
**Test conditions for numerically
controlled broaching machines —
Testing of accuracy — Vertical surface
type broaching machines**

*Conditions d'essai des machines à brocher à commande numérique —
Contrôle de l'exactitude — Machines verticales à brocher*

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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.

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

NOTE In addition to the terms used in official ISO languages (English, French, Russian), this document gives the equivalent terms in the Italian and Persian languages. These are published under the responsibility of the national member bodies for Italy (UNI) and Iran (ISIRI). However, only the terms given in the official languages can be considered as ISO terms.

Introduction

Most numerically controlled broaching machines are classified into two categories characterized by their particular configuration:

- 1) vertical surface type machines;
- 2) horizontal surface type machines.

The main application of numerically controlled surface type broaching machines is for generating slots and grooves in turbine disks.

The object of this document is to supply information as wide and comprehensive as possible on tests on numerically controlled broaching machines which can be carried out for comparison, acceptance, maintenance or any other purposes.

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Test conditions for numerically controlled broaching machines — Testing of accuracy — Vertical surface type broaching machines

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document specifies, with reference to ISO 230-1, the geometric tests on numerically controlled (NC) broaching machines of normal accuracy, with vertical axis acting for cutting operation. The accuracy of rotary axes, if available, is checked with reference to ISO 230-7.

This document also specifies, with reference to ISO 230-2, the positioning tests on vertical surface type broaching machines for both linear and rotary axes.

This document proposes test pieces containing broached slots and grooves with reference to ISO 230-1, cutting tests under finishing conditions. It also specifies the characteristics and dimensions of the test pieces themselves. This document is intended to supply minimum requirements for assessing the cutting accuracy of the machine.

This document also establishes the tolerances for the test results corresponding to general purpose and normal accuracy vertical surface type broaching machines equipped with numerical control.

This document explains different concepts or configurations and common features of NC vertical surface type broaching machines which are normally used in the manufacturing of turbine disks. It also provides a terminology and designation of controlled axes with reference to ISO 841.

This document deals only with the verification of the accuracy of the broaching 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 documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 230-1:2012, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or quasi-static conditions*

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

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

3 Terms and definitions

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

surface broaching operation

machining process in which a *broach* (3.2) is pushed over an external surface to remove material by linear cutting

Note 1 to entry: Principal cutting motion is a relative translation of broach against the non-rotating workpieces and where the cutting energy is brought by the broach or workpiece motion.

3.2

broach

cutting tool that has multiple transverse cutting edges each with progressively increased size

3.3

broaching machine

machine tool in which broaching operation is executed

3.4

vertical broaching machine

broaching machine (3.3) whose main cutting axis (Z-axis) is vertical

3.5

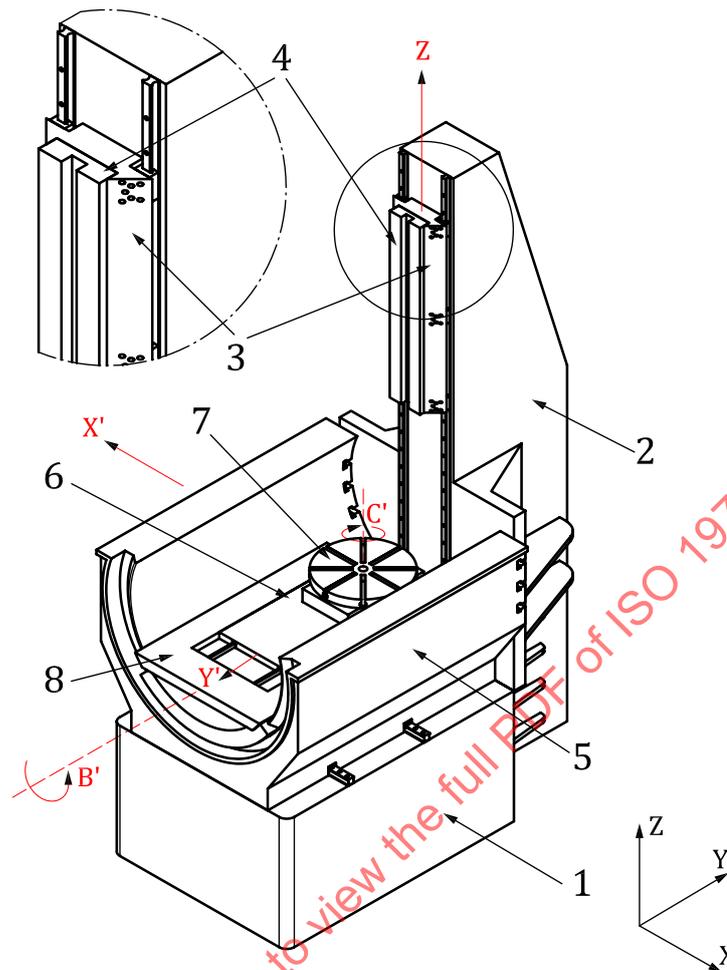
vertical surface type broaching machine

vertical broaching machine (3.4) in which its *broach* (3.2) is pushed or pulled over an external surface of the workpiece to remove material

4 Terminology and designation of axes

See [Figure 1](#) and [Figure 2](#).

A common configuration of NC vertical surface type broaching machines with A-axis is shown in [Figure 2](#). The nomenclature for the structural components of the broaching machine are shown in [Figure 1](#).

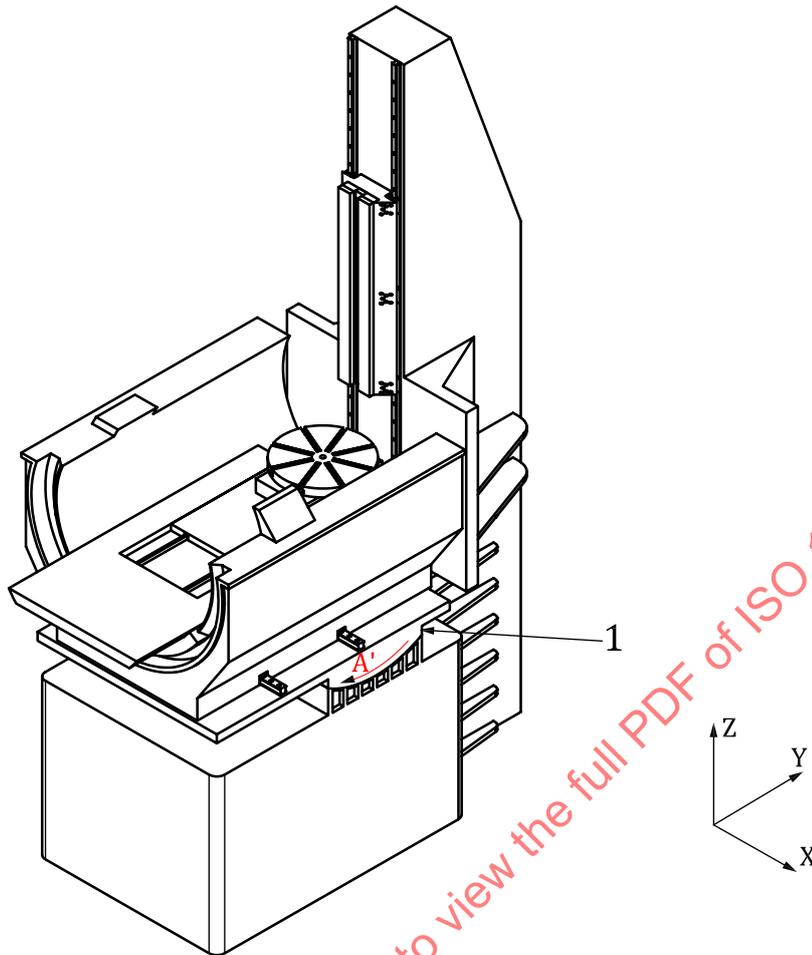
**Key**

English	French
1 bed	bâti
2 column (Z-axis guideway)	colonne (guidage axe Z)
3 saddle (Z-axis)	guidage du coulisseau porte outil (axe Z)
4 broach holder	coulisseau porte-outil
5 cradle saddle (X'-axis)	guidage du berceau (axe X')
6 rotary table saddle (Y'-axis)	guidage de la table tournante (axe Y')
7 rotary table (C'-axis)	table tournante (axe C')
8 cradle (B'-axis)	berceau (axe B')

NOTE 1 Item 7, rotary table, can be called indexer.

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

Figure 1 — Typical example of a vertical surface type broaching machine



Key

English	French
1 A'-axis	axe A'

NOTE For languages other than official ISO languages, see [Table A.3](#).

Figure 2 — Typical example of a vertical surface type broaching machine with A-axis

5 Preliminary remarks

5.1 Measurement 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 as the primary method, but in some cases, microradians or arcseconds may be used for clarification purposes. Formula (1) should be used for conversion of the units of angular deviations or tolerances:

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

5.2 Reference to the ISO 230 series

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

Where the test concerned is in compliance with the specifications of ISO 230-1:2012, ISO 230-2:2014 or ISO 230-7:2015, a reference to the corresponding subclause in ISO 230-1:2012, ISO 230-2:2014 or ISO 230-7:2015 is shown before the instructions in the "Observations" block of the tests described in [Clauses 6 to 8](#).

5.3 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.

5.4 Tests to be performed

When testing a vertical broaching machine, it is neither always necessary nor 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 manufacturer/supplier, 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. 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.

5.5 Tolerances and minimum tolerance

In this document, all tolerance values (see ISO 230-1:2012, 4.1) are guidelines. When they are used for acceptance purposes other values can be agreed on between the user and the manufacturer/supplier. The required/agreed tolerance values are to be clearly stated when ordering the machine.

When establishing the tolerance for a measuring length different from that given in this document (see ISO 230-1:2012, 4.1.2), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

5.6 Measuring instruments

Measuring instruments indicated in the tests described in [Clauses 6 to 8](#) are examples only. Other instruments capable of measuring the same quantities and having the same, or a smaller, measurement uncertainty may be used. Reference shall be made to ISO 230-1:2012, 4.1.1, which indicates the relationship between measurement uncertainties and the tolerances.

