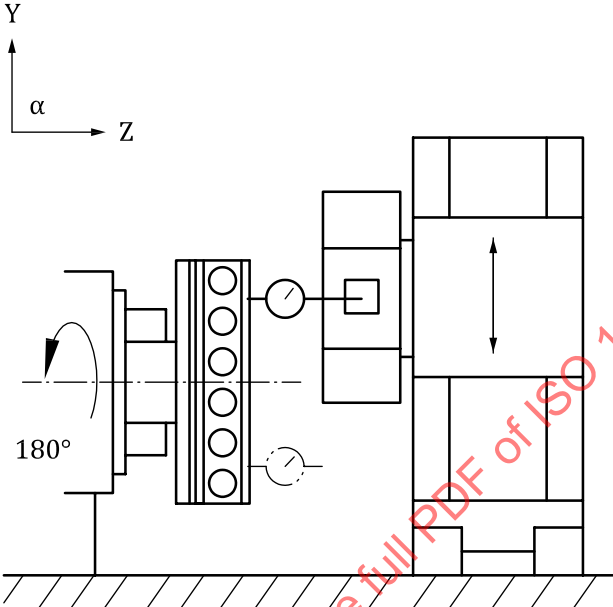
5.3 Relation between linear motions and/or workholding spindle(s)

Object Checking of parallelism error of the workholding spindle axis of rotation to Z-axis motion (carriage): a) in the YZ plane [$E_{A(0Z)(C)}$]; b) in the ZX plane [$E_{B(0Z)(C)}$].		G6
Diagram 		
Tolerance a) 0,060/1 000 (0,015/250) b) 0,040/1 000 (0,010/250)		Measured error For Z = ... a) b)
Measuring instruments a) and b) Dial gauge and test mandrel or optical method		
Observations and references to ISO 230-1:2012, 10.1.4.1 and 10.1.4.3 For each plane of measurement with dial gauge and test mandrel, turn the workholding spindle to find the mean position of run-out and then move the carriage in the Z-axis and take maximum differences of the readings. The spindle shall be locked before measurements are recorded. This test applies to all workholding spindles and Z-axes motions. Set-up may be used for G3.		

Object Checking of squareness error $E_{B(0Z)X}$ of X-axis motion to the Z-axis motion.	G7
Diagram 	
Key 1 square 2 special fixture	
Tolerance 0,050/1 000 (0,015/300)	Measured error
Measuring instruments Dial gauge and square or optical instruments.	
Observations and references to ISO 230-1:2012, 10.3.2 and 12.4 A dial gauge is fixed to the turret close to the tool position. Set the square so its reference surface is parallel to the Z-axis motion. Move the dial gauge so that it contacts the surface on the square which is parallel to XY plane. Measurements are taken in the vertical plane using the X-axis motion. The squareness error to be reported is the maximum difference of this reading over the measured length. The value of the angle α being less than, equal to or greater than 90° , shall be noted. The measurement can be obtained by combining the results from G6 and G10.	

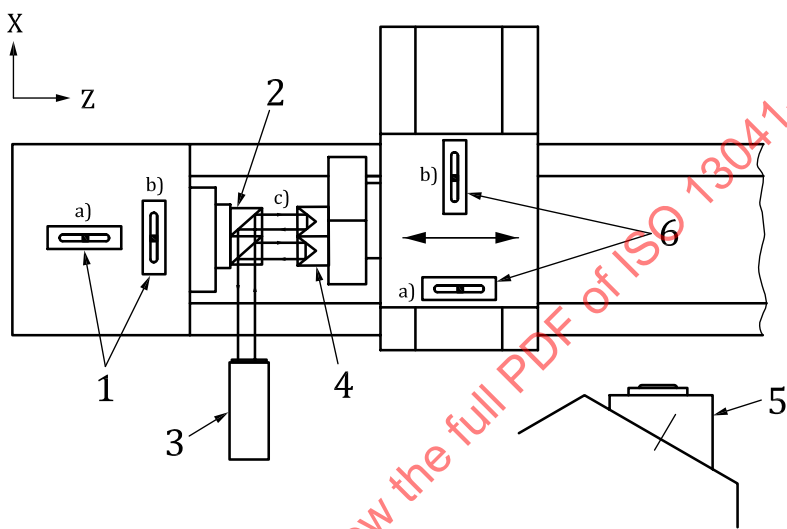
Object Checking of squareness error $E_{A(0Z)Y}$ of Y-axis motion to the Z-axis motion.	G8
Diagram 	
Tolerance 0,070/1 000 (0,020/300)	Measured error
Measuring instruments Dial gauge and square or optical instrument.	
Observations and references to ISO 230-1:2012, 10.3.2 and 12.4 A dial gauge is fixed to the turret close to the tool position. Set a square on the workholding spindle while its reference surface is parallel to the Z-axis motion. Move the dial gauge so that it contacts the surface on the square which is parallel to XY plane. Measurements are taken in the vertical plane using the Y-axis motion. The squareness error to be reported is the maximum difference of this reading over the measured length. The value of the angle, α , being less than, equal to or greater than 90° , shall be noted. The measurement can be obtained by combining the results from G6 and G11.	

