

Test conditions for machining centres —

Part 1: Geometric tests for machines with horizontal spindle and with accessory heads (horizontal Z-axis)

ICS 25.040.10

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW



Document Sharing Hub

National foreword

This British Standard reproduces verbatim ISO 10791-1:1998 and implements it as the UK national standard. It partially replaces BS 4656-30:1992 which will be withdrawn once all other parts of this standard are published.

The UK participation in its preparation was entrusted to Technical Committee MTE/1, Machine tools, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the ISO title page, pages ii to iv, pages 1 to 53 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Sideline in this document indicates the most recent changes by amendment.

Amendments issued since publication

Amd. No.	Date	Comments
10688	November 1999	Corrected standard issued May 1999

This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 November 1998

© BSI 11-1999

ISBN 0 580 30629 1

INTERNATIONAL STANDARD

ISO 10791-1

First edition
1998-09-01

Test conditions for machining centres —

Part 1:

Geometric tests for machines with horizontal spindle and with accessory heads (horizontal Z-axis)

Conditions d'essai pour centres d'usinage —

Partie 1: Essais géométriques des machines à broche horizontale et à têtes accessoires (axe Z horizontal)



Reference number
ISO 10791-1:1998(E)

AVA Documents
Document Sharing Hub

Contents

	Page
Foreword	iii
Introduction	1
1 Scope	1
2 Normative reference	1
3 Preliminary remarks	1
3.1 Measuring units	1
3.2 Reference to ISO 230-1	1
3.3 Testing sequence	2
3.4 Tests to be performed	2
3.5 Measuring instruments	2
3.6 Machining tests	2
3.7 Diagrams	2
3.8 Pallets	2
3.9 Software compensation	2
3.10 Machine configurations	2
3.11 Designation	2
3.12 Minimum tolerance	2
4 Geometric tests	5
4.1 Straightness of linear motions	5
4.2 Angular deviations of linear motions	8
4.3 Squareness between linear motions	11
4.4 Spindle	14
4.5 Table or pallet	19
4.6 Supplementary axes parallel to the Z-axis	27
Annex A (normative) Accessory 45° split indexable heads	31
Annex B (normative) Accessory swivel heads	40
Annex C (normative) Accessory 45° split continuous heads	47
Annex D (informative) Bibliography	53
Figure 1	3
Table 1 — Classification of configurations of horizontal-spindle machining centres	4

Descriptors: Machining centre, numerical control, machine tools, positioning, tests, geometric tests, testing conditions.

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.

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.

International Standard ISO 10791-1 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

ISO 10791 consists of the following parts, under the general title *Test conditions for machining centres*:

- *Part 1: Geometric tests for machines with horizontal spindle and with accessory heads (horizontal Z-axis);*
- *Part 2: Geometric tests for machines with vertical spindle or universal heads with vertical primary rotary axis (vertical Z-axis);*
- *Part 3: Geometric tests for machines with integral indexable or continuous universal heads (vertical Z-axis);*
- *Part 4: Accuracy and repeatability of positioning of linear and rotary axes;*
- *Part 5: Accuracy and repeatability of positioning of work-holding pallets;*
- *Part 6: Accuracy of feeds, speeds and interpolations;*
- *Part 7: Accuracy of a finished test piece;*
- *Part 8: Evaluation of the contouring performance in the three coordinate planes;*
- *Part 9: Evaluation of the operating times of tool change and pallet change;*
- *Part 10: Evaluation of the thermal distortions;*
- *Part 11: Evaluation of the noise emission;*
- *Part 12: Evaluation of the vibration severity.*

Annex A, Annex B and Annex C form an integral part of this part of ISO 10791. Annex D is for information only.

Introduction

A machining centre is a numerically controlled machine tool capable of performing multiple machining operations, including milling, boring, drilling and tapping, as well as automatic tool changing from a magazine or similar storage unit in accordance with a machining programme.

