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Test conditions for numerically controlled turning machines and turning centres —

Part 1: Geometric tests for machines with a horizontal workholding spindle

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

Partie 1: Essais géométriques pour les machines à broche horizontale

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 2.

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

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

ISO 13041-1 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

ISO 13041 consists of the following parts, under the general title *Test conditions for numerically controlled turning machines and turning centres*:

— *Part 1: Geometric tests for machines with a horizontal workholding spindle*

— *Part 2: Geometric tests for machines with vertical workholding spindle*

— *Part 3: Geometric tests for machines with inverted vertical workholding spindle*

— *Part 4: Accuracy and repeatability of positioning of linear and rotary axes*

— *Part 5: Accuracy of feeds, speeds and interpolations*

— *Part 6: Accuracy of a finished test piece*

— *Part 7: Evaluation of contouring performance in the coordinate planes*

— *Part 8: Evaluation of thermal distortions*

Introduction

The object of ISO 13041 is to supply information as wide and comprehensive as possible on tests which can be carried out for comparison, acceptance, maintenance or any other purpose.

ISO 13041 specifies, with reference to the relevant parts of ISO 230, *Test code for machine tools,* tests for turning centres and numerically controlled turning machines with/without tailstocks, standing alone or integrated in flexible manufacturing systems. ISO 13041 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.

Test conditions for numerically controlled turning machines and turning centres —

Part 1: Geometric tests for machines with a horizontal workholding spindle

1 Scope

This part of ISO 13041 specifies, with reference to ISO 230-1, the geometric tests on numerically controlled (NC) turning machines and turning centres, of normal accuracy, with horizontal work spindle(s) as defined in 3.1 and 3.2.

This part of ISO 13041 specifies the applicable tolerances corresponding to the tests mentioned above.

This part of ISO 13041 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 (see Figure 1 and Table 1).

This part of ISO 13041 deals only with the verification of the accuracy of the machine. It does not apply to the operational testing of the machine (e.g. vibration, abnormal noise, stick-slip motion of components), nor to machine characteristics (e.g. speeds, feeds) as such checks are generally carried out before testing the accuracy.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 841:2001, *Industrial automation systems and integration — Numerical control of machines — Coordinate system and motion nomenclature*

ISO 3442:1991, *Self-centring chucks for machine tools with two-piece jaws (tongue and groove type) — Sizes for interchangeability and acceptance test specifications*

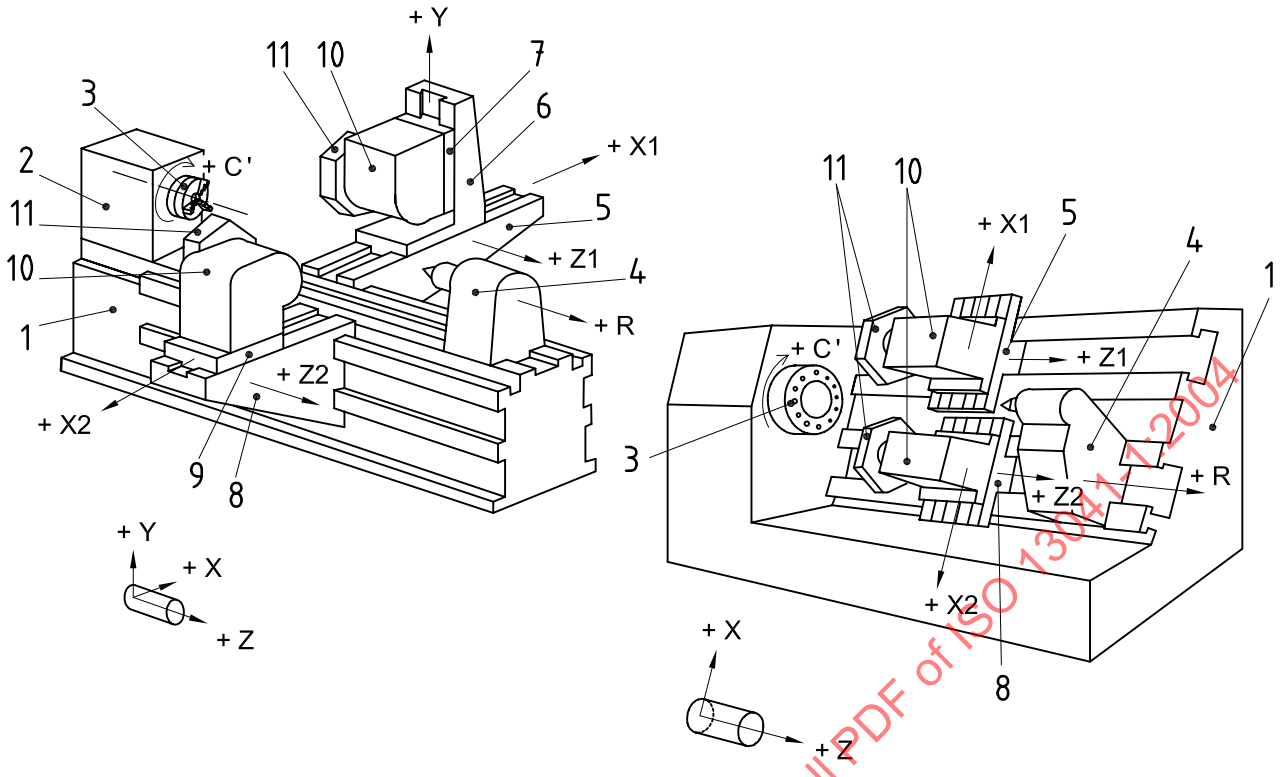


Figure 1 — Example of a horizontal-spindle turning centre

Table 1 — Terminology

Item number	English	French	German
1	Bed	Banc	Bett
2	Workhead	Porte-pièce	Spindelkasten
3	Work spindle, C′ axis	Broche porte-pièce, axe C′	Arbeitsspindel, C′-Achse
4	Tail stock, R axis	Contre-poupée, axe R	Reitstock, R-Achse
5	Carriage 1, Z axis	Chariot 1, axe Z	Schlitten 1, Z- Achse
6	Turret slide 1, X axis	Chariot de tourelle, axe X	Revolverschlitten 1, X-Achse
7	Vertical slide, Y axis	Chariot vertical, axe Y	Verticalschlitten, Y-Achse
8	Carriage 2, Z2 axis	Chariot 2, axe Z2	Schlitten 2, Z2-Achse
9	Turret slide 2, X2 axis	Chariot de tourelle 2, axe X2	Revolverschlitten 2, X2-Achse
10	Turret head 1 and 2	Tourelles 1 et 2	Revolverkopf 1 und 2
11	Indexing turret 1 and 2	Tourelles à indexage 1 et 2	Revolverscheibe 1 und 2

NOTE In addition to terms used in two of the three official ISO languages (English and French), this part of ISO 13041 gives the equivalent terms in German; these are published under the responsibility of the member body/National Committee for Germany (DIN). However, only the terms and definitions given in the official languages can be considered as ISO terms and definitions.

3 Terms and definitions

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

3.1
numerically controlled turning machine
numerically controlled machine tool in which the principal movement is the rotation of the workpiece against the stationary cutting tool(s) and where cutting energy is provided by the workpiece and not by the tool

NOTE The numerical control provides an automatic function.

3.2
turning centre
NC turning machine equipped with power driven tool(s) and the capacity to orientate the work-holding spindle around its axis

NOTE This machine may include additional features such as automatic tool changing from a magazine.

3.3
machine modes of operation
modes of operation of the numerically controlled or data entry devices where entries are interpreted as functions to be executed

3.3.1
manual mode of numerical control
non-automatic mode of numerical control of a machine in which the operator controls it without the use of pre-programmed numerical data

EXAMPLE By push button or joystick control.

3.3.2
manual data input mode
entry of programme data by hand at the numerical control

3.3.3
single block mode
mode of numerical control in which, at the initiation of the operator, only one block of control data is executed

3.3.4
automatic mode
mode of numerical control in which the machine operates in accordance with the programme data until stopped by the programme or the operator

4 Preliminary remarks

4.1 Measuring units

In this part of ISO 13041, 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. The equivalence of the following expressions should always be kept in mind.

0,010/1 000 = 10 µrad ≈ 2"

4.2 Reference to ISO 230-1

To apply this part of ISO 13041, 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” block of the tests described in Clause 5, the instructions are preceded by a reference to the corresponding clause in ISO 230-1:1996 in cases where the test concerned is in compliance with the specifications of ISO 230-1:1996. Tolerances are given for each test (see G1 to G24).

4.3 Machine levelling

Prior to conducting tests on a machine, the machine should be levelled according to the recommendations of the supplier/manufacturer (see 3.11 of ISO 230-1:1996).