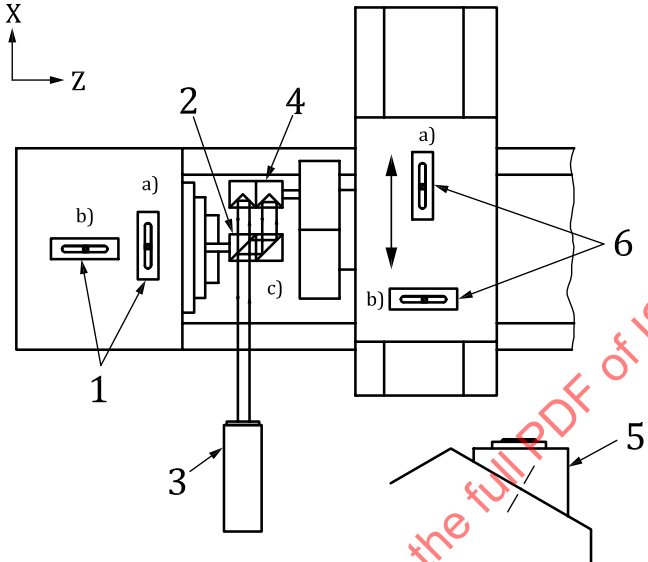
Object Checking of squareness error $E_{C(0X)Y}$ of the Y-axis motion (turret saddle) to the X-axis motion (turret slide). This test applies to all tool turrets with X- and Y-axes.	G9
Diagram 	
Key 1 square 2 special fixture 3 face plate	
Tolerance 0,070/1 000 (0,020/300)	Measured error
Measuring instruments Dial gauge, face plate and square or optical instrument.	
Observations and references to ISO 230-1:2012, 10.3.2 and 12.4 A dial gauge is fixed to the turret close to the tool position. Set a square on the workholding spindle while its reference surface is parallel to the X-axis motion. Move the dial gauge so that it contacts the surface on the square which is perpendicular to XY plane. Measurements are taken in the YZ plane using the Y-axis motion. The squareness error to be reported is the maximum difference of this reading over the measured length. The value of the angle, α , being less than, equal to or greater than 90° , shall be noted.	

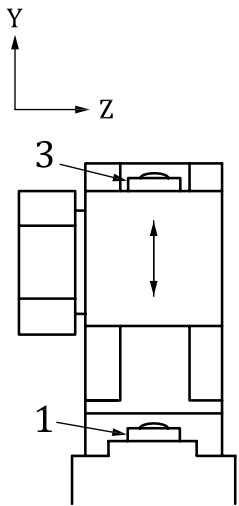
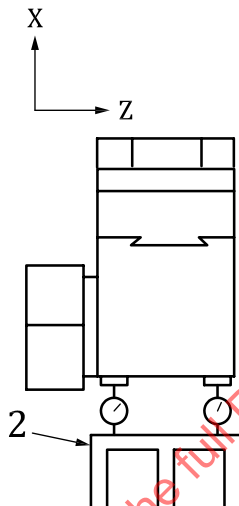
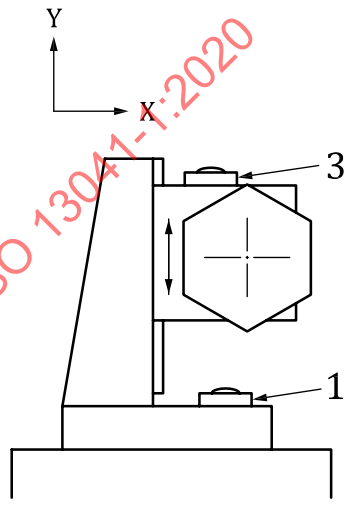
Object Checking of squareness error $[E_{A(0C)Y}]$ of the Y-axis to the C'-axis.	G11
Diagram 	
Tolerance 0,080/1 000 (0,025/300)	Measured error
Measuring instruments Dial gauge, face plate and straightedge	
Observations and references to ISO 230-1:2012, 12.4.7 A dial gauge is fixed to the turret close to the tool position. Fix the straightedge onto the face plate mounted in the workholding spindle. Adjust the face of the straightedge parallel to the plane of rotation of the work spindle (C'-axis) and approximately parallel to the axis motion being tested (Y-axis). Measurements should be taken at several positions of the axis motion (Y-axis), then rotate the spindle by 180° and take a second set of measurements. The squareness to be reported is the mean of both measurements. This test applies to all workholding spindles. The squareness error to be reported is the angle, α , being less than, equal to or greater than 90°. Set-up may be used for G5.	

Object Checking the coaxiality of the sub spindle to the main spindle (for opposing spindles only): a) in the ZX plane [offset $E_{X(0C)C2}$ and parallelism $E_{B(0C)C2}$]; b) in the YZ plane [offset $E_{Y(0C)C2}$ and parallelism $E_{A(0C)C2}$].		G12																					
Diagram 																							
Key 1 main workholding spindle, C'-axis 2 sub workholding spindle, C'2-axis																							
Tolerance For a measuring length of 100 <table border="1"> <thead> <tr> <th></th><th>$D \leq 250$</th><th>$D > 250$</th></tr> </thead> <tbody> <tr> <td>offset</td><td></td><td></td></tr> <tr> <td>a)</td><td>0,010</td><td>0,015</td></tr> <tr> <td>b)</td><td>0,015</td><td>0,020</td></tr> <tr> <td>parallelism</td><td></td><td></td></tr> <tr> <td>a)</td><td>0,100/1 000 (0,010/100)</td><td>0,150/1 000 (0,015/100)</td></tr> <tr> <td>b)</td><td>0,150/1 000 (0,015/100)</td><td>0,200/1 000 (0,020/100)</td></tr> </tbody> </table> where D is the diameter permitted over bed.			$D \leq 250$	$D > 250$	offset			a)	0,010	0,015	b)	0,015	0,020	parallelism			a)	0,100/1 000 (0,010/100)	0,150/1 000 (0,015/100)	b)	0,150/1 000 (0,015/100)	0,200/1 000 (0,020/100)	Measured error offset a) b) parallelism a) b) Distance from position B to sub spindle nose
	$D \leq 250$	$D > 250$																					
offset																							
a)	0,010	0,015																					
b)	0,015	0,020																					
parallelism																							
a)	0,100/1 000 (0,010/100)	0,150/1 000 (0,015/100)																					
b)	0,150/1 000 (0,015/100)	0,200/1 000 (0,020/100)																					
Measuring instruments Dial gauge and test mandrel or optical instrument																							
Observations and references to ISO 230-1:2012, 10.2 and 12.3.4 Fix the dial gauges/support to the workholding main spindle and a test mandrel to the workholding sub spindle. Rotate the workholding spindle so that the dial gauge is in the ZX plane and touch the stylus with the test mandrel at position A and take the first reading. Rotate both spindles by 90° increments and take the readings at each increment. Repeat the measurement for the position B. The difference of the two readings taken at 0° and 180° divided by 2, represents the offsets between the two axes of rotation in the position A and B in ZX-plane. The difference of the two readings taken at 90° and 270° divided by 2, represents the offsets between the two axes of rotation in the position A and B in YZ-plane. The coaxiality error contains both offset and parallelism error. The offset error to be reported is the offset at position B. The parallelism error to be reported is the difference between offsets at point A and B, divided by the distance between points A and B (100 mm).																							