The object of ISO 10791 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 10791 specifies, with reference to the relevant parts of ISO 230, *Test code for machine tools*, several families of tests for machining centres with horizontal or vertical spindle or with universal heads of different types, standing alone or integrated in flexible manufacturing systems. ISO 10791 also establishes the tolerances or maximum acceptable values for the test results corresponding to general purpose and normal accuracy machining centres.

ISO 10791 is also applicable, totally or partially, to numerically controlled milling and boring machines, when their configuration, components and movements are compatible with the tests described herein.

1 Scope

This part of ISO 10791 specifies, with reference to ISO 230-1, the geometric tests for machining centres (or numerically controlled milling machines, boring machines, etc., where applicable) with horizontal spindle (i.e. horizontal Z-axis).

This part of ISO 10791 applies to machining centres having basically four numerically controlled axes, of which three are linear (X, Y and Z) up to 2 000 mm in length, and one is rotary (B'), but refers also to supplementary movements, such as those of sliding spindles, rams, or accessory universal heads. Movements other than those mentioned are considered as special features and the relevant tests are not included in this part of ISO 10791.

This part of ISO 10791 takes into consideration, in Annex A, Annex B and Annex C, three possible types of accessory universal heads, described as follows:

- Annex A: 45° split indexable heads, with mechanical indexing of the different angular positions of the two bodies (e.g. Hirth couplings): the relevant tests (AG1 to AG9) check only the resulting position of the spindle;
- Annex B: swivel heads, with two numerically controlled rotary axes perpendicular to each other (tests BG1 to BG7);

— Annex C: 45° split continuous heads, similar to the first type but provided with continuous positioning of the two numerically controlled rotary axes: the relevant tests (CG1 to CG7) check all the geometric features (planes and axes) which contribute to the resulting position of the spindle, excluding the positioning accuracy of the two rotary axes; these tests can also be used for a deeper investigation of the 45° indexable heads, if their movements and locks allow this.

This part of ISO 10791 deals only with the verification of geometric accuracy of the machine and does not apply to the testing of the machine operation, which should generally be checked separately. Certain tests concerning the performance of the machine operating under no-load or finishing conditions are included in other parts of ISO 10791.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 10791. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10791 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

3 Preliminary remarks

3.1 Measuring units

In this part of ISO 10791, 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 arc seconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind:

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

3.2 Reference to ISO 230-1

To apply this part of ISO 10791, 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 4 and Annex A, Annex B and Annex C, the instructions are followed by a reference to the corresponding clause in ISO 230-1 in cases where the test concerned is in compliance with the specifications of that standard.

3.3 Testing sequence

The sequence in which the tests are presented in this part of ISO 10791 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.

3.4 Tests to be performed

When testing a machine, it is not always necessary nor possible to carry out all the tests described in this part of ISO 10791. 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 10791 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.

3.5 Measuring instruments

The measuring instruments indicated in the tests described in clause 4 and Annex A, Annex B and Annex C are examples only. Other instruments measuring the same quantities and having at least the same accuracy may be used. Dial gauges shall have a resolution of 0,001 mm or better.

3.6 Machining tests

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

3.7 Diagrams

In this part of ISO 10791, for reasons of simplicity, the diagrams associated with geometric tests illustrate only one type of machine.

3.8 Pallets

For machines working with several pallets, the tests concerning the intrinsic geometric features or their behaviour in relation to the axes of the machine (tests G15 to G22) are to be performed on only one representative pallet clamped in position, unless otherwise specified by an agreement between the user and the supplier/manufacturer.

3.9 Software compensation

When software facilities are available for compensating certain geometric deviations, based on an agreement between the user and the supplier/manufacturer, the relevant tests may be carried out with or without these compensations. When the software compensation is used, this shall be stated in the test results.

3.10 Machine configurations

The machines considered in this part of ISO 10791 are divided into 12 basic family configurations based on their architecture and the components moving along the linear axes. These families are identified by means of numbers from 01 to 12 as shown in Figure 1. The classification of these configurations is shown in Table 1.