4.4 Testing sequence

The sequence in which the tests are presented in this part of ISO 13041 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 part of ISO 13041. 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 part of ISO 13041 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 Diagrams

In this part of ISO 13041, for reasons of simplicity, the diagrams associated with geometric tests illustrate only one type of machine.

4.7 Turrets and tool spindle(s)

As already defined in 3.1 and 3.2, turning centres have not only stationary tools but also power-driven rotary tools which means that the turret should also have power-driven 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. An automatic tool-changing device may also be required in cases of power-driven spindles in which the tool can be automatically set.

Figure 2 shows typical examples of turrets and tool spindles. The following configurations are shown:

a) Horizontal turret: the tools are set radial to the axis of rotation of the turret. This turret type can have either stationary or power-driven tools or a combination of both.

b) Wheel-type turret for radial tools: the tools are set radial to the axis of rotation of the turret. 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 the X- and Z-axis directions. 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. Machining is possible in both the Z- and X-axis directions. A tool changer and a tool magazine are needed.

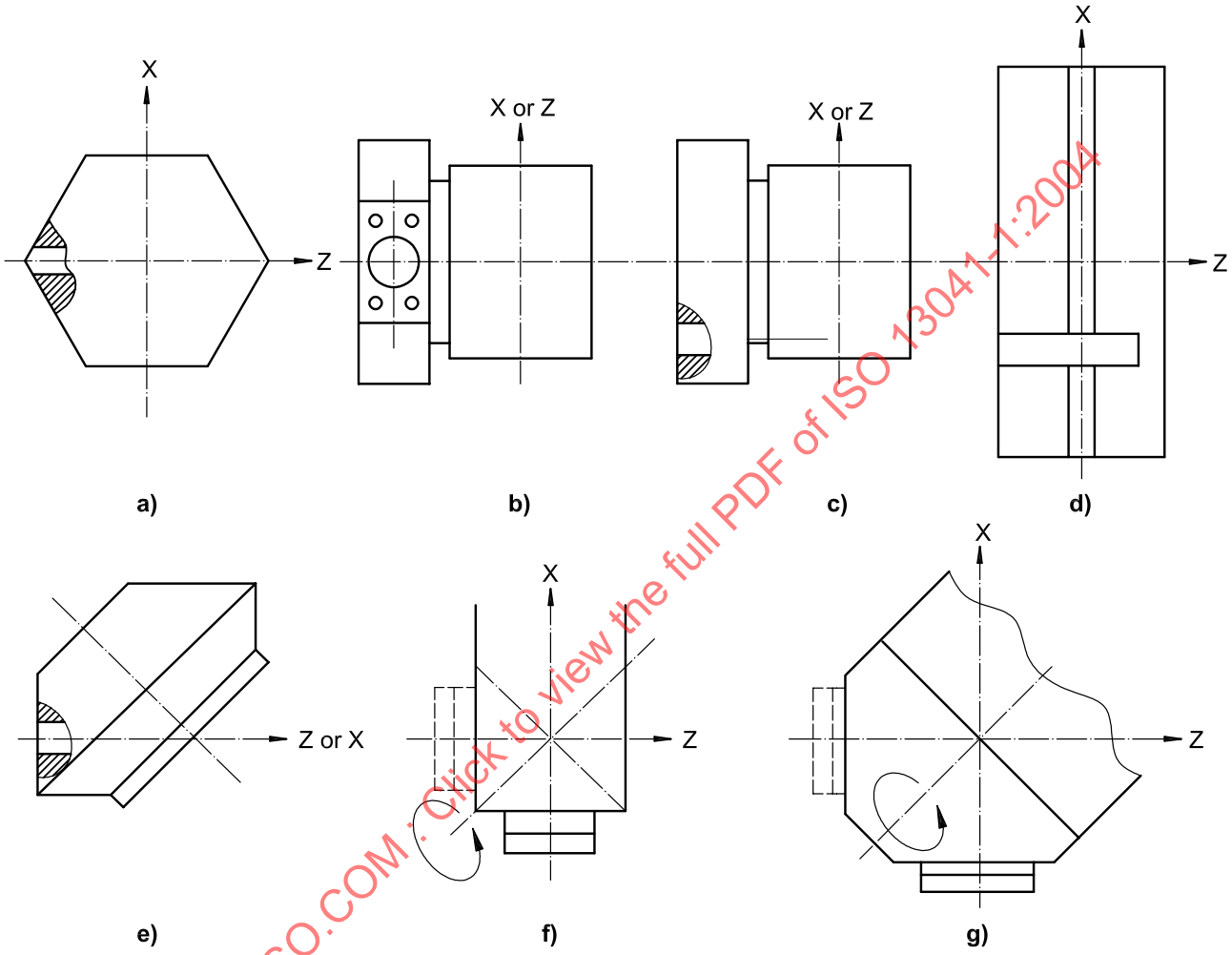


Figure 2 — Examples of turret and tool spindle configurations

4.8 Machine classifications

4.8.1 General

The machines considered in this part of ISO 13041 are divided into two basic configurations (see Table 2):

Type A: Machines with tailstock

Type B: Machines without tailstocks

Type A machines can be generally classified into two further groups:

Group A-1 with one turret

Group A-2 with two turrets

Type B machines can be generally classified into four further groups:

Group B-1 with one workhead

Group B-2 with two coaxial interfacing heads

Group B-3 with a coaxial rotating head

Group B-4 with two parallel heads

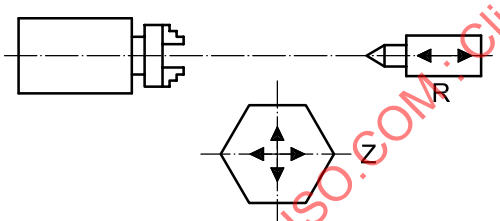
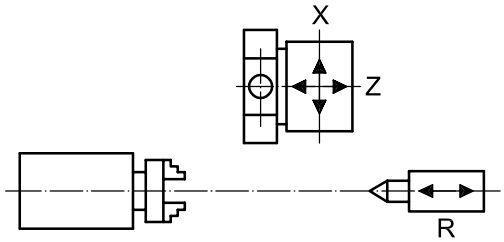
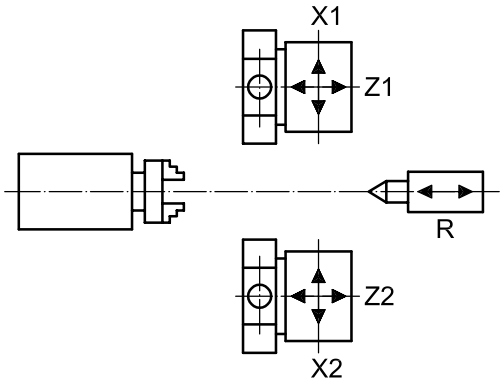
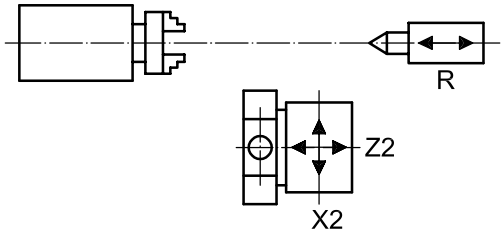
4.8.2 Linear motions

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 6.1 of ISO 841:2001. In all the examples, the use of the letters U, V or R could be substituted.

4.9 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, this shall be stated in the test results.

Table 2 — Examples of machine configuration

Type A — With tailstock	
1. With one turret	**2. With two turrets**
Turret type: all types except d) With turret type a)  With turret type b)  	Turret type: all types except d) NOTE The two turret types can be different. With two turrets of type b)  With turret types b) and f) 

Type B — Without tailstock

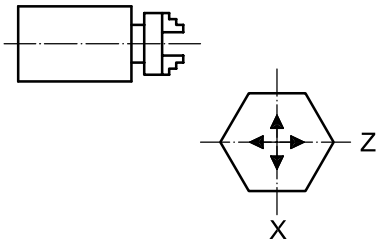
1. With one workhead

Turret type: any of a), b), c), f) or g)

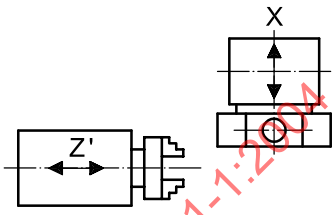
Axes motion	1	2	3	4
Turret	Z or X	Z	X	—
Workhead	—	X	Z	X or Z

Optional: Y axis turret motion (turning centre)
B' axis rotation of workhead

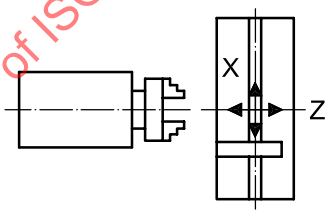
With turret type a)