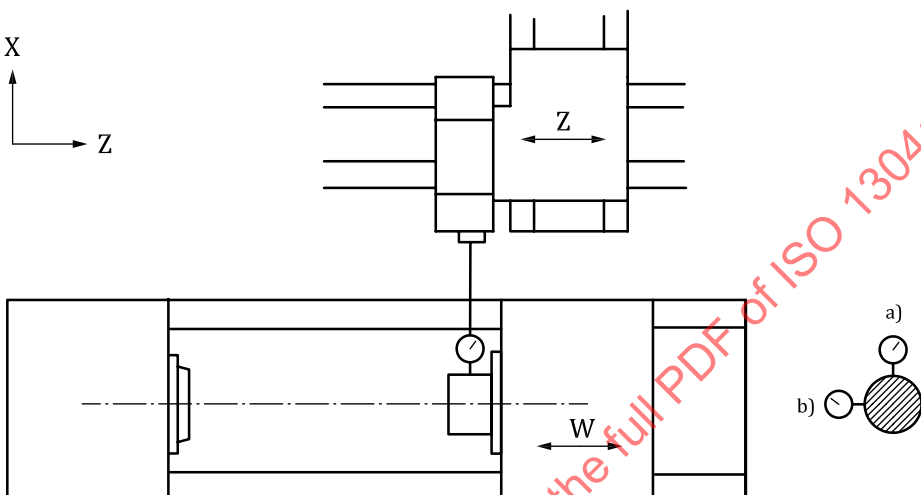
5.4 Angular error of linear axes of motion

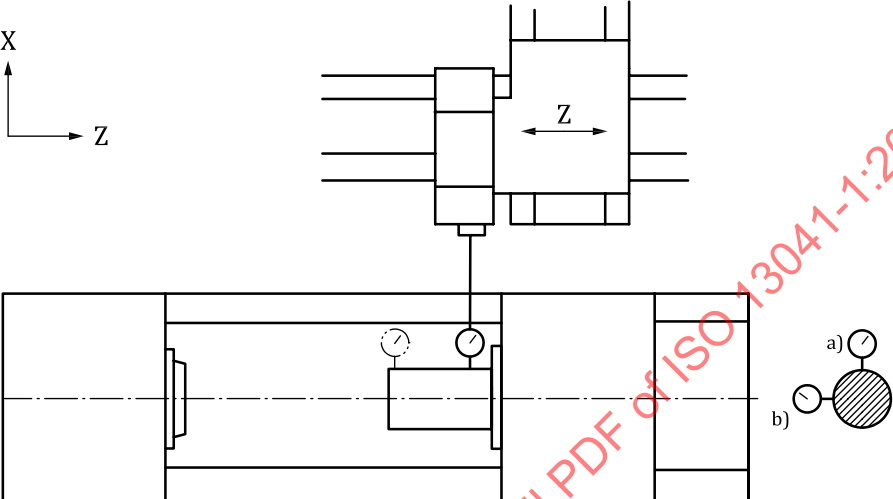
Object Checking of angular errors of the Z-axis motion (carriage):	G13
a) in the YZ plane, E_{AZ} ; b) in the XY plane, E_{CZ} ; c) in the ZX plane, E_{BZ} .	
Diagram 	
Key 1 reference levels 2 angular interferometer 3 laser head 4 angular retro reflector 5 mounting plate, in case of no level mounting plane 6 measuring levels	
Tolerance a), b) and c): $Z \leq 2\,000$ $0,060$ $1\,000$ (12'') $Z > 2\,000$ $0,080$ $1\,000$ (16'')	Measured error a) b) c)
Measuring instruments a) Precision level (only when the X-axis is horizontal), autocollimator and reflector or laser interferometer with angular optics. b) Precision level. c) Autocollimator and reflector or laser interferometer with angular optics.	
Observations and references to ISO 230-1:2012, 8.3.2.1 and 8.4.2.3 In the case of a slant bed, the functional plane is at an angle to the horizontal plane and a special mounting plate should be placed under the precision level for b) roll measurement when it is possible to set the level horizontally, but it shall not be used for a) pitch measurement. When the autocollimator is used, reticle of the eyepiece shall be adjusted so it is parallel or square to the Z-axis. Measurements shall be carried out at a minimum of 5 positions equally spaced along the travel in both directions of motion. The angular error to be reported is the difference between the maximum and minimum readings.	