3.11 Designation

A designation is also supplied, as a short code, in order to define the architecture of a machining centre; this designation is given by the following elements, in the given order:

- a) “machining centre”;
- b) the reference of this part of ISO 10791, i.e. ISO 10791-1;
- c) type H for “horizontal spindle type”;
- d) the number indicated in the relevant box of Figure 1 and the left-hand column of Table 1.

EXAMPLE

A machining centre, of the horizontal spindle type, with the column moving along the X-axis, the spindle head slide moving along the Y-axis and the table moving along the Z-axis is designated as follows:

Machining centre ISO 10791-1 type H02

3.12 Minimum tolerance

When establishing the tolerance for a measuring length different from that given in this part of ISO 10791 (see 2.311 of ISO 230-1:1996), it shall be taken into consideration that the minimum value of tolerance is 0,005 mm.

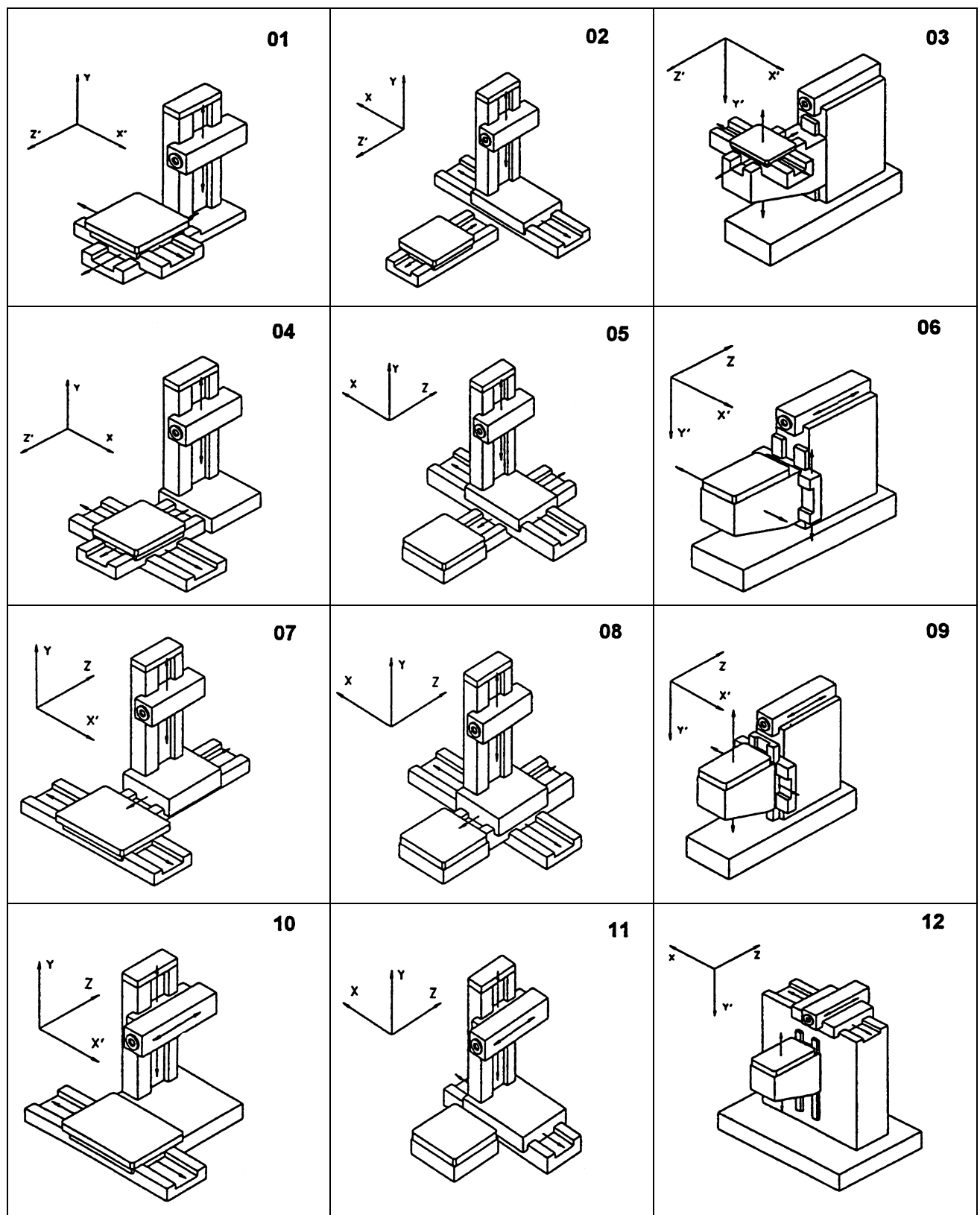