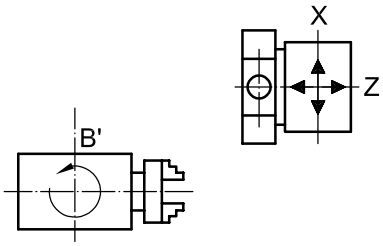
With turret type b)

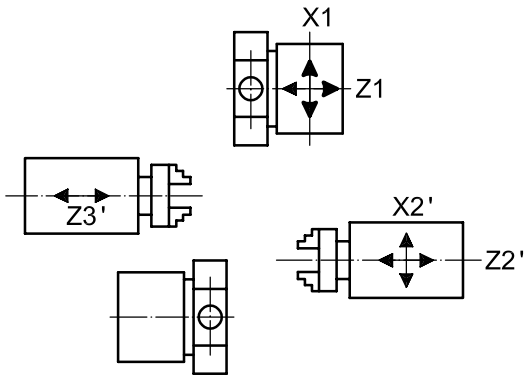
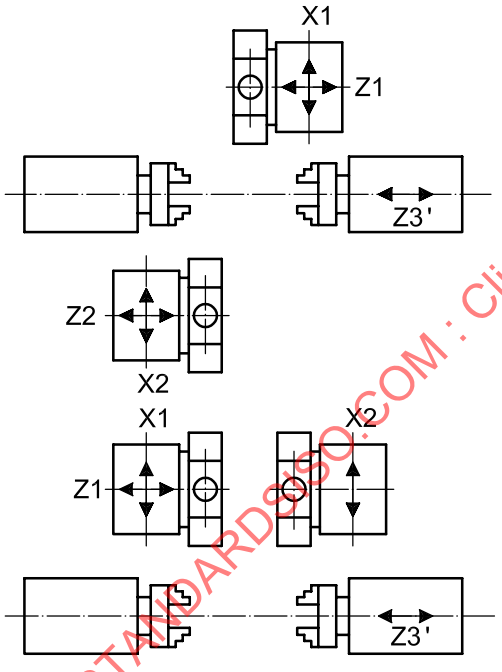
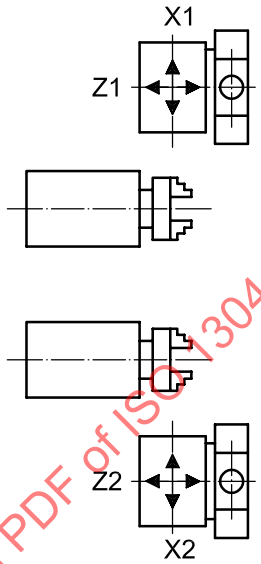


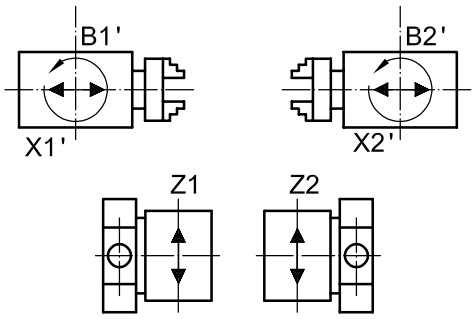
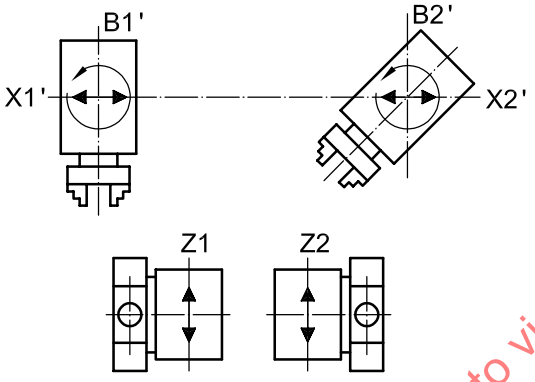
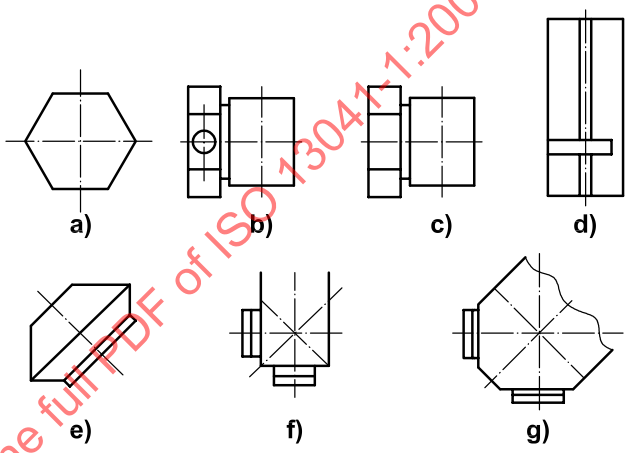
With turret type d)



With B' axis rotary head



Type B — Without tailstock	
2. With two interfacing heads	**3. With two parallel heads**
Any turret type  Both heads can be aligned.  	 Axes of motion may be by the workheads. Y axes motion is optional.

Type B — Without tailstock	
4. With coaxial rotating heads	**Symbols used**
Workhead at handling position  Workhead at machining position  	Workhead Tailstock  Turret types  NOTE No guideways are illustrated to avoid complication.

4.10 Minimum tolerance

When the tolerance for a geometric test is established for a measuring length different from that given in this part of ISO 13041 (see 2.311 of ISO 230-1:1996), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

4.11 Machine size categories

Machines are classified into three size categories, on the basis of the criteria specified in Table 3.

Table 3 — Machine size range

Criteria[a]	Category 1	Category 2	Category 3
Diameter permitted over bed	$D \leqslant 250$	$250 < D \leqslant 500$	$500 < D \leqslant 1\,000$
Nominal bar diameter	$d' \leqslant 25$	$25 < d' \leqslant 63$	$63 < d'$
Nominal chuck diameter [b]	$d \leqslant 125$	$125 < d \leqslant 250$	$250 < d$

[a] The choice of the criteria is at the manufacturer's discretion.

[b] The diameter is defined in ISO 3442.

5 Geometric tests

5.1 Workhead spindle(s)

Object — **G1**

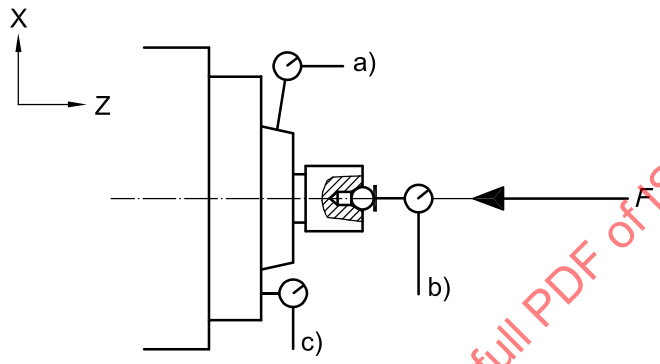
Checking the workhead spindle nose:

a) run-out of centring diameter;

b) periodic axial slip;

c) camming of the spindle face.

Diagram



Tolerance

	Category 1	Category 2	Category 3
a)	0,005	0,008	0,012
b)	0,005	0,005	0,005
c)	0,008	0,010	0,015

Measured deviation

Measuring instruments

Dial gauge and test mandrel with ball

Observations and references to ISO 230-1:1996

The value of an axial force F shall be specified by the supplier/manufacturer of the machine. If preloaded bearings are used then there is no need to apply the force F.

a) 5.612.2

When the surface is conical, the stylus of the dial gauge shall be normal to the contacting surface.

b) 5.622.1, 5.622.2

c) 5.632

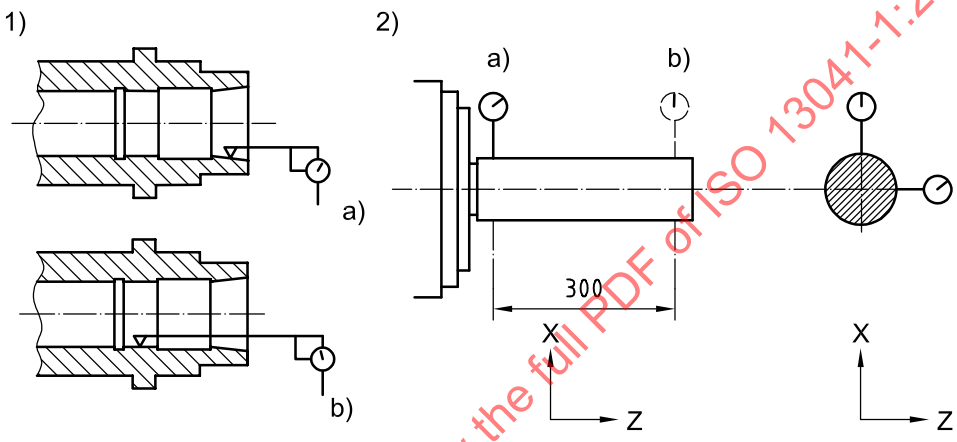
Measurements shall be taken on all workhead spindles, on the maximum diameter.