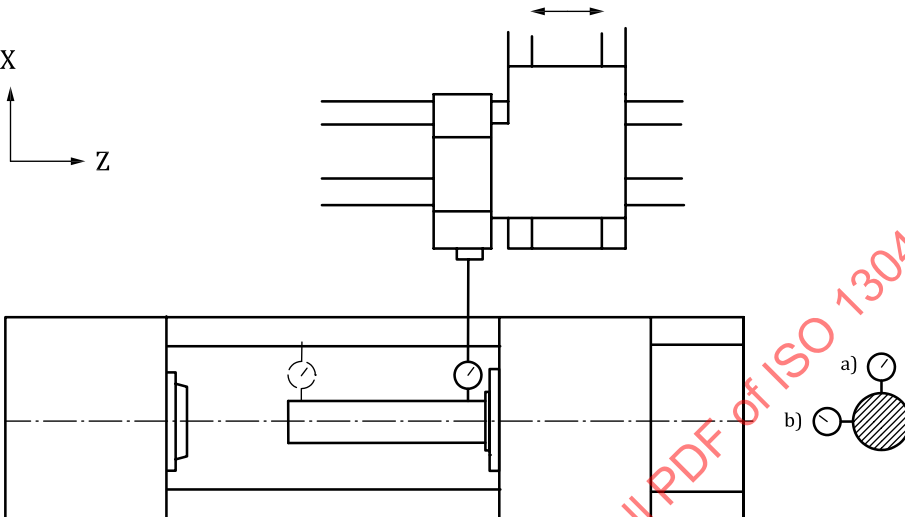
Object Checking of angular errors of the X-axis motion (turret slide motion): a) in the XY plane, E_{CX} ; b) in the YZ plane, E_{AX} ; c) in the ZX plane, E_{BX} .	G14
Diagram  The diagram illustrates the measurement setup for angular errors of the X-axis motion. A laser head (3) is positioned to emit a beam through an angular interferometer (2) towards an angular retro reflector (4). The setup is mounted on a turret slide. Measuring levels (6) are indicated at various points: a) on the vertical axis, b) on the horizontal axis, and c) on the vertical axis. A coordinate system with X and Z axes is shown. A mounting plate (5) is also indicated.	
Key 1 reference levels 2 angular interferometer 3 laser head 4 angular retro reflector 5 mounting plate, in case of no level mounting plane 6 measuring levels NOTE The diagram applies to horizontal X-axis only.	
Tolerance a), b) and c): $X \leq 1\,000 \quad 0,060/1\,000 \text{ (12'')}$	Measured error a) b) c)
Measuring instruments a) Precision level, autocollimator and reflector or laser interferometer with angular optics. b) Precision level (if X-axis is horizontal). c) Autocollimator and reflector, laser interferometer with angular optics.	
Observations and references to ISO 230-1:2012, 8.3.2.1, 8.4.2.3 and 8.4.2.4 In the case of a slant bed, the functional plane is at an angle to the horizontal plane and a special mounting plate should be placed under the precision level for a) pitch measurement, but it shall not be used for b) roll measurement. When the autocollimator is used, reticle of the eyepiece shall be adjusted so it is parallel or square to the X-axis. Measurements shall be carried out at a minimum of 5 positions equally spaced along the travel in both directions of motion. The angular error to be reported is the difference between the maximum and minimum readings.	

Object Checking of angular errors of the Y-axis motion (tool holder motion): a) in the YZ plane, E_{AY} (tilt around X); b) in the ZX plane, E_{BY} (roll); c) in the XY plane, E_{CY} (tilt around Z).	G15
Diagram a)  b)  c)  Key 1 reference precision level 2 square 3 precision level NOTE The diagram applies to vertical Y-axis only.	
Tolerance a), b) and c) $Y \leq 500 \quad 0,040/1\,000 \text{ (8")}$ Tolerances for axes above 500 are to be defined by manufacturer/supplier and user.	Measured error a) b) c)
Measuring instruments a) Precision level (only when Y-axis is vertical) or autocollimator and reflector or laser interferometer with angular optics. b) Surface plate and dial gauges or sweeping laser. c) Precision level placed on a special mounting plate, or autocollimator and reflector or laser interferometer with angular optics.	
Observations and references to ISO 230-1:2012, 8.4.2.1 The precision level shall not be used for a) and c) measurements on slant bed machines. When the autocollimator is used, reticle of the eyepiece shall be adjusted so it is parallel or square to the functional plane. Measurements shall be carried out at a minimum of 5 positions equally spaced along the travel in both directions of motion. The angular error to be reported is the difference between the maximum and minimum readings.	