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

Similarly, when a "straightedge" is referred to, it can mean any type of straightness reference artefact, such as a granite or ceramic or steel or cast iron straightedge, one arm of a square, one generating line on a cylindrical square, any straight path on a reference cube, or a special, dedicated artefact manufactured to fit in the T-slots, optical instruments or other references.

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

5.7 Diagrams

For reasons of simplicity, diagrams in this document illustrate only one type of broaching machine.

5.8 Software compensation

When built-in software facilities are available for compensating certain geometric deviations, their use during these tests for acceptance purposes shall be based on an agreement between the user and the manufacturer/supplier, with due consideration of the machine tool intended use. When the software compensation is used, this shall be stated in the test report. It shall be noted that when software compensation is used, axes shall not be locked for test purposes.

5.9 Axes not under test

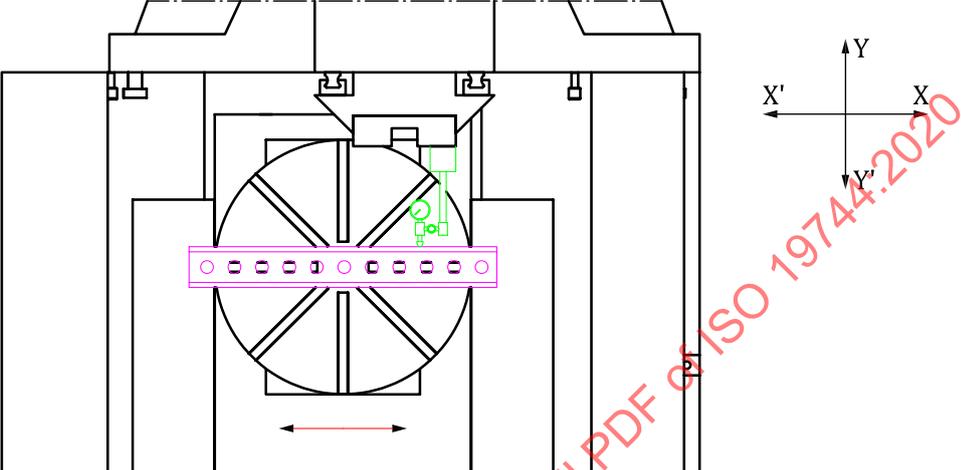
During the execution of some geometric tests on one axis of motion, the position of the other axes, not under test, may affect the results. Therefore, the positions of these axes, as well as the offsets on the tool side and on the workpiece side, are to be stated in the test report.

All measurements shall be done while all unused axes are clamped unless software compensation is applied.

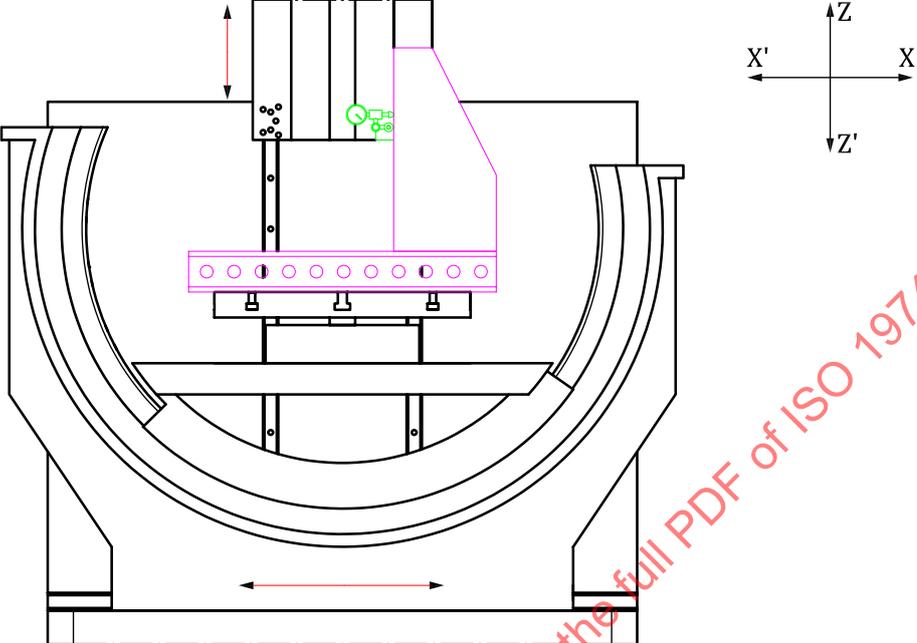
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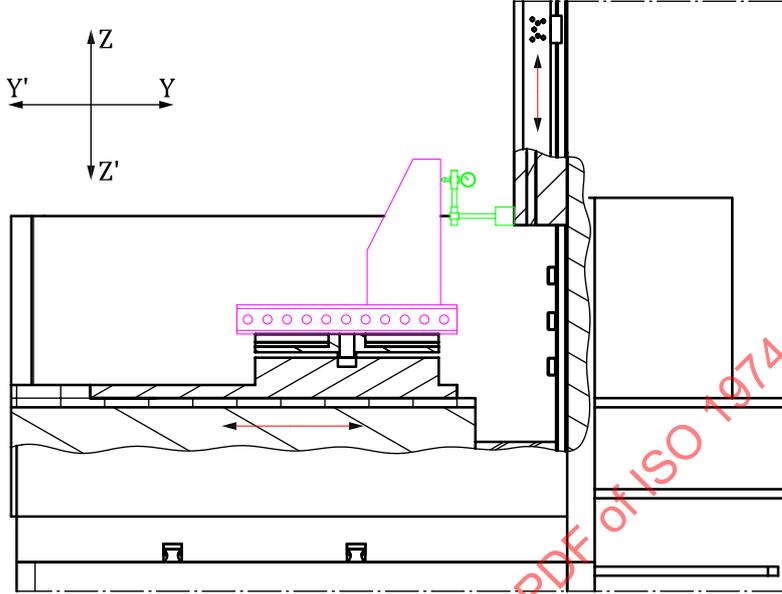
6 Geometric tests

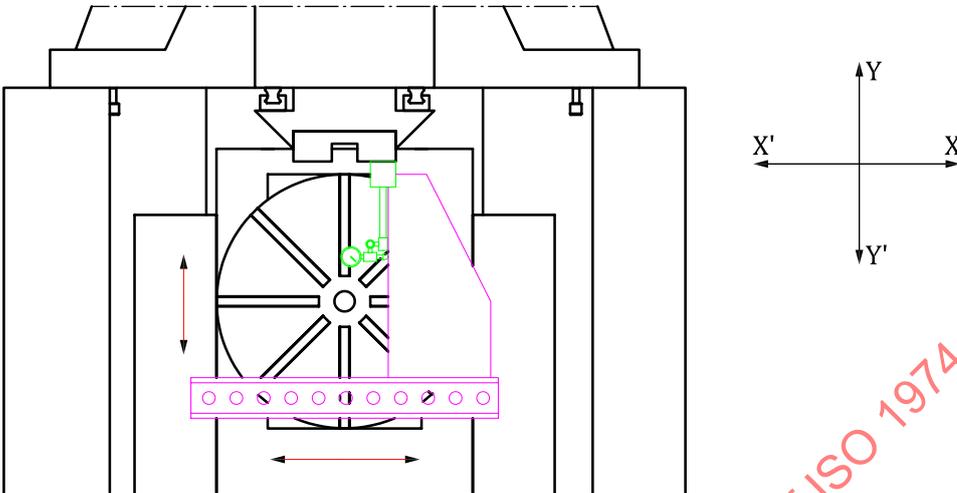
6.1 Straightness errors of linear motions

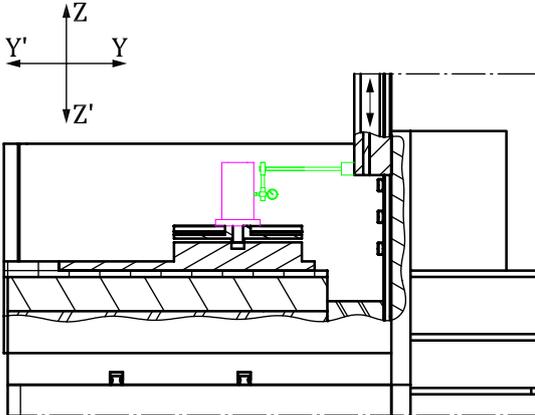
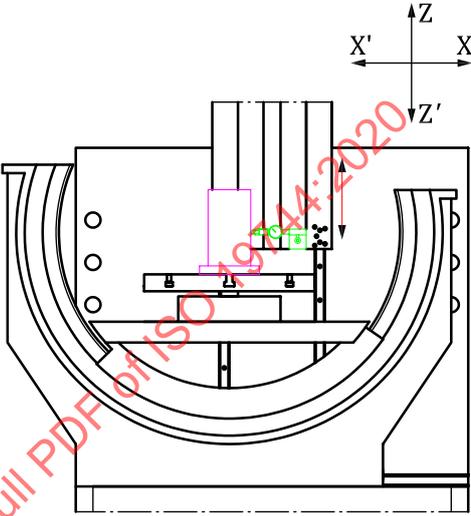
Object Checking of straightness error of the X-axis motion in the XY plane (E_{YX}).	G1
Diagram  <p>The diagram shows a cross-section of a machine tool table. A circular table is mounted on a base. A straightness reflector, represented by a pink horizontal bar with seven circles, is placed on the table's surface. A red double-headed arrow below the table indicates the X-axis of motion. To the right, a coordinate system is shown with X and Y axes, and X' and Y' axes. A red watermark 'STANDARDSISO.COM: Click to view the full PDF © ISO 19744:2020' is overlaid on the diagram.</p>	
Tolerance 0,030 for a measuring length of 300	
Measured error	
Measuring instruments Straightedge and dial gauge; or Optical methods.	
Observations and references to ISO 230-1:2012, 8.2 and 8.2.2 For this test, the straightedge or the straightness reflector shall be placed on the table. Methods based on measurements of angles (ISO 230-1:2012, 12.1.3) shall not be applied as these methods are restricted to measurements of functional surfaces. Measurements shall be carried out on at least six positions along the travel, in both directions of motion, with equally spaced steps.	