Object | **G2**

Checking the run-out of the workhead spindle bore:

1) by direct contact
   a) on the front seating cone,
   b) on the back register;
2) using a test mandrel
   a) at the spindle nose,
   b) at a distance of 300 from the spindle nose.

Diagram



Tolerance

1) a) and b) 0,008

2) For measuring length of 300 or full stroke up to 300.

	Category 1	Category 2	Category 3
a)	0,010	0,015	0,020
b)	0,015	0,020	0,025

Measured deviation

Measuring instruments

Dial gauge and special test mandrel

Observations and references to ISO 230-1:1996 5.612.3

2) Measurements should be taken in the XZ and YZ planes. Rotate the spindle slowly at least two revolutions at each measuring location when measuring the spindle run-out.

The measurements shall be repeated at least four times, the mandrel being rotated through 90° in relation to the spindle. The average of the readings shall be recorded.

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 workhead spindles.

5.2 Relation between workhead spindle(s) and linear motion axes

Object

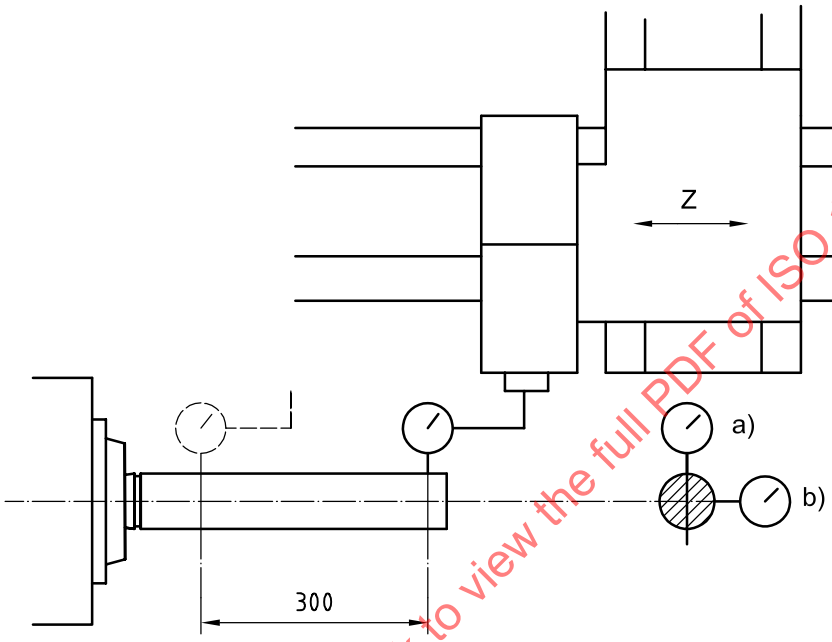
Checking the parallelism between the Z-axis motion (carriage) and the workhead spindle axis of rotation:

a) in the ZX plane;

b) in the YZ plane.

G3

Diagram



Tolerance

For a measuring length of 300 or full stroke up to 300

	Category 1	Category 2	Category 3
a)	0,010	0,015	0,020
b)	0,015	0,020	0,025

Measured deviation

Measuring instruments

Dial gauge and test mandrel

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

For each plane of measurement, turn the workhead spindle to find the mean position of run-out and then move the carriage in the Z direction and take maximum differences of the readings.

This test applies to all workhead spindles and Z-axes motions.

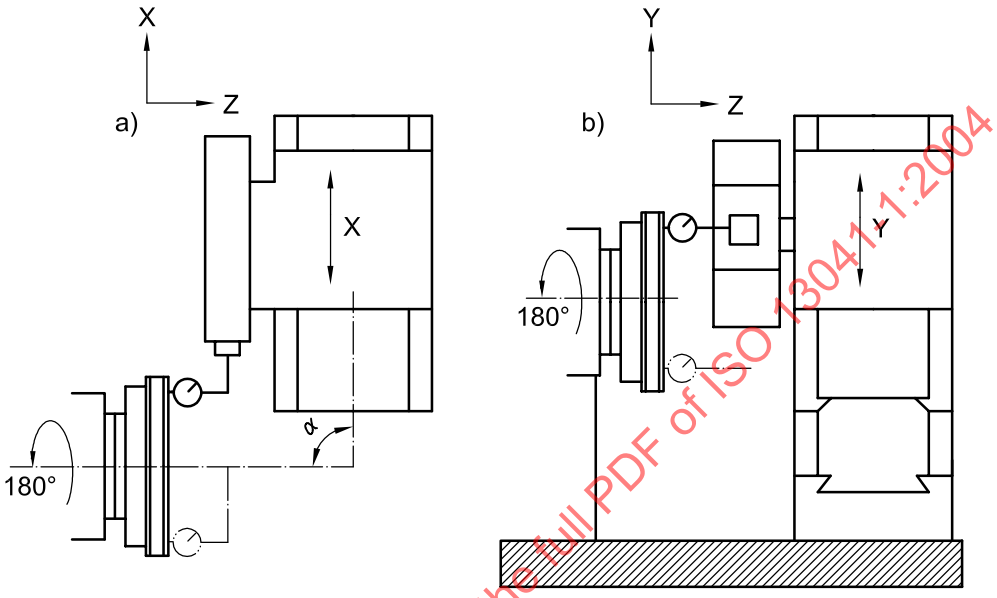
Object | **G4**

Checking the squareness between the workhead spindle (C' axis) and

a) X-axis motion in the ZX plane;

b) Y-axis motion in the YZ plane (when applicable).

Diagram



Tolerance

For a measuring length of 300 or full stroke up to 300

	Category 1	Category 2	Category 3
a)	0,015	0,015	0,025
b)	0,020	0,020	0,020

Direction of error $\alpha \geqslant 90°$

Measured deviation

Measuring instruments

Dial gauge, face plate and straightedge

Observations and references to ISO 230-1:1996 5.522.3

A dial gauge is fixed to the turret close to the tool position.

Fix the straightedge onto the faceplate mounted in the workholding position.

Adjust the face of the straightedge parallel to the plane of rotation of the work spindle (C' axis) and approximately parallel to the linear axis being tested (X or Y axis).

Measurements should be taken at several positions of the X-(Y-) axis motion, then rotate the spindle through 180° and take a second set of measurements. The squareness deviation is the maximum difference between the mean of both sets of measurements. The surface generated must be CONCAVE, unless there is a special arrangement between the user and supplier/manufacturer.

This test applies to all workhead spindles.

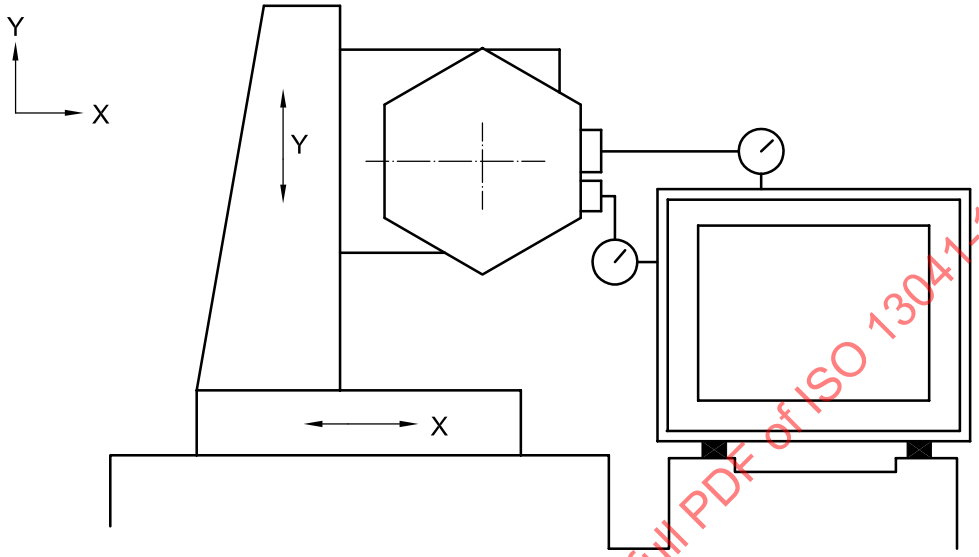
Object

Checking the squareness between the Y-axis motion (turret) and the X-axis motion (turret saddle).

G5

This test is also applied to the X1- and Y2-axis motions.