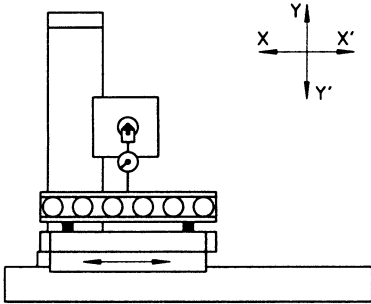
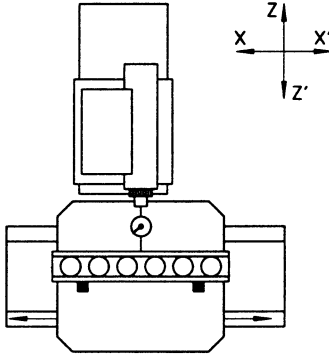
Figure 1

Table 1 — Classification of configurations of horizontal-spindle machining centres

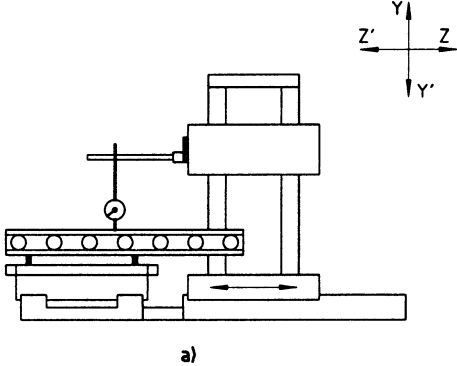
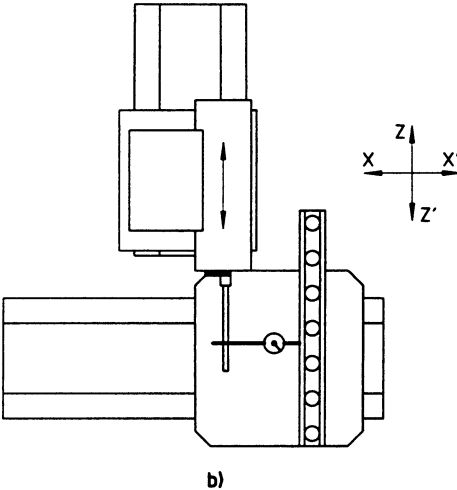
	X	X'	Y	Y'	Z	Z'
01		Table on its saddle	Spindle head			Table saddle
02	Column		Spindle head			Table
03		Table on its saddle		Knee		Table saddle
04		Table saddle	Spindle head			Table on its saddle
05	Column on its saddle		Spindle head		Column saddle	
06		Knee		Knee saddle	Spindle head	
07		Table	Spindle head		Column	
08	Column saddle		Spindle head		Column on its saddle	
09		Knee saddle		Knee	Spindle head	
10		Table	Spindle-head slide		Spindle head on its slide	
11	Column		Spindle-head slide		Spindle head on its slide	
12	Spindle-head slide			Knee	Spindle head on its slide	

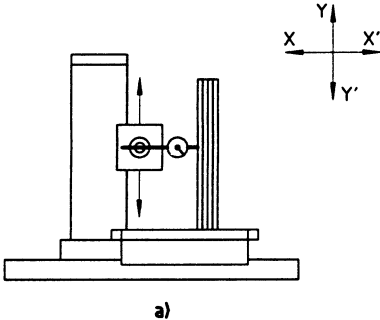
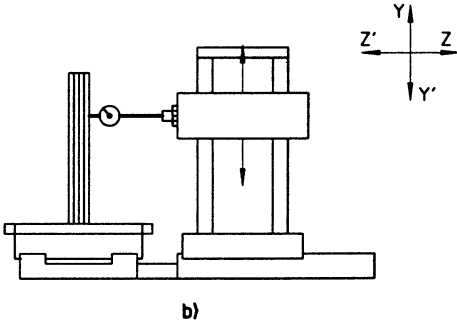
4 Geometric tests