6.2 Squareness/Parallelism errors between linear/rotary motions

<p>Object</p>	<p>G2</p>
<p>Checking of squareness error of the X-axis motion to the Z-axis motion $E_{B(0Z)X}$.</p>	
<p>Diagram</p>  <p>NOTE This test can be executed while the rotary table is not mounted on the rotary table saddle.</p>	
<p>Tolerance</p>	
<p>0,130/1 000 (0,040/300) or 26"</p>	
<p>Measured error</p>	
<p>Measuring instruments</p>	
<p>Straightedge or surface plate, square and dial gauge.</p>	
<p>Observations and references to ISO 230-1:2012, 10.3 and 10.3.2</p>	
<p>Set the straightedge or the surface plate along the X-axis movement. Place a square on the straightedge.</p>	
<p>Try to make measuring side of the square parallel to Z-axis by having the same readings of the dial gauge touching the square at two ends of the stroke of Z-axis or the lack of parallelism shall be considered in the measurement. After this adjustment, apply the dial gauge to the straightedge, while orientation of its stylus is in the Z-direction and the dial gauge is moved along X-axis and record the readings of the dial gauge.</p>	
<p>The measured squareness error is the ratio between the reading and the travelled distance along the X-axis.</p>	
<p>NOTE The direction of Z-axis motion is stated in the test result.</p>	

Object	G3
Checking of squareness error of the Y-axis motion to the Z-axis motion $E_{A(0Z)Y}$.	
<p>Diagram</p> 	
<p>NOTE This test can be executed while the rotary table is not mounted on the rotary table saddle.</p>	
<p>Tolerance 0,130/1 000 (0,040/300) or 26''</p>	
<p>Measured error</p>	
<p>Measuring instruments Straightedge or surface plate, square and dial gauge.</p>	
<p>Observations and references to ISO 230-1:2012, 10.3 and 10.3.2</p> <p>Set the straightedge or the surface plate along the Y-axis movement. Place a square on the straightedge. Try to make measuring side of the square parallel to Z-axis by having the same readings of the dial gauge touching the square at two ends of the stroke of Z-axis or the lack of parallelism shall be considered in the measurement. After this adjustment, apply the dial gauge to the straightedge, while orientation of its stylus is in the Z-direction and the dial gauge is moved along Y-axis and record the readings of the dial gauge.</p> <p>The measured squareness error is the ratio between the reading and the travelled distance along the Y-axis.</p> <p>NOTE The direction of Z-axis motion is stated in the test result.</p>	

<p>Object</p>	<p>G4</p>
<p>Checking of squareness error of the Y-axis motion to X-axis motion $E_{C(0X)Y}$.</p>	
<p>Diagram</p> 	
<p>Tolerance 0,165/1 000 (0,050/300) or 33''</p>	
<p>Measured error</p>	
<p>Measuring instruments Straightedge, square and dial gauge</p>	
<p>Observations and references to ISO 230-1:2012, 10.3 and 10.3.2</p> <p>Set a straightedge on the table and align its side parallel to the X-axis, or the lack of parallelism shall be considered in the measurement.</p> <p>Apply the stylus of the dial gauge to the square, measuring in the X-direction. Position the Y-axis to measure close to one end of the square surface and zero the dial gauge.</p> <p>Move the Y-axis to measure close to the other end of the square surface and note the reading. The measured squareness error is the ratio between the reading and the travelled distance along the Y-axis.</p>	

Object	G5
<p>Checking of parallelism error of the Z-axis motion to the C'-axis of rotation:</p> <p>a) in the vertical YZ plane, $E_{A(0Z)C}$;</p> <p>b) in the vertical ZX plane, $E_{B(0Z)C}$.</p>	
<p>Diagram</p> <p>a) </p> <p>b) </p>	
<p>Tolerance</p> <p>For a) 0,100/1 000 (0,030/300) or 20''</p> <p>For b) 0,165/1 000 (0,050/300) or 33''</p>	
<p>Measured error</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>Cylindrical square and dial gauge</p>	
<p>Observations and references to ISO 230-1:2012, 3.6.4, 10.1.4 and 10.1.4.3</p> <ol style="list-style-type: none"> 1) Fix a cylindrical square on the rotary table and centre it approximately on the axis of rotation. 2) Fix the dial gauge with the stylus oriented in the Y-axis direction for a) and X-axis direction for b). 3) Touch the cylindrical square by the stylus, close to the cylinder bottom, and find the maximum reading by making small movements along the X-axis for a) and along Y-axis for b). Zero the dial gauge. 4) Move the saddle away from the table along the Z-axis and touch the cylinder close to its top. Note the Z-axis travel length. Find the maximum reading by making small movements along the X-axis for a) and along Y-axis for b) and note the new reading. 5) Turn the table by 180° and repeat steps 3) and 4). 6) For both measurements, a) and b), the average value (half the algebraic sum) of the two readings on top of the cylinder, divided by the Z-axis travel length, is the deviation to be reported. <p>NOTE The measurement b) can be affected by E_{BB} at B=0.</p>	

Object

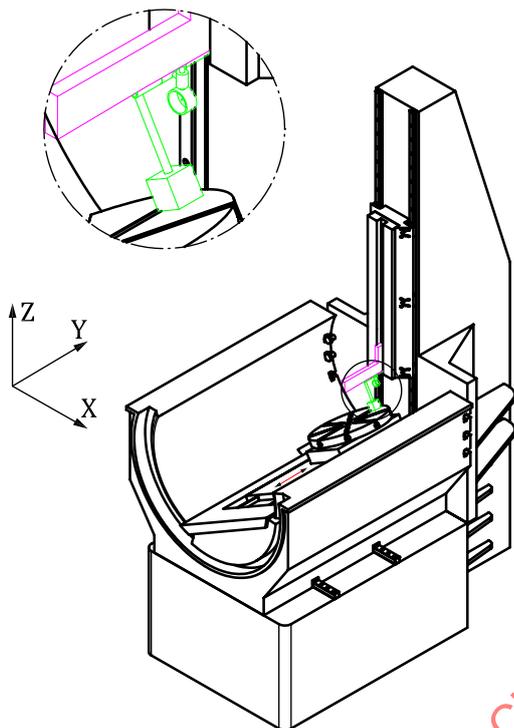
Checking of parallelism error of the Y-axis motion to the B'-axis of rotation:

- a) in the vertical YZ plane, $E_{A(0B)Y}$;
- b) in the horizontal XY plane, $E_{C(0B)Y}$.

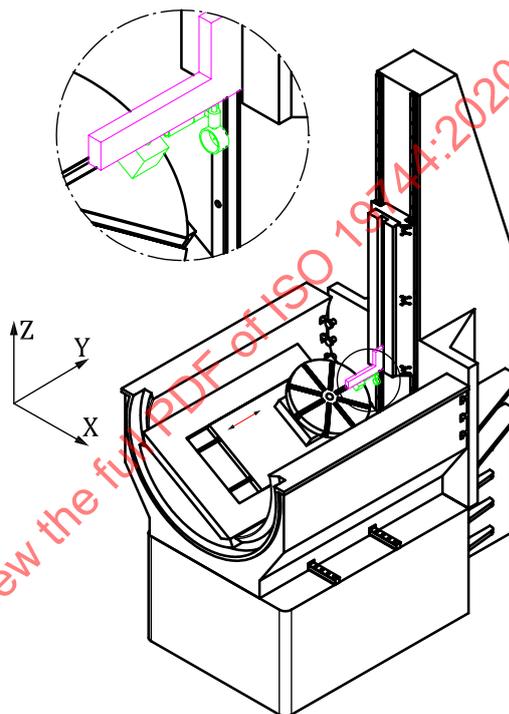
Diagram

a)