Diagram



Tolerance				**Measured deviation**
For a measuring length of 300 or full stroke up to 300				
	Category 1	**Category 2**	**Category 3**	
a)	0,020	0,020	0,030	

Measuring instruments

Dial gauge, square

Observations and references to ISO 230-1:1996 5.522.4

Set the square so that its reference surface is parallel to the X-axis motion.

Move the dial gauge so that it contacts the vertical plane of the square.

Measurements are taken in the vertical plane using the Y-axis motion. The measured deviation is the maximum difference of this reading over the measured length.

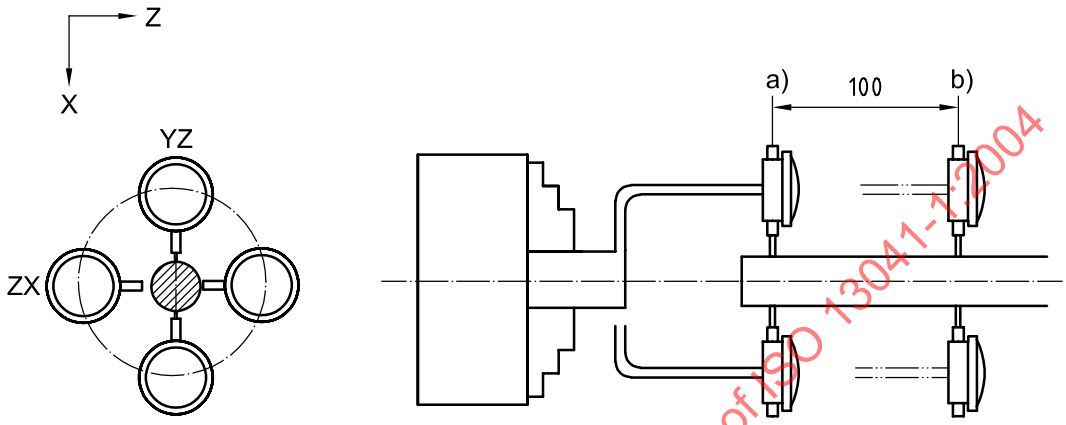
Object | **G6**

Checking the coaxiality between the two workhead spindles (for opposing spindles only)

a) in the ZX plane;

b) in the YZ plane.

Diagram



Tolerance

For a measuring length of 100

	Category 1	Category 2	Category 3
a)	0,010	0,015	0,015
b)	0,010	0,015	0,015

Measured deviation

Measuring instruments

Dial gauge and test mandrel

Observations and references to ISO 230-1:1996 5.442

Fix the dial gauges/support to the first workhead spindle and a test mandrel to the second spindle.

a) Rotate the first spindle so that the dial gauge is in the ZX plane and touch the stylus to the test mandrel at a distance 100 mm from the second spindle nose (position A). Rotate the second spindle to find the mean run-out position and take the reading. Then rotate the first spindle by 180° and take the second reading. Repeat the measurement for the position B.

b) Repeat this measurement process for the YZ plane.

At positions A and B in both the ZX and YZ planes, the difference between the readings taken at 0° and 180° represents twice the coaxiality in each plane.

5.3 Angular deviations of linear axes motion

Object | **G7**

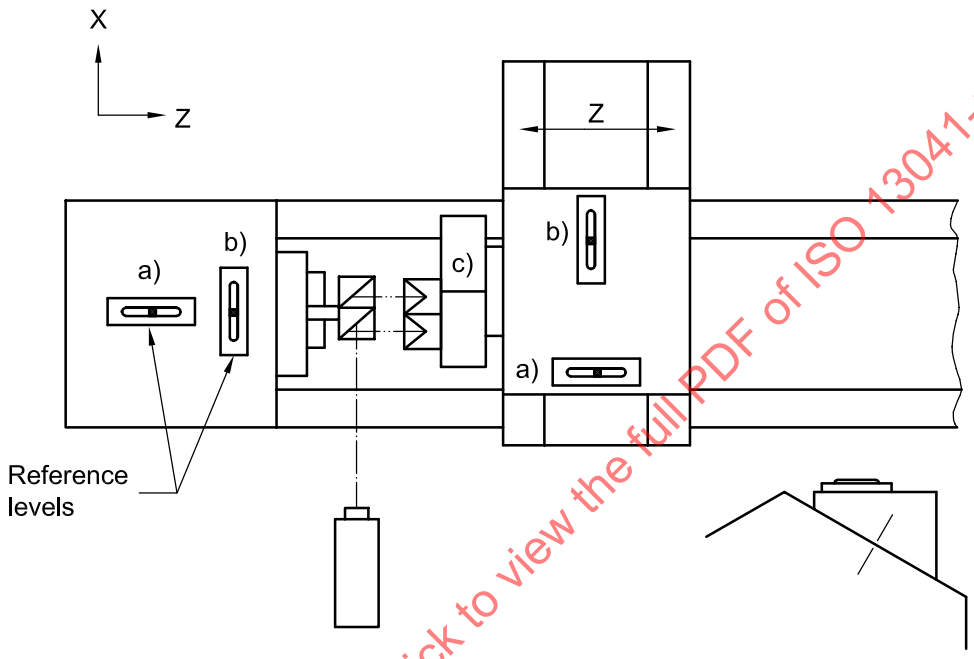
Checking the angular deviations of the Z-axis motion (carriage motion)

a) in the YZ plane, EAZ (pitch);

b) in the XY plane, ECZ (roll);

c) in the ZX plane, EBZ (yaw).

Diagram



Tolerance			**Measured deviation**
	$Z \leqslant 500$	0,040/1 000 or 8"	
a), b) and c)	$500 < Z \leqslant 1\,000$	0,060/1 000 or 12"	
	$1\,000 < Z \leqslant 2\,000$	0,080/1 000 or 16"	

Measuring instruments

a) Precision level, autocollimator and reflector or laser instrument

b) Precision level

c) Autocollimator and reflector or laser instrument

Observations and references to ISO 230-1:1996 5.232.21, 5.232.22, 5.232.23

In the case of a slant bed, the functional plane is at an angle to the horizontal plane and a special bridge and precision level can be used for b) roll measurement when it is possible to set the level horizontally, but it is not recommended for a) pitch measurement. When the autocollimator is used, it shall be adjusted so that the micrometer eyepiece is square or parallel to the functional plane.

Measurements shall be carried out at a minimum of five positions equally spaced along the direction of travel in both directions of motion. The difference between the maximum and minimum readings is the angular deviation.

Pitch and roll are only 2nd order deviations for NC turning machines.

Object | **G8**

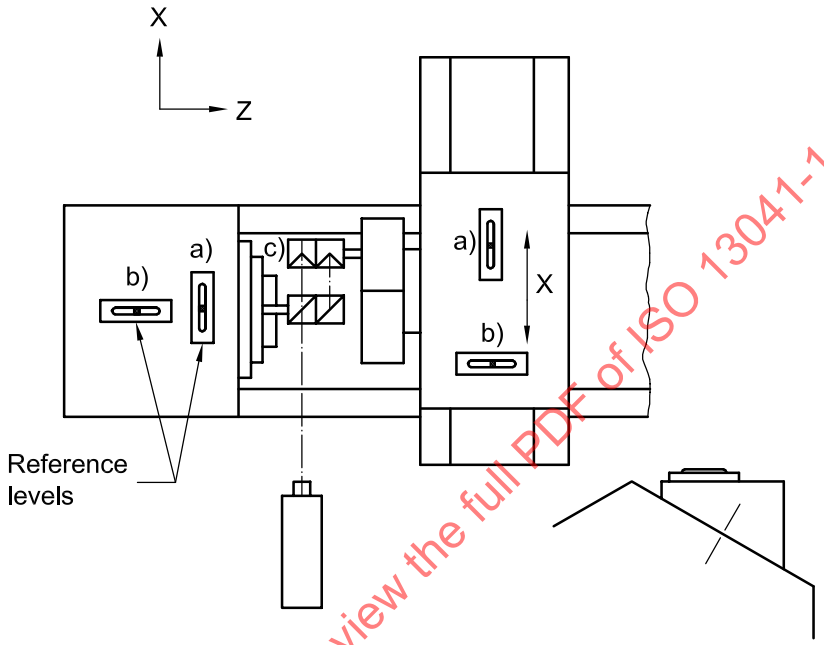
Checking the angular deviations of the X-axis motion (turret slide motion)

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

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

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

Diagram



In the case of no level mounting plane

Tolerance			**Measured deviation**
	$X \leqslant 500$	0,040/1 000	or 8"
a), b) and c)	$500 < X \leqslant 1\,000$	0,060/1 000	or 12"
	$1\,000 < X \leqslant 2\,000$	0,080/1 000	or 16"

Measuring instruments

a) Precision level or autocollimator and reflector or laser instrument

b) Surface plate and dial gauges or precision level

c) Autocollimator and reflector or laser instrument

Observations and references to ISO 230-1:1996 5.232.21, 5.232.22, 5.232.23

In the case of a slant bed, the functional plane is at an angle to the horizontal plane and a special bridge and precision level can be used for a).