4.1 Straightness of linear motions

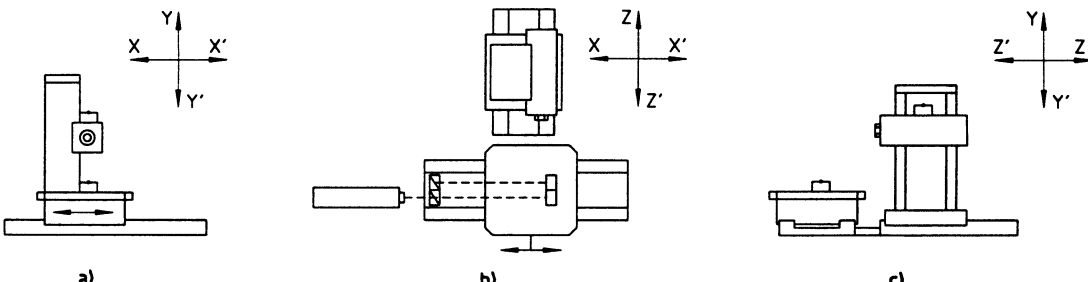
Object Checking of straightness of the X-axis motion: a) in the vertical XY plane (EYX); b) in the horizontal ZX plane (EZX).	G1								
Diagram   a) b)									
Tolerance For a) and b) <table style="margin-left: 40px; margin-top: 20px;"> <tr> <td>$X \leq 500$</td><td>0,010</td></tr> <tr> <td>$500 < X \leq 800$</td><td>0,015</td></tr> <tr> <td>$800 < X \leq 1\,250$</td><td>0,020</td></tr> <tr> <td>$1\,250 < X \leq 2\,000$</td><td>0,025</td></tr> </table> Local tolerance: 0,007 for a measuring length of 300	$X \leq 500$	0,010	$500 < X \leq 800$	0,015	$800 < X \leq 1\,250$	0,020	$1\,250 < X \leq 2\,000$	0,025	Measured deviation for X = ... a) b)
$X \leq 500$	0,010								
$500 < X \leq 800$	0,015								
$800 < X \leq 1\,250$	0,020								
$1\,250 < X \leq 2\,000$	0,025								
Measuring instruments a) Straightedge and dial gauge or optical methods b) Straightedge and dial gauge or microscope and taut wire or optical methods									
Observations and references to ISO 230-1 For all machine configurations, either the straightedge, the taut wire or the straightness reflector shall be placed on the table. If the spindle can be locked, either the dial gauge, the microscope or the interferometer may be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine. The measuring line should pass as close to the centre of the table as possible.									

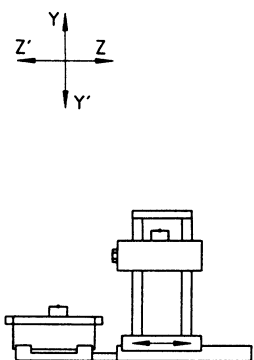
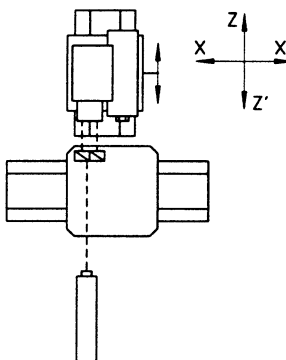
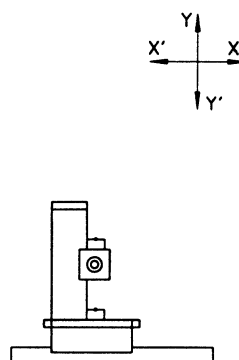
5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1