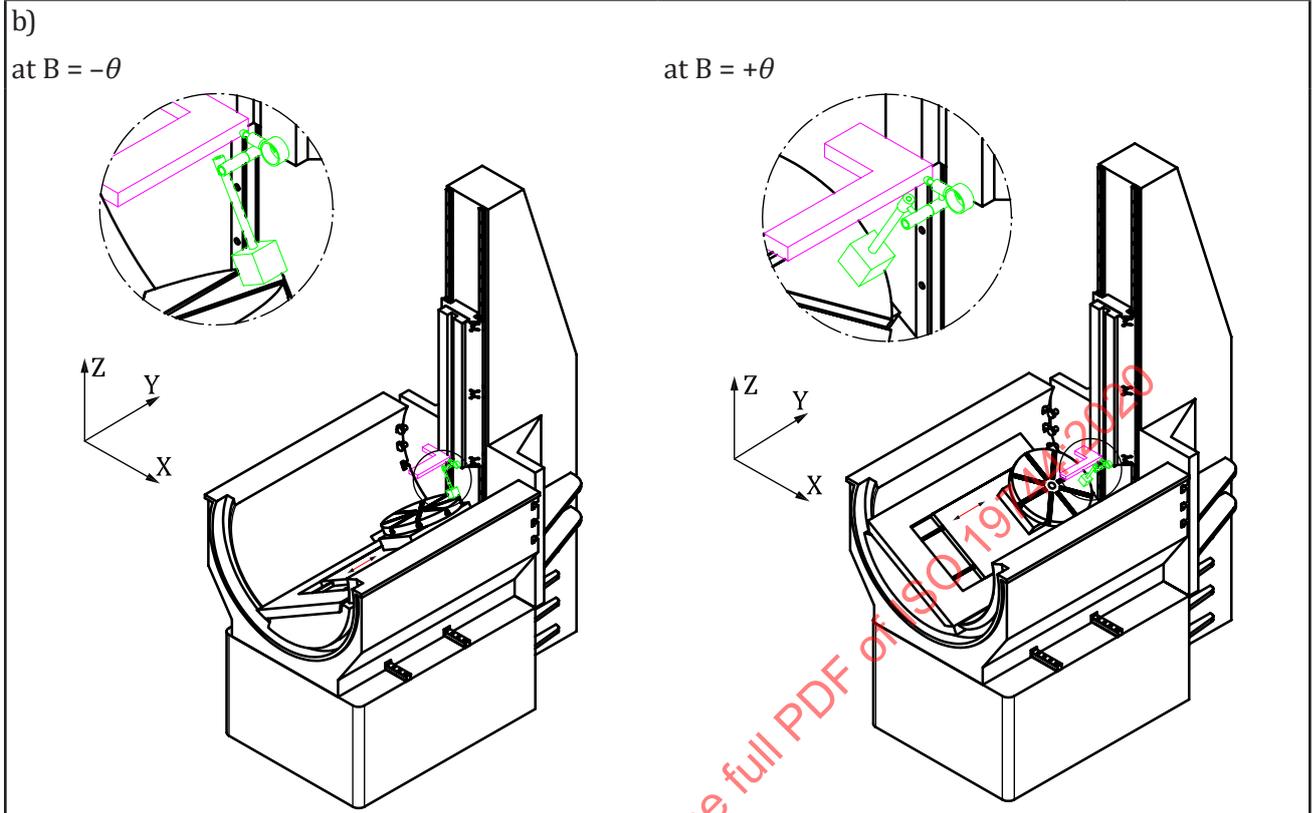
at $B = -\theta$



at $B = +\theta$



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Tolerance

For a) and b)

0,160/1 000 (0,040/250) or 32''

Measured error

a) b)

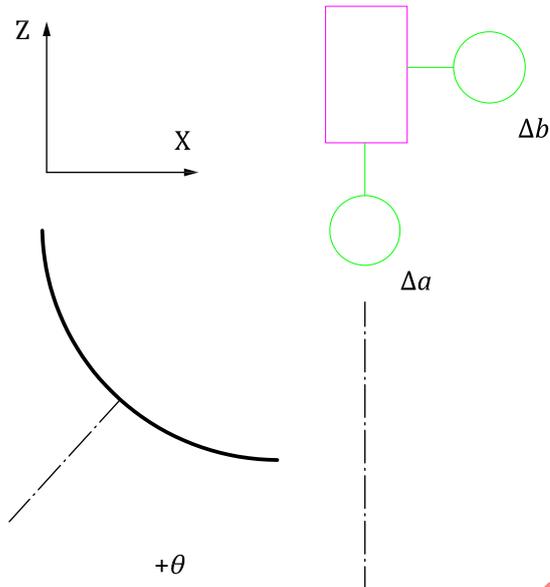
Measuring instruments

Square and dial gauge

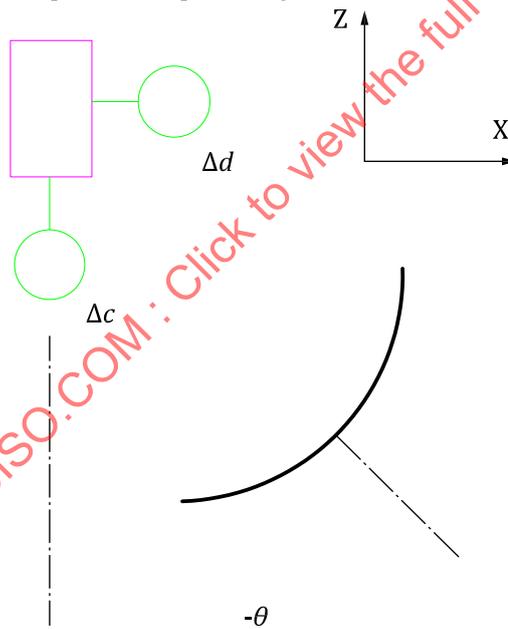
Observations and references to ISO 230-1:2012, 3.6.4, 10.1.4 and 10.1.4.3

- 1) Fix a square (or straightedge) to the broach holder or saddle of Z-axis and align the long side of square approximately parallel to the Y-axis motion in two vertical YZ and horizontal XY planes.
- 2) Rotate the B-axis to its maximum travel in positive direction ($+\theta$). Set a dial gauge on the table and let the dial gauge touch the bottom-face of the square in vertical YZ plane. By moving Y-axis, read the dial gauge variations at measurement distance L and record Δa as the difference between the dial gauge readings divided by the distance $L[\Delta a = (a_2 - a_1)/L]$.

- 3) Similarly, set the dial gauge on the table and let the dial gauge touch the side-face of the square in the horizontal XY plane and record Δb .



- 4) Rotate the B-axis to $-\theta$ position and repeat step 2 and step 3 in order to determine Δc and Δd for vertical YZ and horizontal XY planes respectively.



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5) Parallelism error in both vertical YZ and horizontal XY planes is as follows:

$$E_{A(OB)Y} = (\Delta a - \Delta c) / [2 \times \sin(\theta)]$$

$$E_{C(OB)Y} = (\Delta b - \Delta d) / [2 \times \sin(\theta)]$$

where

$E_{A(OB)Y}$: Parallelism error of Y-axis to B-axis in vertical YZ plane;

$E_{C(OB)Y}$: Parallelism error of Y-axis to B-axis in horizontal XY plane;

Δa : difference of dial gauge readings divided by their distance (L) in vertical YZ plane at $+\theta$ angle of B-axis;

Δb : difference of dial gauge readings divided by their distance (L) in horizontal XY plane at $+\theta$ angle of B-axis;

Δc : difference of dial gauge readings divided by their distance (L) in vertical YZ plane at $-\theta$ angle of B-axis;

Δd : difference of dial gauge readings divided by their distance (L) in horizontal XY plane at $-\theta$ angle of B-axis;

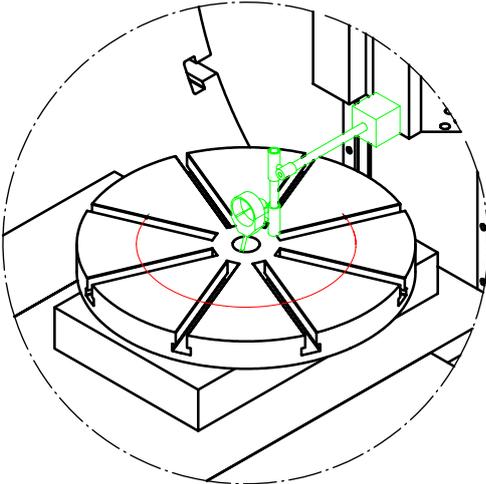
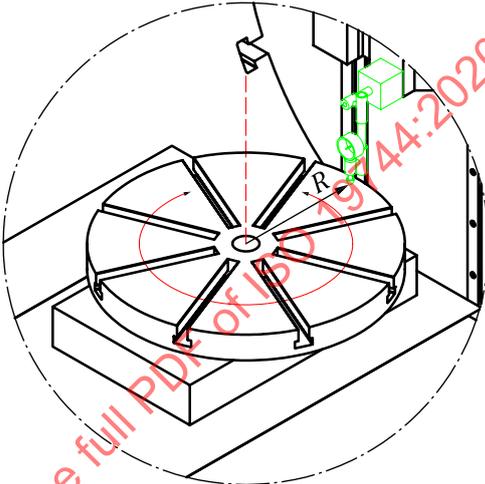
θ : angle of B-axis in which the measurements are implemented.

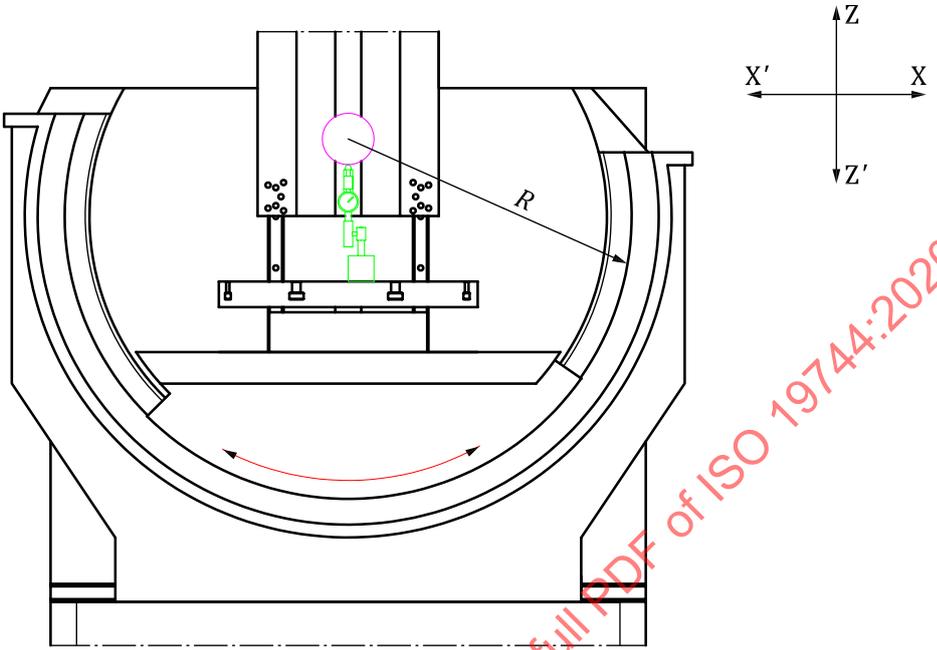
NOTE 1 This test can be done by laser tracker.

NOTE 2 The setup of G8 can also be used for this test.