When the autocollimator is used, it shall be adjusted so that the micrometer eyepiece is square for a), and parallel for c), to the functional plane.

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

The difference between the maximum and minimum readings is the angular deviation.

Object | **G9**

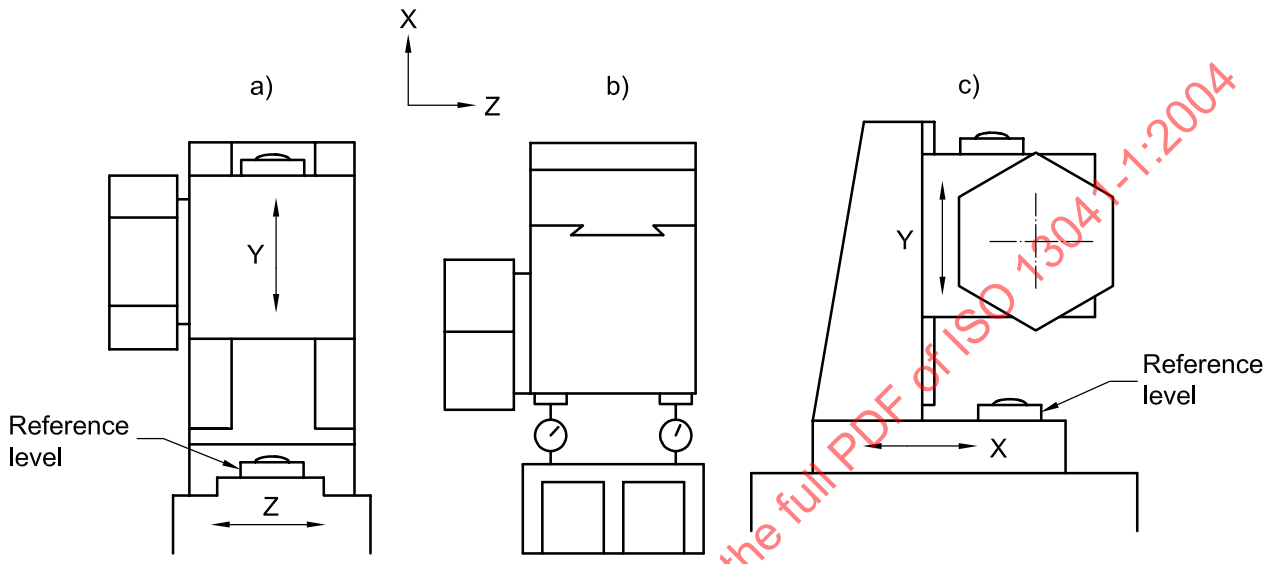
Checking the angular deviations of the Y-axis motion (turret head motion)

a) in the YZ plane, EAY (yaw around X);

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

c) in the XY plane, ECY (pitch around Z).

Diagram



Tolerance	**Measured deviation**
a), b) and c) $Y \leqslant 500$ 0,040/1 000 or 8"	

Measuring instruments

a) Precision level or autocollimator and reflector or laser instrument

b) Surface plate and dial gauges

c) Precision level or autocollimator and reflector or laser instrument

Observations and references to ISO 230-1:1996 5.232.21, 5.232.22, 5.232.23

The use of a precision level for measurements a) and c) on a slant bed is not recommended.

When the autocollimator is used, it shall be adjusted so that the micrometer eyepiece is square or parallel to the functional plane.

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

The difference between the maximum and minimum readings is the angular deviation.

5.4 Tailstock

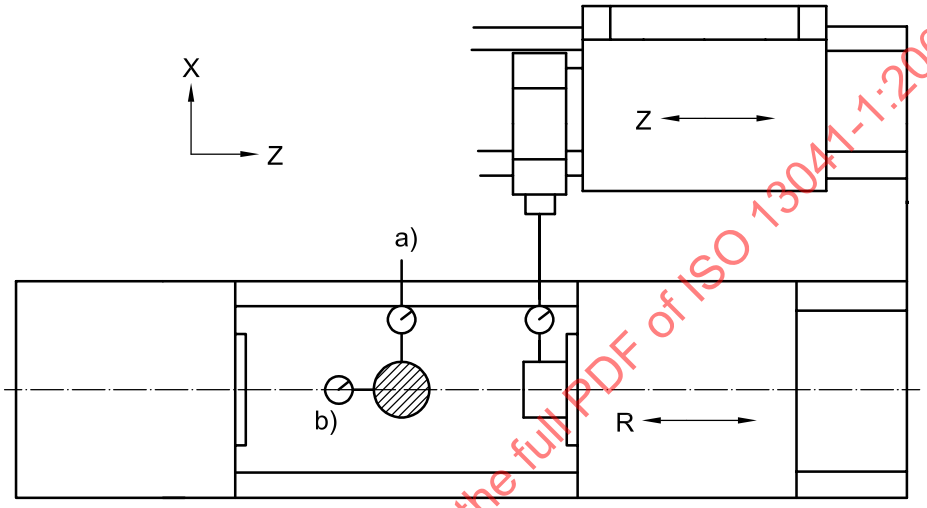
Object | **G10**

Checking the parallelism between the R-axis motion of tailstock and Z-axis motion of the carriage

a) in the ZX plane;

b) in the YZ plane.

Diagram



Tolerance			**Measured deviation**
$Z \leqslant 1\,000$	a) 0,020	b) 0,030	
$1\,000 < Z \leqslant 2\,000$	a) 0,030	b) 0,050	

Measuring instruments

Dial gauge/support

Observations and references to ISO 230-1:1996 5.422.5

Fix two sets of dial gauges/supports to the turret and touch the styli of the dial gauges to the tailstock sleeve. Move the carriage Z-axis and tailstock R-axis together and record the dial gauge readings.

Measurements shall be carried out at a minimum of five positions equally spaced along the travel in both directions of motion. The difference between the maximum and minimum readings is the parallelism deviation.

If the tailstock is manually operated, the tailstock-locking device must be applied before measurements are recorded. Care should be taken to ensure that readings are taken on the same points on the tailstock sleeve.

When it is difficult to move the two axes together, 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 changed.

Object

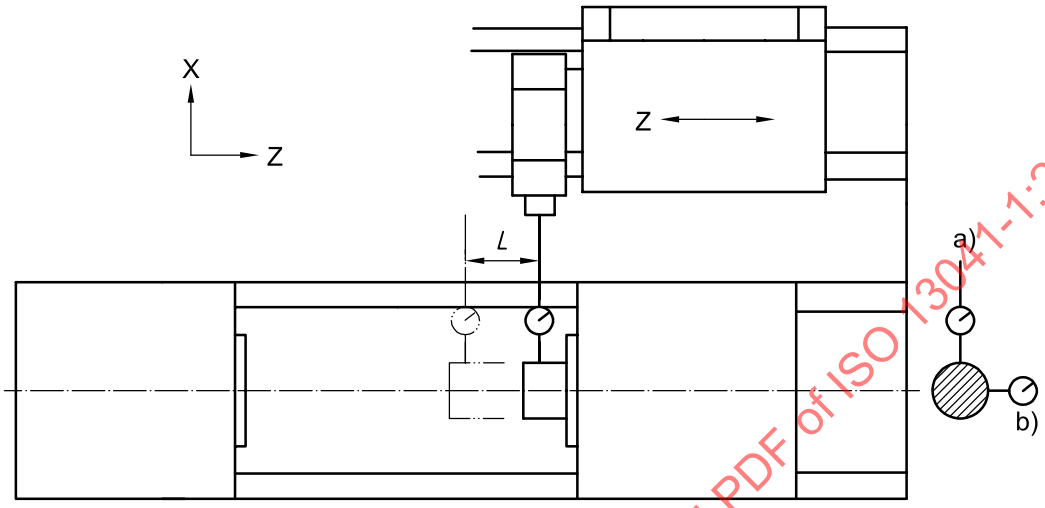
Checking the parallelism between the tailstock sleeve motion and Z-axis motion of the carriage

G11

a) in the ZX plane;

b) in the YZ plane.

Diagram



Tolerance

For a measurement length of L

	(L = 50)	(L = 100)	(L = 150)
a)	0,010	0,015	0,020
b)	0,015	0,020	0,025

The sleeve end shall not be lower when extended.

Measured deviation

Measuring instruments

Dial gauge/support

Observations and references to ISO 230-1:1996 5.422.5

With the tailstock sleeve at its retracted position and locked, fix the dial gauges/support to the turret and touch the dial gauge stylus to the tailstock sleeve. Record the dial gauge reading.