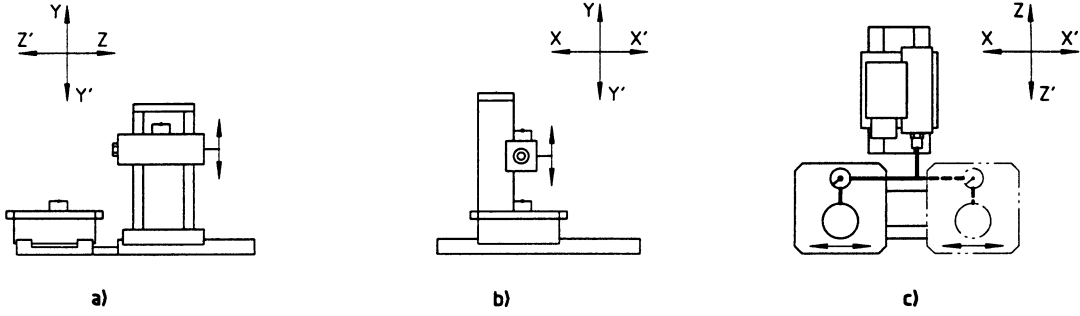
Object	G2								
Checking of straightness of the Z-axis motion: a) in the vertical YZ plane (EYZ); b) in the horizontal ZX plane (EXZ).									
Diagram  									
Tolerance For a) and b) <table border="0" style="margin-left: 40px;"> <tr> <td style="padding-right: 20px;">$Z \leq 500$</td><td>0,010</td></tr> <tr> <td>$500 < Z \leq 800$</td><td>0,015</td></tr> <tr> <td>$800 < Z \leq 1\,250$</td><td>0,020</td></tr> <tr> <td>$1\,250 < Z \leq 2\,000$</td><td>0,025</td></tr> </table> Local tolerance: 0,007 for a measuring length of 300	$Z \leq 500$	0,010	$500 < Z \leq 800$	0,015	$800 < Z \leq 1\,250$	0,020	$1\,250 < Z \leq 2\,000$	0,025	Measured deviation for Z = ... a) b)
$Z \leq 500$	0,010								
$500 < Z \leq 800$	0,015								
$800 < Z \leq 1\,250$	0,020								
$1\,250 < Z \leq 2\,000$	0,025								
Measuring instruments a) Straightedge and dial gauge or optical methods b) Straightedge and dial gauge or microscope and taut wire or optical methods									
Observations and references to ISO 230-1 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1 For all machine configurations, either the straightedge, the taut wire or the straightness reflector shall be placed on the table. If the spindle can be locked, either the dial gauge, the microscope or the interferometer may be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine. The measuring line should pass as close to the centre of the table as possible.									

Object Checking of straightness of the Y-axis motion: a) in the vertical XY plane (EXY); b) in the Vertical YZ plane (EZY).	G3								
Diagram  									
Tolerance For a) and b) <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: right; width: 150px;">$Y \leq 500$</td> <td style="text-align: right;">0,010</td> </tr> <tr> <td style="text-align: right;">$500 < Y \leq 800$</td> <td style="text-align: right;">0,015</td> </tr> <tr> <td style="text-align: right;">$800 < Y \leq 1\,250$</td> <td style="text-align: right;">0,020</td> </tr> <tr> <td style="text-align: right;">$1\,250 < Y \leq 2\,000$</td> <td style="text-align: right;">0,025</td> </tr> </table> Local tolerance: 0,007 for a measuring length of 300	$Y \leq 500$	0,010	$500 < Y \leq 800$	0,015	$800 < Y \leq 1\,250$	0,020	$1\,250 < Y \leq 2\,000$	0,025	Measured deviation for Y = ... a) b)
$Y \leq 500$	0,010								
$500 < Y \leq 800$	0,015								
$800 < Y \leq 1\,250$	0,020								
$1\,250 < Y \leq 2\,000$	0,025								
Measuring instruments For a) and b): Square and dial gauge or microscope and taut wire or optical methods									
Observations and references to ISO 230-1 5.211, 5.23, 5.231.2, 5.232.1 and 5.233.1 For all machine configurations, either the square, the taut wire or the straightness reflector shall be placed as close to the centre of the table as possible. If the spindle can be locked, either the dial gauge, the microscope or the interferometer may be mounted on it; if the spindle cannot be locked, the instrument shall be placed on the spindle head of the machine.									