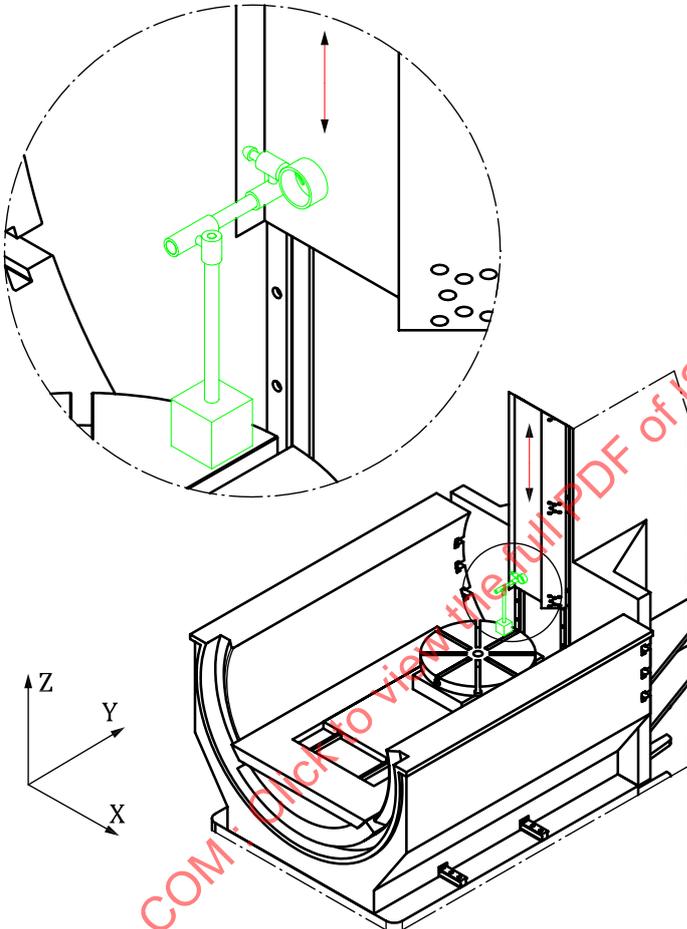
NOTE 3 At small angles of θ , measurement uncertainty increases.

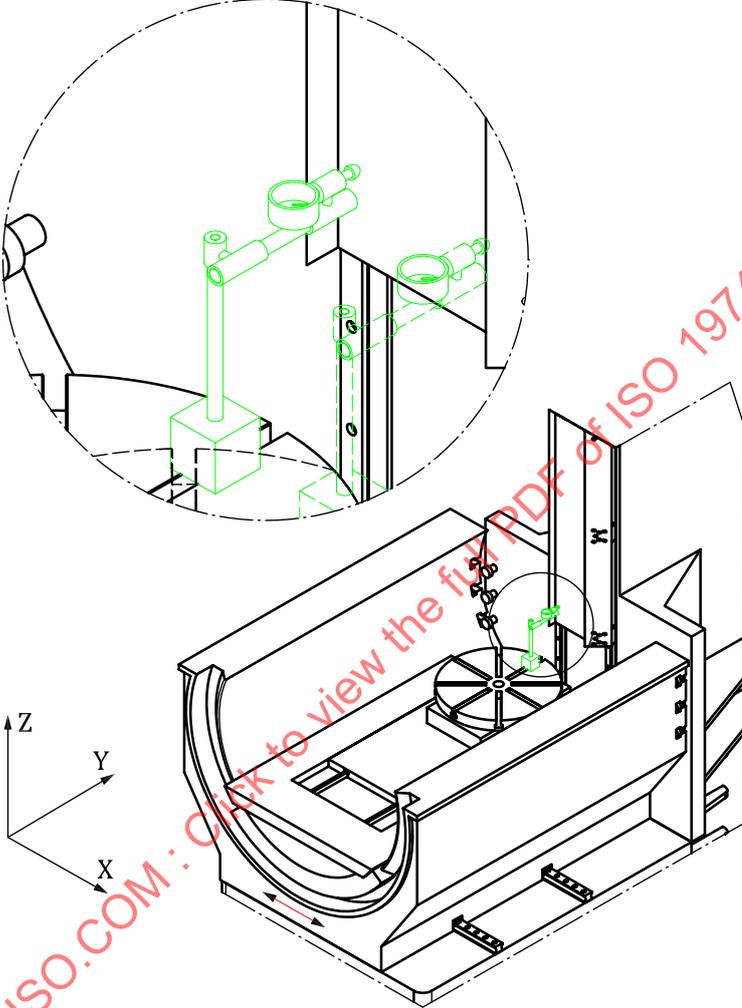
6.3 Table and work holding rotary axis

<p>Object</p> <p>Checking of:</p> <p>a) run-out of the centring hole of the rotary table;</p> <p>b) face error motion of the rotary table surface.</p>	<p>G7</p>
<p>Diagram</p> <p>a) </p> <p>b) </p>	
<p>Tolerance</p> <p>For a) and b) 0,010 for table diameter up to 750 0,020 for table diameter larger than 750</p>	
<p>Measured error</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>a) Dial gauge b) Gauge blocks and dial gauge</p>	
<p>Observations and references to ISO 230-1:2012, 12.5.2 and 12.5.2.3 (see also ISO 230-7)</p> <p>For a)</p> <p>Set the stylus of the dial gauge in the same plane with the axis of the centring hole and as near as possible to the table surface.</p> <p>Rotate the table and record the difference between the maximum and the minimum readings at single positions of the rotary table while the table is clamped.</p> <p>For b)</p> <p>The radius R shall be as large as possible. Test b) can also be carried out without continuous contact between stylus and table surface, by using an intermediate gauge block and measuring in discrete positions (e.g. 8 points at 45° steps). Record the difference between the maximum and the minimum readings.</p> <p>Different effects of tilt error motions, E_{AC} and E_{BC}, shall be mentioned for this test.</p>	

Object Checking of radial error motion of the B'-axis	G8
Diagram 	
Tolerance 0,040 over the whole stroke of B'-axis	
Measured error	
Measuring instruments Test mandrel and dial gauge	
Observations and references to ISO 230-1:2012, 12.5.3 (see also ISO 230-7) Attach a test mandrel to the broach holder or saddle of Z-axis at the centre of rotation of B'-axis while the centre line of the mandrel is parallel to the direction of Y-axis. For finding the centre of B'-axis of rotation, follow the instruction of the machine manufacturer. Errors in the position of the test mandrel in relation to the centre of B'-axis of rotation can influence the test result. Set the base of dial gauge on the table surface and let its stylus touch the test mandrel. Rotate the cradle in its whole stroke and record the difference between the maximum and the minimum readings of the dial gauge.	

6.4 Broach holder

<p>Object</p>	<p>G9</p>
<p>Checking equidistance of a reference point between Z-axis motion and reference surface of the saddle of broach holder in X direction at different positions of Z-axis.</p>	
<p>Diagram</p> 	
<p>Tolerance Local tolerance: 0,020 over a measuring length of 1 000 Total tolerance: 0,030</p>	
<p>Measured error</p>	
<p>Measuring instruments Dial gauge</p>	
<p>Observations and references to ISO 230-1:2012, 12.3.2.5.1 Move the Z-axis to its upper position. Fix the dial gauge on the table with the stylus oriented in the X-axis direction. Touch the reference surfaces by the stylus. Zero the dial gauge. Measurements should be carried out at least at four points per meter equally spaced. Traverse the Z-axis from one measurement position to the following. At each measurement position, note the readings. Range of readings is to be reported. The distance between reference point of Z-axis and the table shall be stated in the test report.</p>	

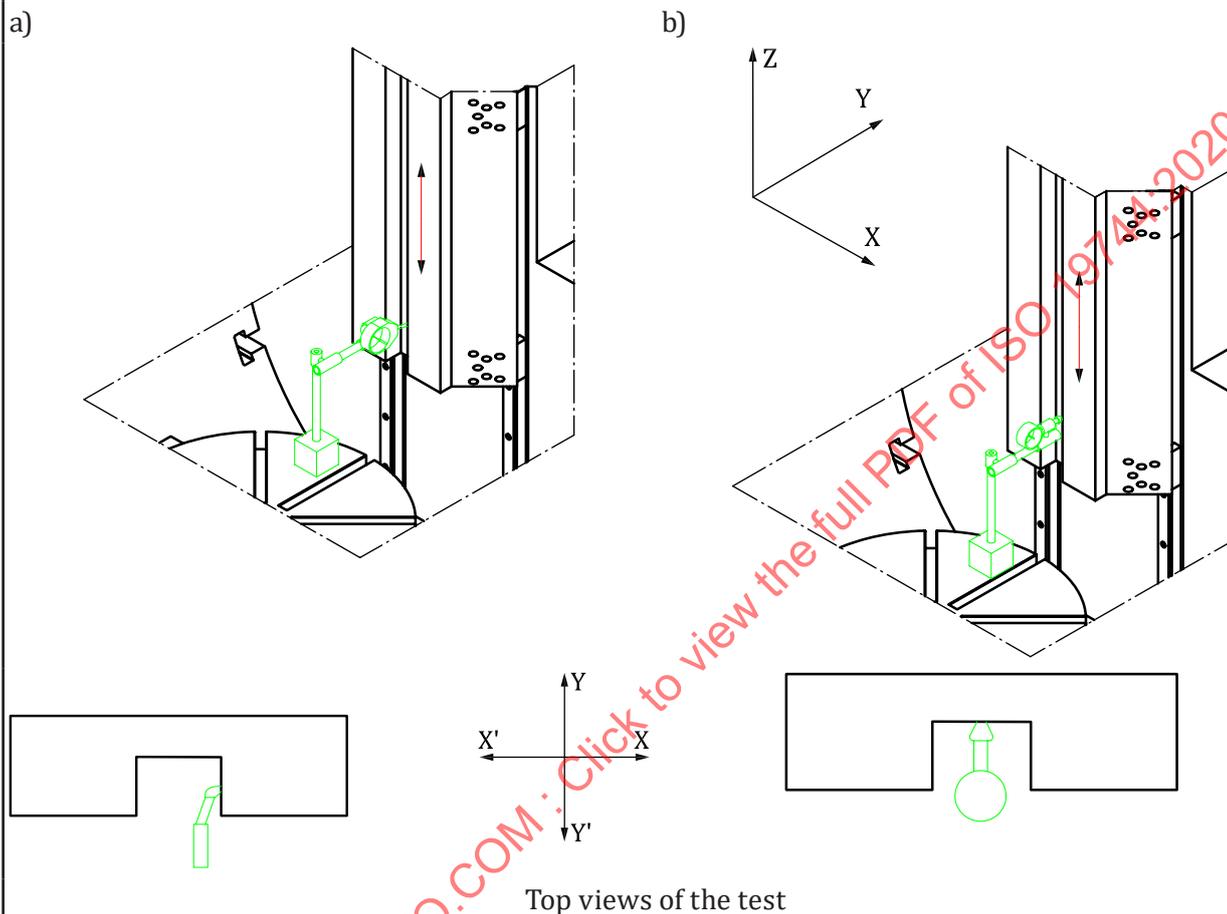
Object	G10
<p>Checking equidistance of a reference point between Z-axis motion and reference surface of the saddle of broach holder in Y direction at different positions of Z-axis.</p>	
<p>Diagram</p> 	
<p>Tolerance</p> <p>Local tolerance: 0,020 over a length of 1 000 along Z-axis</p> <p>Total tolerance: 0,030</p>	
<p>Measured error</p>	
<p>Measuring instruments</p> <p>Dial gauge</p>	
<p>Observations and references to ISO 230-1:2012, 12.3.2.5.1</p> <p>Move the Z-axis to its upper position. Fix the dial gauge on the table with the stylus oriented in the Y-axis direction.</p> <p>Touch the reference surfaces by the stylus. Zero the dial gauge. Move the X-axis along the cross section of the reference surface. Measurements should be carried out at least at four points per metre equally spaced along the Z-axis. Traverse the Z-axis from one measurement position to the following. At each measurement position note the readings. The range of all readings is the error to be reported.</p> <p>The distance between reference point of Z-axis and the table shall be stated in the test report.</p>	