5.5 Tailstock

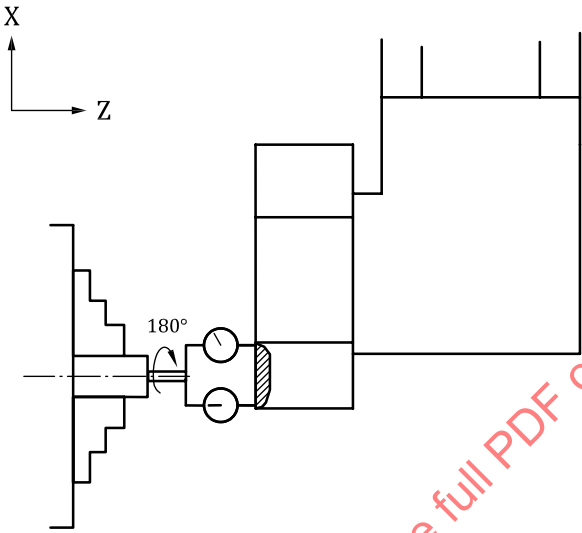
Object Checking the consistency of a distance of the W-axis motion of the tailstock to the Z-axis motion of the carriage: a) in the ZX plane; b) in the YZ plane.		G16						
Diagram 								
Tolerance <table border="1"> <tr> <td>$Z \leq 1\,000$</td> <td>a) 0,040</td> <td>b) 0,060</td> </tr> <tr> <td>$1\,000 < Z \leq 2\,000$</td> <td>a) 0,060</td> <td>b) 0,100</td> </tr> </table>		$Z \leq 1\,000$	a) 0,040	b) 0,060	$1\,000 < Z \leq 2\,000$	a) 0,060	b) 0,100	Measured error a) b)
$Z \leq 1\,000$	a) 0,040	b) 0,060						
$1\,000 < Z \leq 2\,000$	a) 0,060	b) 0,100						
Measuring instruments Dial gauge or optical instrument								
Observations Fix two sets of dial gauges/supports to the turret and touch the styli of the dial gauge to the tailstock sleeve. Move the carriage (Z-axis) and tailstock (W-axis) together and record the dial gauge readings. Measurements shall be carried out at a minimum of 5 positions equally spaced along the travel in both directions of motion. The difference between the maximum and minimum readings is the consistency of a distance. If the tailstock is manually operated, then the tailstock-locking device shall be applied before measurements are recorded. Care should be taken to ensure that readings are taken on the same point on the tailstock sleeve. When it is difficult to move the two axes together, then the carriage should be moved in the direction towards the headstock to the first measurement position. The tailstock is then moved until the dial gauges touch the measurement position. For the movement in the opposite direction, the sequence of the movement is reversed.								

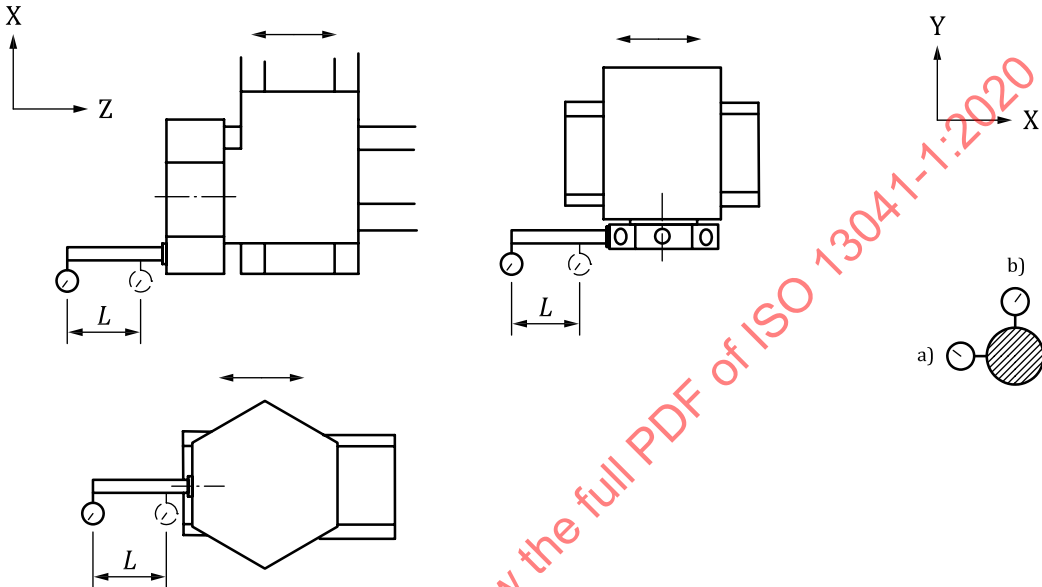
Object Checking the parallelism of the tailstock sleeve to the Z-axis motion:	G17
a) in the ZX plane [$E_{B(0Z)}_{\text{sleeve}}$]; b) in the YZ plane [$E_{A(0Z)}_{\text{sleeve}}$].	
Diagram 	
Tolerance 0,025 over a measuring length of 250 mm.	Measured error a) b)
Measuring instruments Dial gauge	
Observations and references to ISO 230-1:2012, 12.3.3 Keep the sleeve in its extracted position and move the Z-axis with the dial gauge stylus running on the sleeve. Record the dial gauge readings. The parallelism error to be reported is the maximum difference between the readings.	

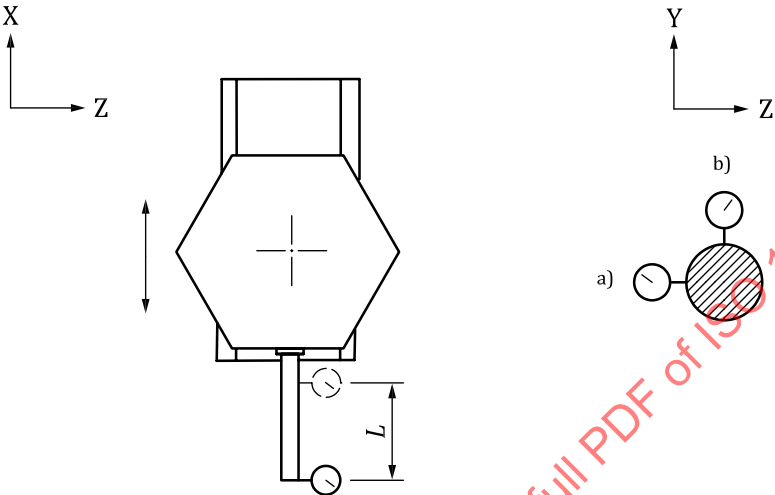
Object Checking of parallelism errors of the tailstock sleeve internal taper bore to the Z-axis motion of the carriage:	G18
a) in the ZX plane; b) in the YZ plane.	
Diagram 	
Tolerance a) and b) 0,060/1 000 (0,015/250)	Measured error a) b)
Measuring instruments Test mandrel and dial gauge or alignment laser	
Observations and references to ISO 230-1:2012, 10.1.4.1 With the tailstock sleeve at its retracted position, insert the test mandrel into the sleeve. Fix the dial gauge to the turret and touch the mandrel with the dial gauge stylus as close as possible to the tailstock nose. Move the carriage (Z-axis) for the measuring length and record the measurements. Repeat the measurement procedure with the mandrel re-inserted at 180° rotated position. The parallelism error to be reported is the average of the two deviations, before and after the 180° rotation of the test mandrel, divided by the distance between the two measured points.	