Extend the sleeve to the end position and relock and move the carriage until the dial gauge styli touches the tailstock sleeve at the previous measurement position. Record the dial gauge reading.

The difference between the readings is the parallelism deviation.

Object

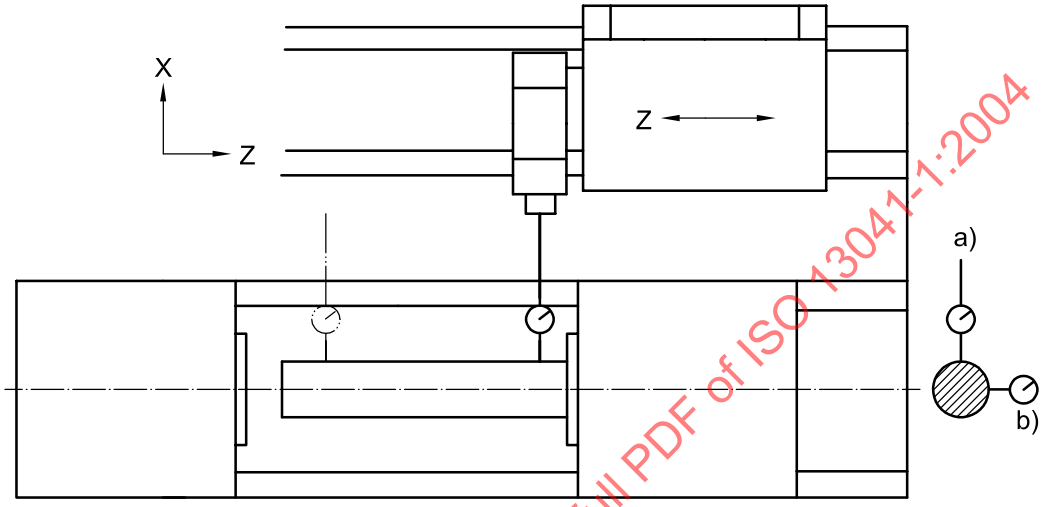
Checking the parallelism between the tailstock-sleeve internal-taper bore and the Z-axis motion of the carriage

a) in the ZX plane;

b) in the YZ plane.

G12

Diagram



Tolerance			**Measured deviation**
For a measuring length of 300 or full stroke up to 300			
	Category 1	**Category 2**	**Category 3**
a) and b)	0,010	0,020	0,025

Measuring instruments

Test mandrel and dial gauge/support

Observations and references to ISO 230-1:1996 5.422.3

With the tailstock sleeve at its retracted position, insert the test mandrel into the sleeve. Fix the dial gauges/support to the turret and touch the dial gauge stylus onto the mandrel at a position close to the tailstock nose.

Move the carriage for the measuring length and record the measurements.

Repeat the measurement procedure with the mandrel reinserted at the 180° rotated position.

The maximum difference of the two averaged measurements gives the parallelism deviation.

Object | **G13**

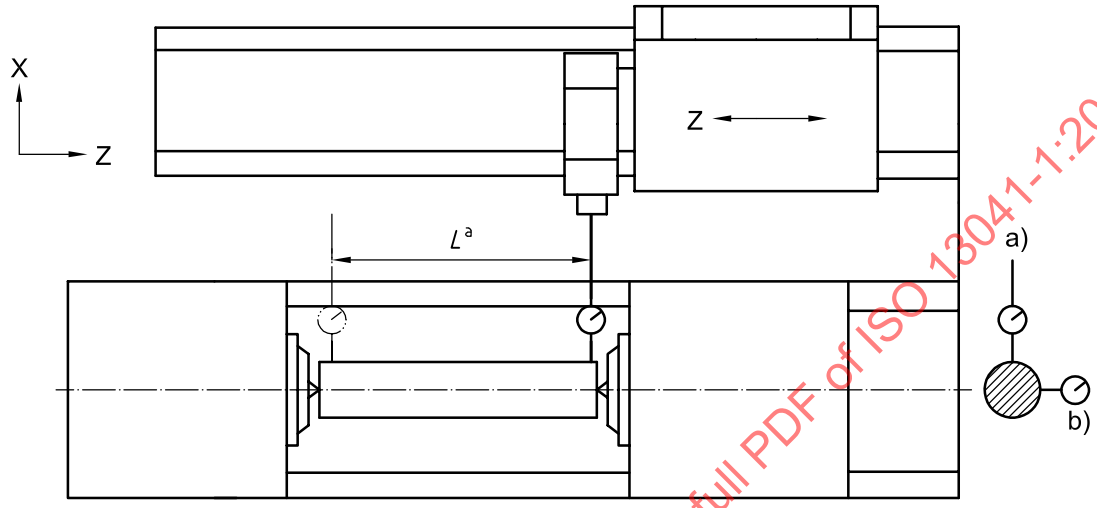
Checking of parallelism between the Z-axis motion and the turning axis

a) in the ZX plane;

b) in the YZ plane.

NOTE The turning axis is defined as the axis between centres.

Diagram



a L = 75 % of DC, where DC is the distance between centres.

Tolerance

	DC ⩽ 500	500 < DC ⩽ 1 000
a)	0,010	0,015
b)	0,020	0,030

NOTE For the Z2-axis, add 0,01 to each tolerance.

Measured deviation

Measuring instruments

Test mandrel between centres or test mandrels and dial gauge/support

Observations and references to ISO 230-1:1996 5.422.3, A4.2, A4.3

Fix the dial gauge/support to the turret so that the dial gauge stylus touches the mandrel in the ZX/YZ plane.

The measurement shall be taken along the mandrel in several positions. The maximum difference of the readings is the parallelism deviation.

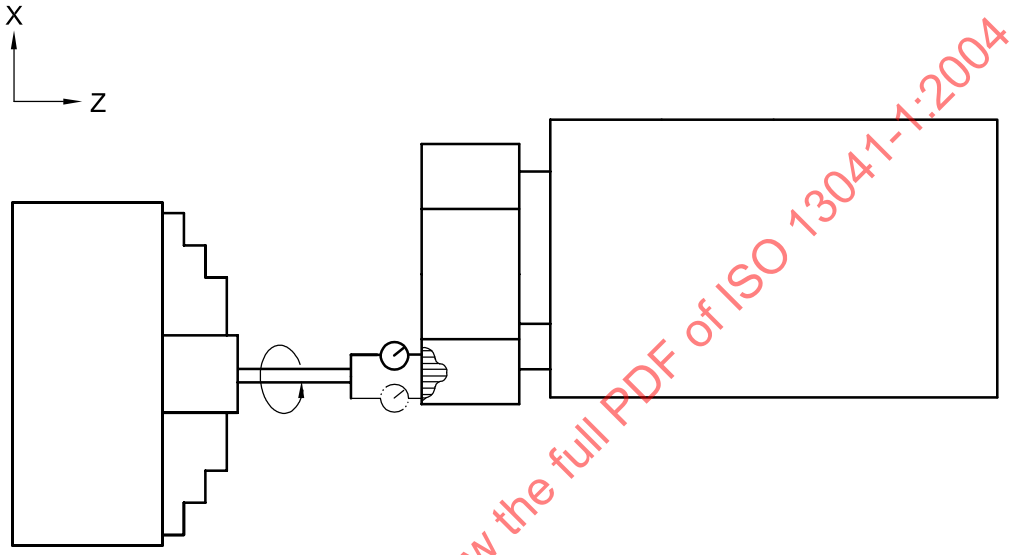
For machines where DC exceeds 1 000, type A in Table 2 applies. The alignment deviation is the maximum difference of all the measurements.

5.5 Turret and tool spindle

5.5.1 Turret for stationary tools

Object	**G14**
Checking of squareness of the turret tool-fixing faces to the work spindle axis NOTE The test applies to turrets whose tool-fixing face is square to the work spindle axis.	

Diagram



Tolerance	**Measured deviation**
0,020/100[a] [a] 100 is the measured diameter.	

Measuring instruments

Dial gauge/support

Observations and references to ISO 230-1:1996 5.512.1, 5.512.4

The test should be repeated for each turret fixing face.