Object

Checking of parallelism error of the reference surface of broach holder to Z-axis movement:

- a) in the vertical ZX plane;
- b) in the vertical YZ plane.

Diagram



Top views of the test

Tolerance

For a) and b)

Local tolerance: 0,025 over a measuring length of 1 000

Total tolerance: 0,050

Measured error

- a) b)

Measuring instruments

Dial gauge

Observations and references to ISO 230-1:2012, 12.3.2.5.1

Move the Z-axis to its upper position. Fix the dial gauge on the table with the stylus oriented in the X-axis direction for a) and Y-axis direction for b).

Touch the reference surfaces of broach holder by the stylus. Zero the dial gauge. Measurements should be carried out at least at four points per metre equally spaced. Traverse the Z-axis from one measurement position to the following.

At each measurement position, note the readings.

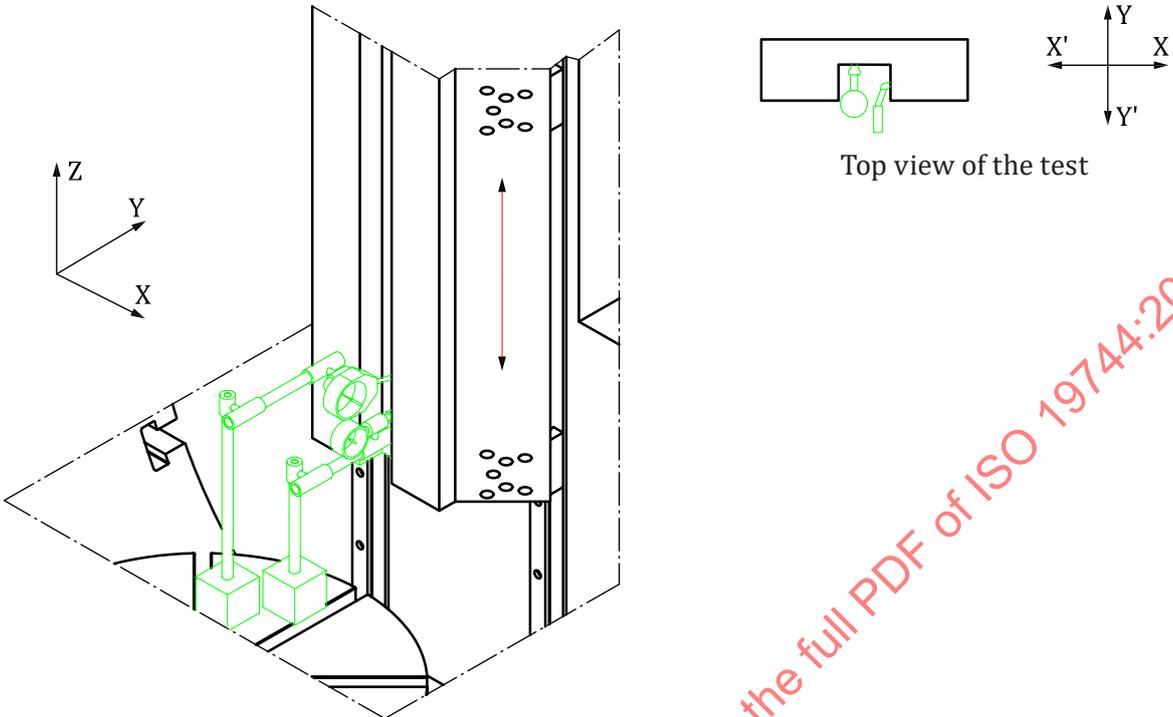
The parallelism error is the difference between the maximum and the minimum readings.

The signs of the parallelism errors in both planes shall be reported.

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<p>Object</p>	<p>G12</p>
<p>Checking of variation of equidistance of the reference surface of broach holder motion over a distance of 100:</p> <p>a) in the vertical YZ plane;</p> <p>b) in the vertical ZX plane.</p>	
<p>Diagram</p> <p style="text-align: center;">Top views of the test</p>	
<p>Tolerance</p> <p>For a) and b)</p> <p>0,010 at the distance of 100 between two reference points</p>	
<p>Measured error</p> <p>a) b)</p>	
<p>Measuring instruments</p> <p>Dial gauges</p>	
<p>Observations and references to ISO 230-1:2012, 3.4.16 and 8.4, 8.4.2</p> <p>Set two dial gauges on the table and let their stylus touch the reference surface of the broach holder in YZ and ZX planes for a) and b) respectively. The distance between stylus of dial gauges shall be set 100 apart from each other. Zero both dial gauges and move the Z-axis in front of dial gauges. Record the maximum and minimum readings of the dial gauges in the whole stroke of Z-axis. The range of differences between two simultaneous readings is the test result.</p> <p>To determine position (distance from table surface) of dial gauges, it is highly recommended to implement this test in the cutting area same as broached slots on real pieces.</p> <p>NOTE Results of G11 can be derived from this test.</p>	

Object	G13
Checking of repeatability of broach holders change.	
Diagram <p>The diagram illustrates the experimental setup. On the left, a 3D perspective view shows a broach holder mounted on a table. Two dial gauges are positioned to measure the reference surfaces of the holder. A coordinate system with X, Y, and Z axes is shown. On the right, a top view of the test setup is shown, with a coordinate system with X' and Y' axes. The text 'Top view of the test' is placed below the top view diagram.</p>	
Tolerance 0,030	
Measured error	
Measuring instruments Dial gauge	
Observations <p>Fix two dial gauges on the table so that they contact the reference surfaces of the broach holder. Zero the dial gauges. Move the Z-axis to clear off the dial gauges reading while X-axis and Y-axis are locked. Unload and then load again the same broach holder under an automatic cycle. Move back the Z-axis to the same position as before in order to contact the dial gauges to the reference surfaces again and record the readings.</p> <p>Repeat the cycle three times. The dial gauges should be set to zero at the start of the test. The deviation is the maximum difference between all sets of readings.</p>	

<p>Object</p>	<p>G14</p>
<p>Checking the error of a batch of broach holders positioning along X and Y directions.</p>	
<p>Diagram</p>  <p>The diagram illustrates the measurement setup. On the left, a 3D perspective view shows a broach holder assembly mounted on a table. Two dial gauges are positioned to measure the holder's position. A coordinate system with X, Y, and Z axes is shown. A red double-headed arrow indicates movement along the Z-axis. On the right, a top view shows the broach holder with a coordinate system with X', Y', X, and Y' axes.</p>	
<p>Tolerance 0,050</p>	
<p>Measured error</p>	
<p>Measuring instruments Dial gauge</p>	
<p>Observations</p> <p>Fix two dial gauges on the table so that they contact the reference surfaces of one of the broach holders. Zero the dial gauges. Move the Z-axis to clear off the dial gauges reading while X-axis and Y-axis are locked. Unload the broach holder and then load the other broach holders one after other under an automatic cycle. Move back the Z-axis to the same position as before in order to contact the dial gauges to the reference surfaces again and record the readings.</p> <p>The maximum difference of all dial gauge readings is the error of broach holders positioning.</p>	

7 Accuracy and repeatability of positioning tests

In performing the tests, reference should be made to ISO 230-2, especially for the environmental conditions, warming up of the machine, measuring methods, evaluation, and interpretation of the results.

7.1 Positioning of numerically controlled linear axes

Object		P1	
Checking of accuracy and repeatability of positioning of X-axis, E_{XX} .			
Diagram			
Key			
1 laser head			
2 interferometer			
3 retro reflector			
Tolerance	For the whole stroke		Measured deviation
Bi-directional positioning accuracy of X-axis ^a	$E_{XX,A}$	0,040	
Unidirectional positioning repeatability of X-axis	$E_{XX,R↑}; E_{XX,R↓}$	0,010	
Bi-directional positioning repeatability of X-axis ^a	$E_{XX,R}$	0,021	
Mean reversal error of X-axis	$E_{XX,\bar{B}}$	0,015	
Bi-directional systematic positioning error of X-axis ^a	$E_{XX,E}$	0,035	
Mean bi-directional positioning error of X-axis ^a	$E_{XX,M}$	0,020	
^a Can provide a basis for machine acceptance.			
Measuring instruments			
Laser measurement equipment or linear scale			
Observations and references to ISO 230-2:2014, Clause 3, 5.3.2 and 5.3.3			
The linear scale or the beam of laser measurement equipment shall be set parallel to the travelling axis. Positioning feed speed shall be agreed between manufacturer/supplier and user.			
The position of the starting point of measurement shall be stated.			