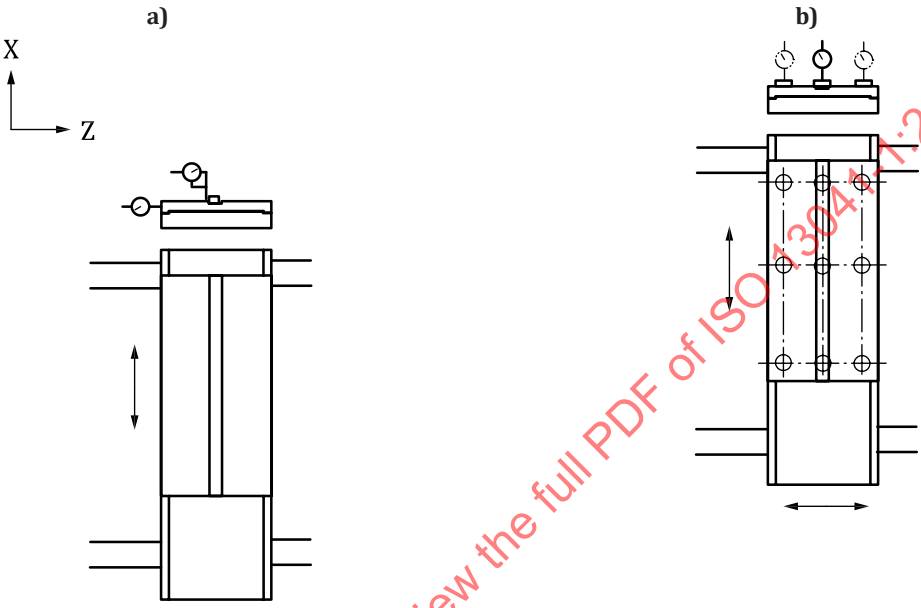
Object		G19
Checking the equidistance of the centres of workholding spindle and tailstock to the Z-axis:		
a) in the ZX plane;		
b) in the YZ plane.		
Diagram		
Tolerance		Measured error
Mandrel length ≤ 500		500 < Mandrel length ≤ 2 000
a)	0,020	0,030
b)	0,040	0,060
Measuring instruments		
Test mandrel between centres and dial gauge.		
Observations and references to ISO 230-1:2012, 10.1.4.3 and 10.1.5		
The measurement shall be taken along the mandrel in several positions.		
The deviation to be reported is the difference between the two extreme readings on the test mandrel, keeping into account the run-out at both points.		
Ensure minimal run-out of mandrel at both points of measurement.		
As an alternative method, two test mandrels calibrated for diameter can be used, one mounted in the workholding spindle and the other mounted in the tail stock.		