Object | **G15**

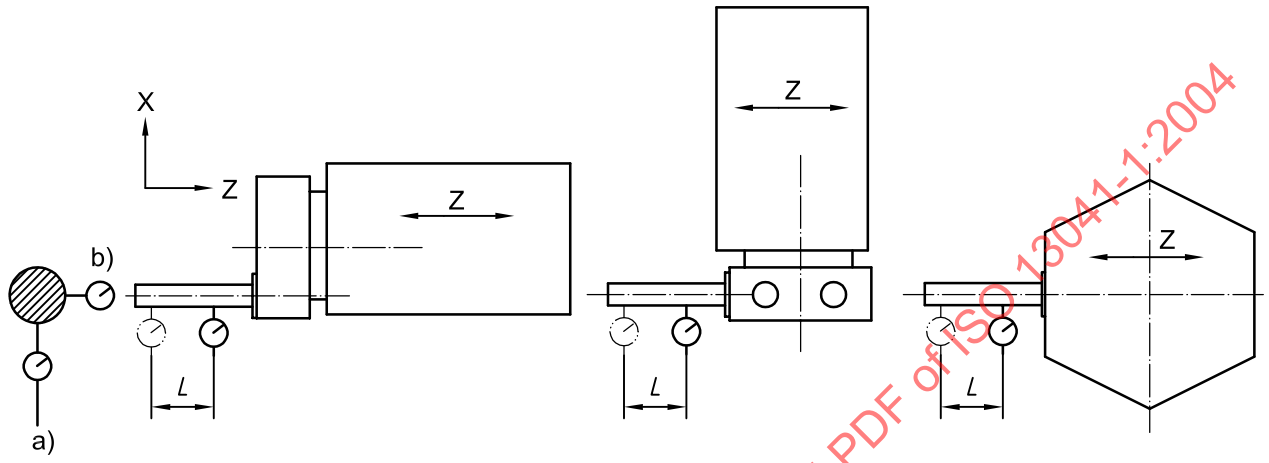
Checking of parallelism between the turret tool-fixing bore axis and the Z-axis motion

a) in the ZX plane;

b) in the YZ plane.

NOTE The test applies to turrets whose tool-fixing bore is parallel to the Z-axis motion.

Diagram



Tolerance	**Measured deviation**
a) and b) 0,030 for L = 100	

Measuring instruments

Test mandrel and dial gauge

Observations and references to ISO 230-1:1996 5.422.3

Fix the mandrel to the 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/YZ plane.

The test shall be repeated for all turret fixing bores.

The turret should be in the forward position or as near as possible to the spindle.

If the tool location method requires a flange abutment then the design of the test mandrel should replicate it.

Object | **G16**

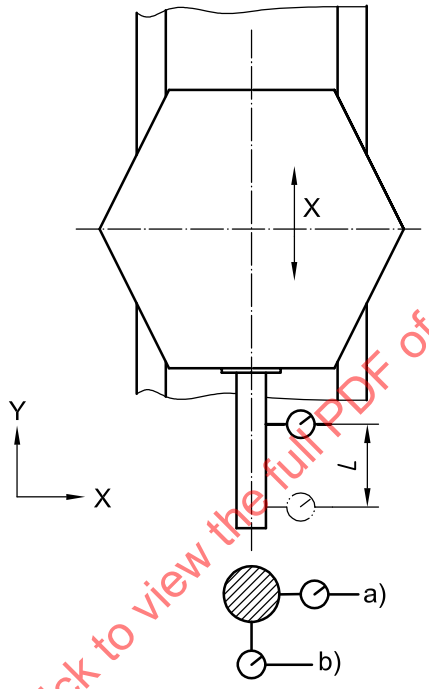
Checking of parallelism between the turret fixing bore axes and the axis of motion of the turret (X, X2 axis)

a) in the ZX plane;

b) in the XY plane.

NOTE The test applies to the turret whose tool fixing direction is square to the work spindle axis.

Diagram



Tolerance	**Measured deviation**
a) and b) 0,030 for L = 100	

Measuring instruments

Test mandrel and dial gauge/support

Observations and references to ISO 230-1:1996 5.422.3

Fix the mandrel to the 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/YZ plane.

The test shall be repeated for all turret fixing bores.

The turret should be in the forward position or as near as possible to the spindle.

If the tool location method requires a flange abutment then the design of the test mandrel should replicate it.

Object

Testing of linear turret

G17

1) Parallelism between the reference slot or reference side face of the cross-slide and its X-axis motion.

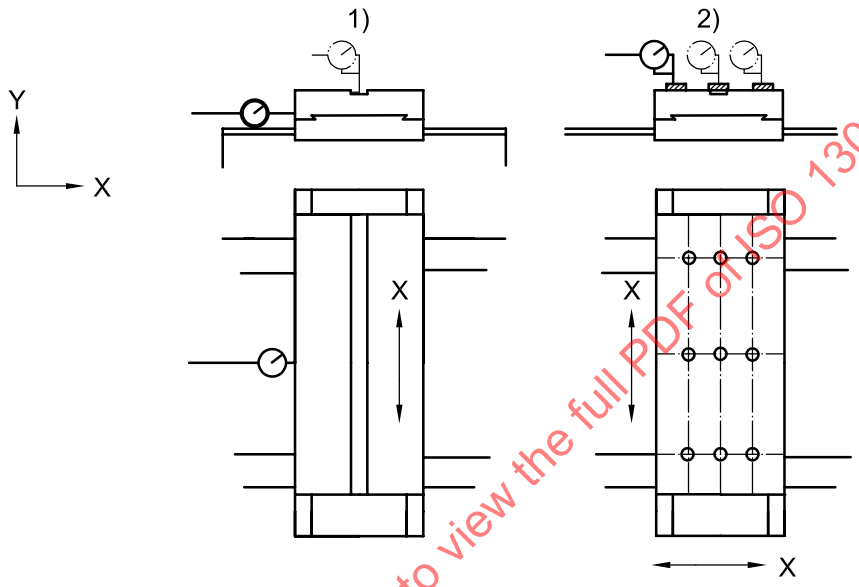
2) Parallelism between the tool-mounting surface of the cross-slide and the

   a) Z-axis motion of the carriage;

   b) X-axis motion of the cross-slide.

NOTE For turret configuration type d (see 4.8) only.

Diagram



Tolerance	**Measured deviation**
1) 0,03 for any measuring length of 300 or full stroke up to 300 2) a) and b) 0,025 for any measuring length of 300 or full stroke up to 300	

Measuring instruments

Dial gauge/support, slip block

Observations and references to ISO 230-1:1996 5.422.21

1) The measurement shall be taken along the measuring length in several positions. The maximum difference between the readings is the parallelism deviation.

2) Check in both X and Z directions in a 3 × 3 grid pattern. Measurement positions shall be in the middle and ends of the mounting surface. Use a slip gauge block to span the centre slot (ISO 230-1:1996, 5.422.21, Figure 66).

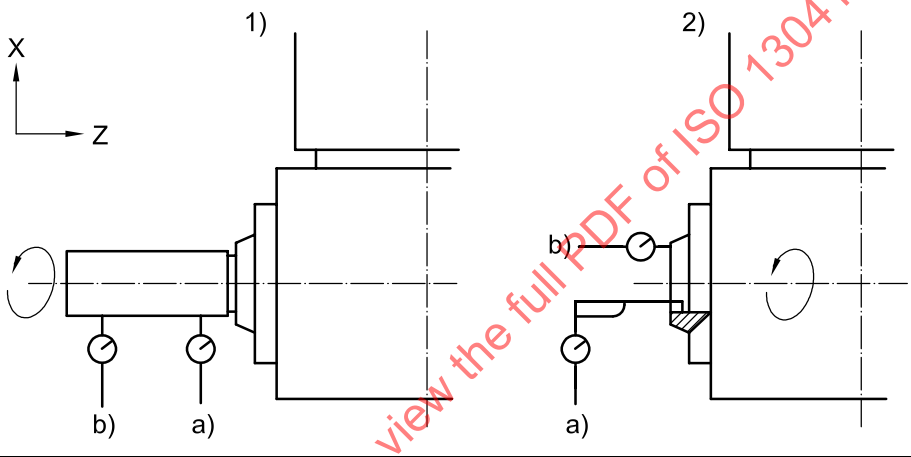
5.5.2 Turret for rotating tools and tool spindle(s)

Object | **G18**

Testing of the run-out and camming of the tool spindle(s):

1) run-out of internal taper bore
   a) at spindle nose,
   b) at a position of 100 mm from spindle nose;
2) cylindrical bore
   a) run-out of spindle nose,
   b) camming of spindle nose.

Diagram



Tolerance

		Category 1	Category 2	Category 3
1)	a)	0,010	0,015	0,020
	b)	0,015	0,020	0,025
2)	a)	0,010	0,015	0,020
	b)	0,010	0,015	0,020

Measured deviation

Measuring instruments

Test mandrel, dial gauge/support

Observations and references to ISO 230-1:1996 5.612.3, 5.632

Measurements should be taken in both XZ and YZ planes.

The measurements shall be repeated at least four times, the mandrel being rotated through 90° in relation to the spindle. The average of the readings shall be recorded.

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 tool spindles and taken on the maximum diameter.

Test 2) b) shall be checked at the maximum possible radius.