Object		P2
Checking of accuracy and repeatability of positioning of Y-axis, E_{YY} .		
Diagram		
Key		
1 laser head		
2 interferometer		
3 retro reflector		
Tolerance	For the whole stroke	Measured deviation
Unidirectional positioning accuracy of Y-axis ^a	$E_{YY,A\uparrow}; E_{YY,A\downarrow}$	0,012
Bi-directional positioning accuracy of Y-axis	$E_{YY,A}$	0,018
Unidirectional positioning repeatability of Y-axis ^a	$E_{YY,R\uparrow}; E_{YY,R\downarrow}$	0,008
Bi-directional positioning repeatability of Y-axis	$E_{YY,R}$	0,012
Mean reversal error of Y-axis	$E_{YY,\bar{B}}$	0,005
Unidirectional systematic positioning error of Y-axis ^a	$E_{YY,E\uparrow}; E_{YY,E\downarrow}$	0,010
Bi-directional systematic positioning error of Y-axis	$E_{YY,E}$	0,015
Mean bi-directional positioning error of Y-axis	$E_{YY,M}$	0,010
^a Can provide a basis for machine acceptance.		
Measuring instruments		
Laser measurement equipment or linear scale		
Observations and references to ISO 230-2:2014, Clause 3, 5.3.2 and 5.3.3		
The linear scale or the beam of laser measurement equipment shall be set parallel to the travelling axis. Positioning feed speed shall be agreed between manufacturer/supplier and user.		
The position of the starting point of measurement shall be stated.		

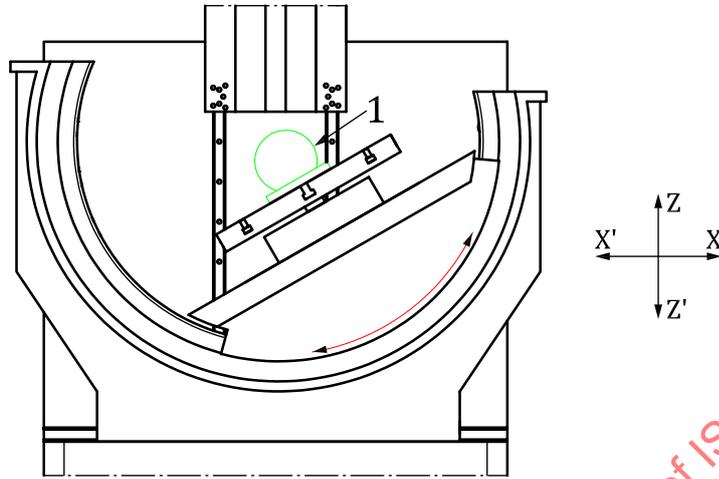
7.2 Positioning of numerically controlled rotary axes

Object		P3	
Checking of accuracy and repeatability of positioning of C-axis, E_{CC} .			
Diagram			
Key			
1 autocollimator			
2 optical polygon			
Tolerance		For 360°	Measured deviation
Unidirectional positioning accuracy of C-axis ^a	$E_{CC,A\uparrow}; E_{CC,A\downarrow}$	8''	
Bi-directional positioning accuracy of C-axis	$E_{CC,A}$	12''	
Unidirectional positioning repeatability of C-axis ^a	$E_{CC,R\uparrow}; E_{CC,R\downarrow}$	4''	
Bi-directional positioning repeatability of C-axis	$E_{CC,R}$	8''	
Mean reversal error of C-axis	$E_{CC,\bar{B}}$	4''	
Unidirectional systematic positioning error of C-axis ^a	$E_{CC,E\uparrow}; E_{CC,E\downarrow}$	6''	
Bi-directional systematic positioning error of C-axis	$E_{CC,E}$	9''	
Mean bi-directional positioning error of C-axis	$E_{CC,M}$	6''	
^a Can provide a basis for machine acceptance. Tolerance for tables with diameter less than 350 should be agreed between supplier/manufacturer and user.			
Measuring instruments			
Optical polygon and autocollimator, or laser measuring equipment, or rotary encoder			
Observations and references to ISO 230-2:2014, Clause 3, 5.3.4 and 5.3.5			
Fix the autocollimator in a proper position e.g. on the broach holder of the machine and fix the optical polygon near to the centre of the rotary table in alignment with the autocollimator at the first measuring rotary position.			
If the movement of the rotary table does not cause any movement between the ram and a fixed part of the machine tool, the autocollimator may be fixed on the fixed part of the machine tool, e.g. on the machine bed.			
Target positions shall be agreed between manufacturer/supplier and user.			
Angular positioning feed speed shall be agreed between manufacturer/supplier and user.			

Object

Checking of accuracy and repeatability of positioning of B'-axis, E_{BB} .

Diagram



Key

1 swivelling angle measuring device

Tolerance		For the whole stroke	Measured deviation
Unidirectional positioning accuracy of B-axis ^a	$E_{BB,A\uparrow}; E_{BB,A\downarrow}$	16"	
Bi-directional positioning accuracy of B-axis	$E_{BB,A}$	25"	
Unidirectional positioning repeatability of B-axis ^a	$E_{BB,R\uparrow}; E_{BB,R\downarrow}$	10"	
Bi-directional positioning repeatability of B-axis	$E_{BB,R}$	15"	
Mean reversal error of B-axis	$E_{BB,\bar{B}}$	5"	
Unidirectional systematic positioning error of B-axis ^a	$E_{BB,E\uparrow}; E_{BB,E\downarrow}$	14"	
Bi-directional systematic positioning error of B-axis	$E_{BB,E}$	20"	
Mean bi-directional positioning error of B-axis ^a	$E_{BB,M}$	15"	

^a Can provide a basis for machine acceptance.

Measuring instruments

Swivelling angle measuring device; or
Rotary encoder and pendulum.

Observations and references to ISO 230-2:2014, Clause 3, 5.3.4 and 5.3.5

Target positions shall be selected according to ISO 230-2:2014, Table 1.

Angular positioning feed speed shall be agreed between manufacturer/supplier and user.

NOTE For more information about swivelling angle measuring device, refer to ISO/TR 230-11:2018, 12.4.2

8 Machining tests

Because of the diversity of shape of components produced by NC vertical surface type broaching machines, details of the machining tests shall be agreed between the manufacturer/supplier and the user. The following information should be stated in the agreement and final test result:

- test piece (e.g. material, dimensions);
- broach (e.g. material, geometry, tooling and sharpening process);
- broaching conditions (e.g. cutting speed, coolant, fixturing);
- geometry of broached features (e.g. technical drawing, dimensions, tolerance);
- measuring instrument for checking the accuracy of the finished test piece (e.g. resolution, uncertainty).

[Annex B](#) shows recommended shapes of slots and explains other details of machining conditions.

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Annex A (informative)

Terms in other languages

See [Tables A.1, A.2](#) and [A.3](#).

Table A.1 — Terms in other than official ISO languages for Terms in [Clause 3](#)

Reference	Italian	Persian
3.1	operazione di brocciatura esterna	عملیات خان‌کشی سطحی
3.2	broccia	ابزار خان‌کشی (خان)
3.3	brocciatrice	ماشین خان‌کشی
3.4	brocciatrice verticale	ماشین خان‌کشی عمودی
3.5	brocciatrice verticale per esterni	ماشین خان‌کشی عمودی سطحی

Table A.2 — Terms in other than official ISO languages for [Figure 1](#)

Item number	Italian	Persian
1	basamento	بستر
2	montante (guida dell'asse Z)	ستون (کشویی محور Z)
3	slitta verticale (asse Z)	کشویی (محور Z)
4	porta-broccia	ابزارگیر (نگهدار خان)
5	slitta della culla (asse X')	کشویی گهواره (محور X')
6	slitta della tavola girevole (asse Y')	کشویی میز دورانی (محور Y')
7	tavola girevole (asse C')	محور دورانی (محور C')
8	culla (asse B')	گهواره (محور B')

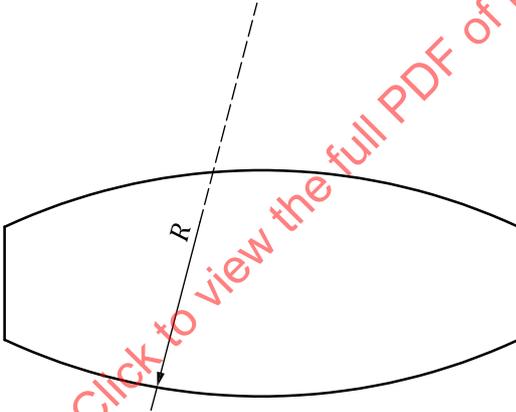
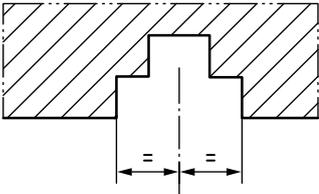
Table A.3 — Terms in other than official ISO languages for [Figure 2](#)

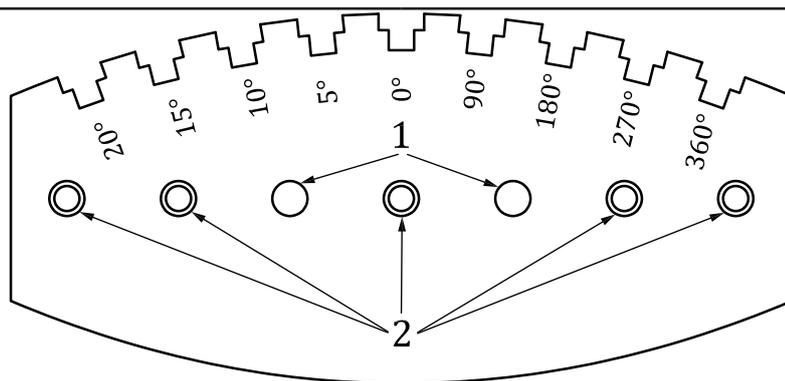
Item number	Italian	Persian
1	asse A'	محور A'

Annex B (informative)

Recommended tests for surface broaching operation

This annex proposes two machining tests, M1 and M2.