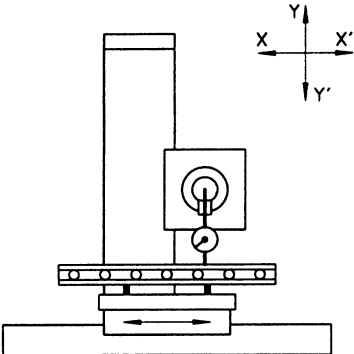
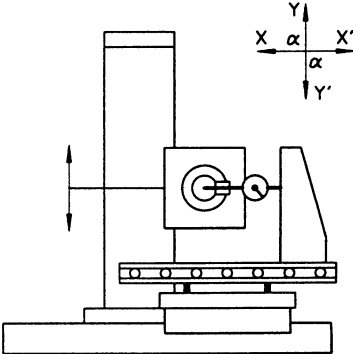
4.2 Angular deviations of linear motions

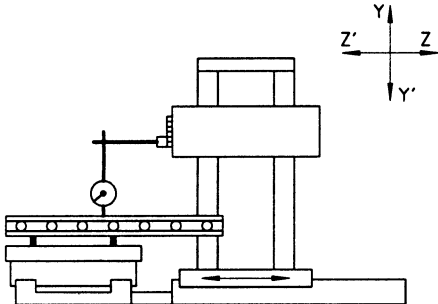
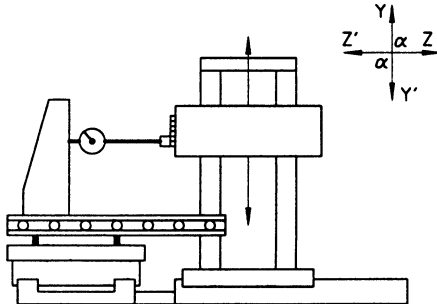
Object		G4
Checking of angular deviations of the X-axis motion: a) in the vertical XY plane perpendicular to the spindle-axis (pitch ECX); b) in the horizontal ZX plane (yaw EBX); c) in the vertical YZ plane parallel to the spindle axis (roll EAX).		
Diagram		
		
Tolerance		Measured deviation
For a), b) and c) 0,060/1 000 (or 60 μ rad or 12'')		a) b) c)
Measuring instruments		
a) (pitch ECX) Precision level or optical angular-deviation measuring instruments b) (yaw EBX) Optical angular-deviation measuring instruments c) (roll EAX) Precision level		
Observations and references to ISO 230-1		5.231.3, 5.232.2 and 5.233.2
The instrument shall be placed on the movable component:		
a) (pitch ECX) longitudinally; b) (yaw EBX) horizontally; c) (roll EAX) transversely.		
When X-axis motion causes an angular movement of both spindle head and workholding table, differential measurements of the two angular movements shall be made and this shall be stated. In this case, when using precision levels for measurement, the reference level shall be located on the non-moving component (spindle head or workholding table) of the machine.		
Measurements shall be taken at least at five positions equally spaced along the travel in both directions of movement at every position. The difference between the maximum and the minimum readings shall not exceed the tolerance.		

Object Checking of angular deviations of the Z-axis motion: a) in the vertical YZ plane parallel to the spindle axis (pitch EAZ); b) in the horizontal ZX plane (yaw EBZ); c) in the vertical XY plane perpendicular to the spindle axis (roll ECZ).	G5
Diagram  a)  b)  c)	
Tolerance For a), b) and c) 0,060/1 000 (or 60 μ rad or 12")	Measured deviation a) b) c)
Measuring instruments a) (pitch EAZ) Precision level or optical angular-deviation measuring instruments b) (yaw EBZ) Optical angular-deviation measuring instruments c) (roll ECZ) Precision level	
Observations and references to ISO 230-1	5.231.3, 5.232.2 and 5.233.2
The instrument shall be placed on the movable component: a) (pitch EAZ) longitudinally; b) (yaw EBZ) horizontally; c) (roll ECZ) transversely. When Z-axis motion causes an angular movement of both spindle head and workholding table, differential measurements of the two angular movements shall be made and this shall be stated. In this case, when using precision levels for measurement, the reference level shall be located on the non-moving component (spindle head or workholding table) of the machine. Measurements shall be taken at least at five positions equally spaced along the travel in both directions of movement at every position. The difference between the maximum and the minimum readings shall not exceed the tolerance.	