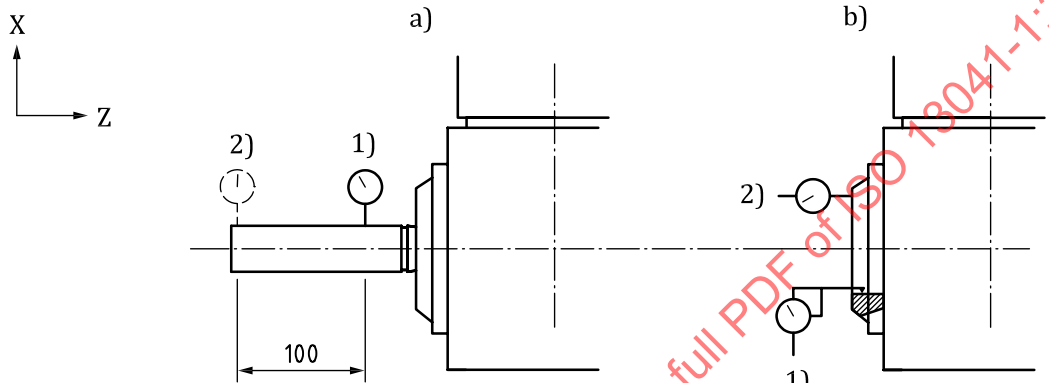
5.6 Tool turret and tool spindle

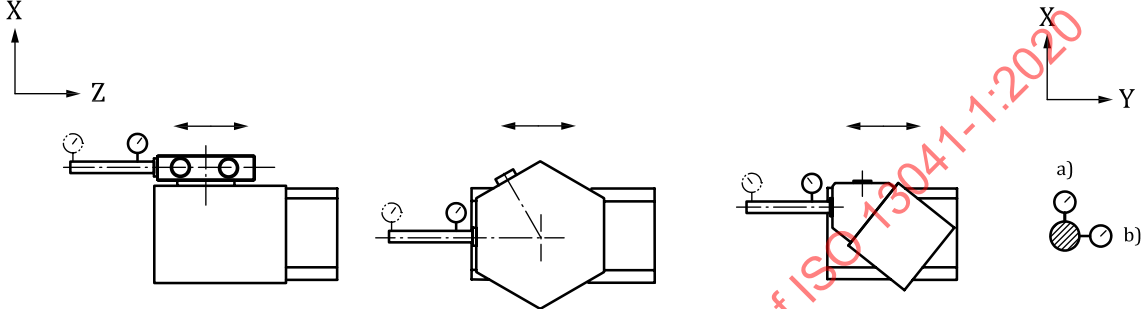
Object Checking of squareness error of the turret tool fixing faces to the workholding spindle axis. NOTE The test applies to turrets whose tool fixing face is square to the workholding spindle axis.		G20
Diagram 		
Tolerance 0,020 for a swing diameter of 100 mm		Measured error
Measuring instruments Dial gauge		
Observations and references to ISO 230-1:2012, 10.3.3 The test should be repeated for each turret fixing face. The swing diameter should be the maximum measurable diameter considering the locating area of the cutting tool. The squareness error to be reported is the difference in readings over the measured length.		

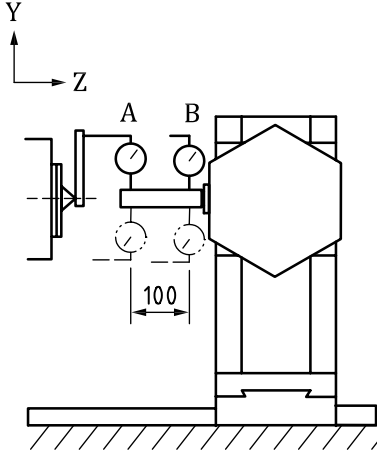
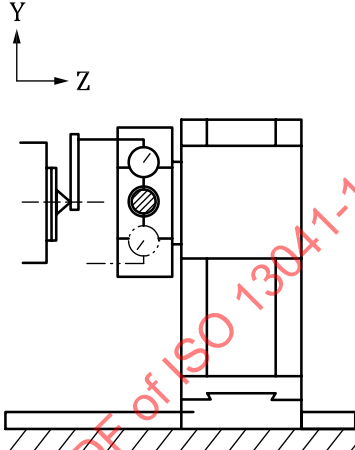
Object Checking of parallelism error of the tool turret fixing bore axis to the Z-axis motion: a) in the ZX plane; b) in the YZ plane. NOTE The test applies to tool turrets with tool fixing bore parallel to Z-axis motion.	G21
Diagram 	
Tolerance a) and b) 0,030 for L=100	Measured error a) b)
Measuring instruments Test mandrel and dial gauge	
Observations and references to ISO 230-1:2012, 10.1.4.1 and 10.1.4.3 Fix the mandrel to the tool turret fixing bore and fix the dial gauge/support to the fixed part of the machine so that the dial gauge stylus touches the mandrel in the ZX and YZ plane. The test shall be repeated for all turret fixing bores. The tool turret should be in the forward position or as near as possible to the spindle. If tool mounting requires a flange, then the design of the test mandrel should replicate it. The parallelism error to be reported is the difference between the readings over the measured length.	

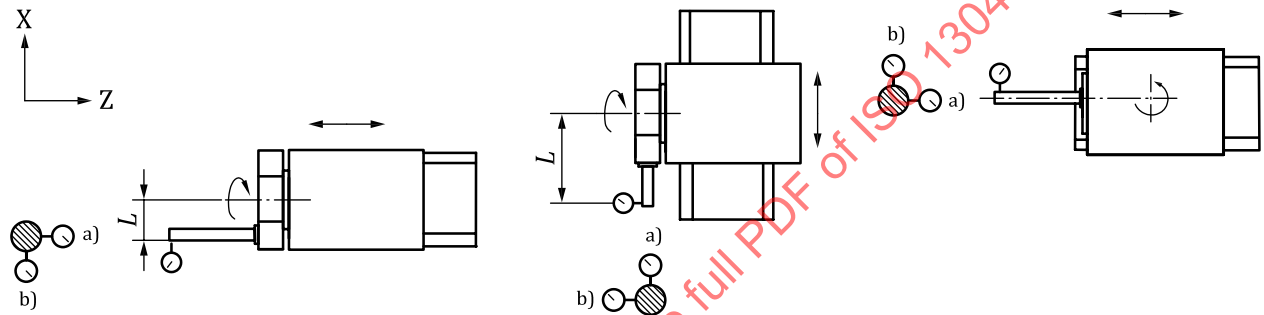
Object Checking of parallelism errors of tool turret fixing bore axes to the X-axis of motion. a) in the ZX plane, b) in the XY plane. NOTE The test applies to tool turrets with tool fixing bore parallel to X-axis of motion.	G22
Diagram 	
Tolerance a) and b) 0,030 for $L = 100$	Measured error a) b)
Measuring instruments Test mandrel and dial gauge	
Observations and references to ISO 230-1:2012, 10.1.4.1 and 10.1.4.3 Mount the mandrel to the tool turret fixing bore and mount the dial gauge to the fixed part of the machine so that the dial gauge stylus touches the mandrel in the ZX plane for a) and XY plane for b). The test shall be repeated for all turret fixing bores. The tool turret should be in the forward position or as near as possible to the spindle. If the tool location method requires a flange, then the design of the test mandrel should replicate it. The parallelism error to be reported is the difference between the readings over the measured length.	