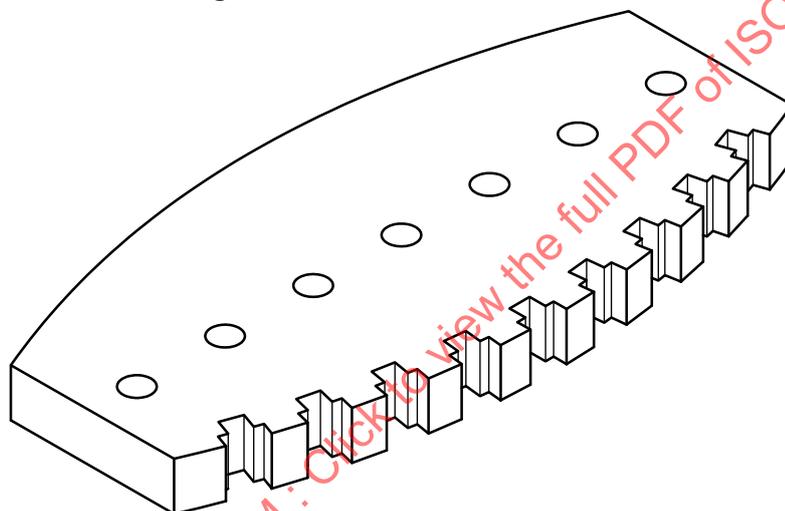
Object	M1
<p>Checking the cutting performance of machine under broaching condition at different C'-axis of rotation and B'=0.</p>	
<p>Raw test piece and its dimensions</p> <p>A test piece is used with circular outer curves. Nominal radius of the circular arc (R) shall be selected according to desirable diameters of real turbine disks and shall be agreed between user and manufacturer/supplier.</p> <div style="text-align: center;">  </div>	
<p>Diagram and machining shape</p> <p>The schematic geometry of broached grooves is head-and-shoulder and shown below. All nominal dimensions of slots shall be agreed between user and manufacturer/supplier.</p> <div style="text-align: center;">  </div>	



Key

- 1 holes for positioning the test piece
- 2 holes for fixing the test piece

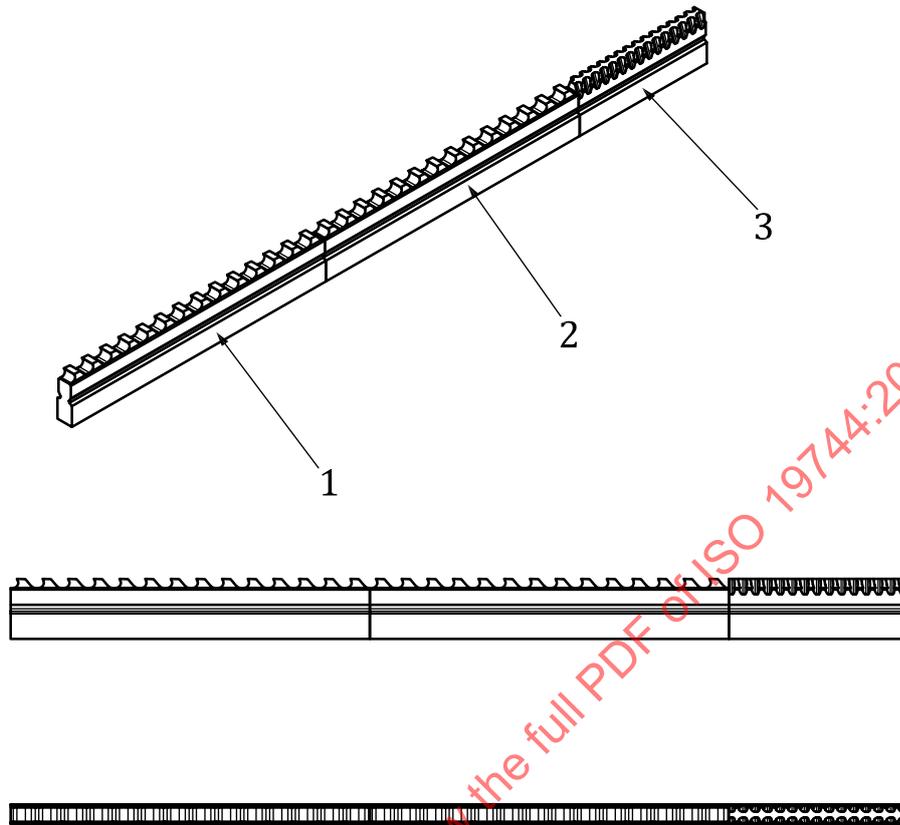
Overview of the part after machining is shown below:



Broach (cutting tool)

A simple HSS slot broach with a rake angle of 15°, clearance angle of 4° and rise per tooth of 0,05 mm is recommended for normal applications.

The schematic diagram of the mentioned broach and its details are shown below:



Key

- 1 first tool segment: depth cutter
- 2 second tool segment: depth cutter
- 3 third tool segment: finishing broach

Tooling and recommended sharpening process

Before starting broaching operation, the broach should be sharpened according to tool manufacturer/supplier instruction.

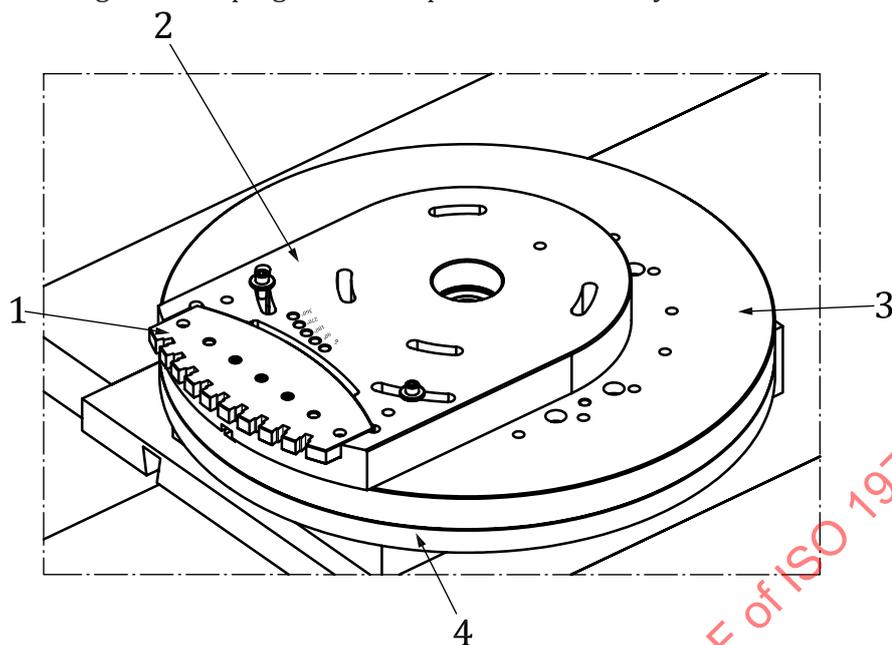
Machining condition, fixturing and procedure of broaching in different positions of indexing

There are some positioning holes existing in the fixture for inserting positioning pins. The rotary table (C'-axis) is set to a certain angle position, e.g. to 0° . The positioning pin is inserted into its dedicated positioning hole and the screws are tightened. Then the slot is machined at $C'=0^\circ$.

Afterwards, the rotary table (C'-axis) is rotated to the next position, e.g. 90° . The fixture is unscrewed and rotated manually backwards to the machining position. The positioning pin is inserted again to its dedicated hole and the screws are tightened. Then the next slot can be machined. By shifting the position of the positioning pin for some angle degrees, the next slot will be machined besides the existing slots.

The same procedure is executed for desired angles e.g. 0° , 90° , 180° , 270° and 360° .

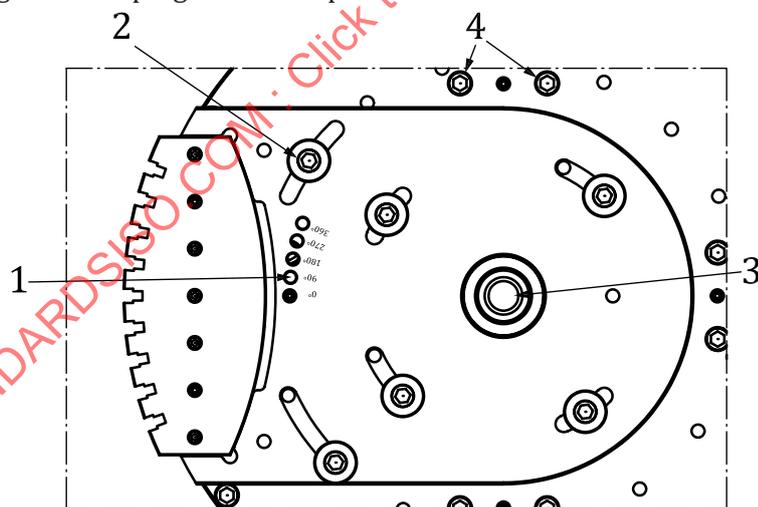
Overview of positioning and clamping of the test piece on the rotary table is shown below.



Key

- 1 test piece
- 2 fixture
- 3 base plate
- 4 rotary table (indexer)

Details of positioning and clamping of the test piece and its fixture are seen below:



Key

- 1 positioning holes
- 2 screws for clamping the fixture to the base plate
- 3 central hole of the fixture and c'-axis of rotation
- 4 screws for clamping the base plate to the rotary table

The following schematic diagram show the procedure of setting the fixture with the test piece for the machining of the slots.