Object	G6
Checking of angular deviations of the Y-axis motion: a) in the vertical YZ plane parallel to the spindle axis (EAY); b) in the vertical XY plane perpendicular to the spindle axis (ECY); c) in the horizontal ZX plane (roll EBY).	
Diagram 	
Tolerance For a), b) and c) 0,060/1 000 (or 60 μ rad or 12")	Measured deviation a) b) c)
Measuring instruments a) and b) Precision level or optical angular-deviation measuring instruments c) (roll EBY) Cylindrical square, precision level and dial gauge, or precision cube and dial gauges	
Observations and references to ISO 230-1 5.231.3, 5.232.2 and 5.233.2 Measurements shall be taken at five positions equally spaced along the direction of travel, in both directions of movement and at every position. The difference between the maximum and the minimum readings shall not exceed the tolerance. The instrument shall be placed on the moving component (spindle head or workholding table) a) (pitch, EAZ) longitudinally; b) (yaw, EBZ) horizontally. When Y-axis motion causes an angular movement of both spindle head and workholding table, differential measurements of the two angular movements shall be made and this shall be stated. In this case, when using precision levels for measurement, the reference level shall be located on the non-moving component (spindle head or workholding table) of the machine. For c) (roll, ECZ), place a cylindrical square on the table, approximately parallel to the Y-axis, and set the stylus of a dial gauge mounted on a special arm against the square. Note the readings and mark the corresponding heights on the square. Move the table along the X-axis and move the dial gauge to the other side of the spindle head so that the stylus can touch the square again along the same line. The possible roll deviation of the X-axis motion shall be measured and taken into account. The dial gauge shall be zeroed again and the new measurements shall be taken at the same heights as the previous ones, then noted. For each measurement height, calculate the difference of the two readings. The maximum and the minimum of these differences shall be selected and the result of $\frac{\text{maximum difference} - \text{minimum difference}}{d}$ shall not exceed the tolerance, "d" being the distance between the two positions of the dial gauge.	

4.3 Squareness between linear motions

Object		G7
Checking of squareness between the Y-axis motion and the X-axis motion.		
Diagram		
 Step 1)  Step 2)		
Tolerance		Measured deviation
0,02 for a measuring length of 500		
Measuring instruments		
Straightedge or surface plate, square and dial gauge		
Observations and references to ISO 230-1 5.522.4		
In Step 1), the straightedge or the surface plate shall be set parallel to the X-axis.		
In Step 2), the Y-axis shall then be checked by means of a square standing on the straightedge or on the surface plate.		
If the spindle can be locked, the dial gauge may be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine.		
The value of angle α , being less than, equal to or greater than 90° , should be noted for information and possible corrections.		

Object Checking of squareness between the Y-axis motion and the Z-axis motion.	G8
Diagram  Step 1)  Step 2)	
Tolerance 0,02 for a measuring length of 500	Measured deviation
Measuring instruments Straightedge or surface plate, square and dial gauge	
Observations and references to ISO 230-1 5.522.4 In Step 1), the straightedge or the surface plate shall be set parallel to the Z-axis. In Step 2), the Y-axis shall then be checked by means of a square standing on the straightedge or on the surface plate. If the spindle can be locked, the dial gauge may be mounted on it; if the spindle cannot be locked, the dial gauge shall be placed on the spindle head of the machine. The value of angle α , being less than, equal to or greater than 90° , should be noted for information and possible corrections.	