Object Testing of linear turret a) Parallelism error of the reference slot or reference side face of the cross slide to X-axis motion. b) Parallelism error of the tool mounting surface of the cross slide and the ZX plane. NOTE For turret configuration type d) only (see Figure 3).	G23
Diagram 	
Tolerance a) 0,030 for measuring length 300 mm b) 0,025 for measuring length 300 mm	Measured error a) or b)
Measuring instruments Dial gauge and gauge block	
Observations and references to ISO 230-1:2012, 12.3.2.5.1 For a): The measurement shall be taken along the measuring length in several positions. The parallelism error to be reported is the maximum difference between the readings. For b): Check in both X- and Z-axis in a 3 × 3 grid pattern. Measurement positions shall be in the middle and ends of the mounting plane. Use a gauge block to span centre slot.	

Object Testing of the run-out and face run-out of the tool spindle(s) bores:	G24
a) run-out of internal taper bore: 1) at spindle nose; 2) at a position of 100 mm from spindle nose; b) run-out of cylindrical bore: 1) run-out of spindle nose; 2) face run-out of spindle nose.	
Diagram 	
Tolerance a) 1) 0,010 2) 0,015 b) 1) 0,010 2) 0,010	Measured error a) b)
Measuring instruments Test mandrel and dial gauge	
Observations and references to ISO 230-1:2012, 12.5.3 For a) and b): Measurements should be taken in both ZX- and YZ-plane. The measurements shall be repeated at least four times, the mandrel being rotated through 90° in relation to the spindle. The run-out to be recorded is the average of the readings. Measurements shall be performed on all tool spindles and taken on the maximum diameter. For b)2): Measurements shall be checked at the maximum possible radius. NOTE For measurement of tool spindle error motion, see Annex A , Test AR2.	

Object Checking of parallelism of the tool spindle axis to the Z-axis carriage movement: a) in the ZX plane; b) in the YZ plane. NOTE 1 The test applies to all rotating tool turret spindles. NOTE 2 Z can be substituted by W or R.	G25
Diagram 	
Tolerance a) and b) 0,200/1 000 (0,020/100)	Measured error a) b)
Measuring instruments Test mandrel and dial gauge	
Observations and references to ISO 230-1:2012, 10.1.4.1 and 10.1.4.3 Turn the tool spindle to find the mean position of run-out and then move the turret in the Z-direction. Alternatively, take readings along the test mandrel and then rotate the spindle by 180° and take readings at initial positions. The parallelism error to be recorded is the mean of the two measurements. This test applies to all tool spindles.	

Object		G26	
Checking of coaxiality or intersection error of the tool spindle axis to the workholding spindle axis:			
a) coaxiality when the tool spindle is parallel to work spindle in the ZX plane and YZ plane;			
b) intersection when the tool spindle is orthogonal to work spindle in the YZ plane.			
Diagram			
			
Tolerance		Measured error	
a)	offset	parallelism	a) ZX plane YZ plane
	0,030	0,300/1 000 (0,030/100)	offset
			parallelism
b)	offset		b) YZ plane
	0,030		offset
NOTE For a), the tolerances apply for both ZX plane and YZ plane.			
Measuring instruments			
Test mandrel and dial gauge			
Observations and references to ISO 230-1:2012, 10.2 and 10.4			
Fix the dial gauge onto the workholding spindle and fix the test mandrel to the tool spindle bore.			
a) Rotate the workholding spindle so that the dial gauge is in the ZX plane and touch the stylus with the test mandrel at position A and take the first reading. Rotate both spindles by 90° increments and take the readings at each increment. Repeat the measurement for the position B. The difference of the two readings taken at 0° and 180° divided by 2, represents the offsets between the two axes of rotation in the position A and B in ZX-plane.			
The difference of the two readings taken at 90° and 270° divided by 2, represents the offsets between the two axes of rotation in the position A and B in YZ-plane.			
The coaxiality error contains both offset and parallelism error. The offset error to be recorded is the offset at position B.			
The parallelism error to be recorded is the difference between offsets at point A and B, divided by the distance between points A and B (100 mm).			
b) Position the dial gauge so that it contacts the test mandrel in the YZ plane, move the turret along the Z direction and record the top point of the mandrel. Record the Z position. Move the carriage away so that it is clear of the dial gauge. Rotate the workholding spindle 180° and then reposition the carriage to recorded Z position. Repeat the carriage motion to find the lowest point and record this value.			
The intersection error to be reported is half the difference between the measurements at 0° and 180°.			
Repeat tests for all turret locations.			

Object Checking the repeatability of the tool turret indexing:	G27
a) YZ plane: 1) tool spindle parallel to work spindle; 2) tool spindle orthogonal to work spindle; 3) machines with automatic tool changer; b) ZX plane: 1) tool spindle parallel to work spindle; 2) tool spindle orthogonal to work spindle; 3) machines with automatic tool changer.	
Diagram  Key <i>L</i> radial distance from centre of turret to contact point for dial gauge	
Tolerance a) and b) $L \leq 100$ 0,005 $L > 100$ 0,010	Measured error a) b)
Measuring instruments Test mandrel and dial gauge	
Observations For 1) and 2): With the turret in mid-stroke, position the dial gauges so they contact the test mandrel at the 0° and 90° measurement positions. Record the turret's axis position and the dial gauge readings. Move the turret position clear of the dial gauges with the axis parallel to the mandrel and index the turret through 360°. Move the turret axis to the recorded position under automatic cycle. Record dial gauge readings. For 3): Remove tool turret (in X- and Z-axis) from the measuring range of the dial gauges, then the tool turret pivots to one of its end positions and swings back to its recorded position. Position the tool turret back (in X- and Z-axis) in the recorded position within the automatic cycle. The readings of the dial gauges shall be recorded. For 1), 2) and 3): Repeat the cycle 3 times, the dial gauges should be reset to zero at the start of the test. The repeatability error to be recorded is the maximum difference between the three sets of readings. Test should be repeated at a minimum of 3 different turret locations and for each location the dial gauge should be set to zero.	