INTERNATIONAL STANDARD

ISO 10791-6

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Test conditions for machining centres — Part 6: Accuracy of feeds, speeds and interpolations

Conditions d'essai pour centres d'usinage —

Partie 6: Précision des avances, vitesses et interpolations

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.

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 10791-6 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 of this part of ISO 10791 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.

Test conditions for machining centres — Part 6: Accuracy of feeds, speeds and interpolations

1 Scope

This part of ISO 10791 specifies, with reference to ISO 230-1, certain kinematic tests for machining centres, concerning the spindle speeds, the feeds of the individual NC linear axes and the accuracy of the paths described by the simultaneous movement of two or more NC linear and/or rotary axes (see clause 4).

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10791. At the time of publication, the editions indicated were 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 editions of the standards 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.*

ISO 230-4:1996, *Test code for machine tools — Part 4: Circular tests for numerically controlled machine tools*.

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 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:

$$0{,}010/1\,000 = 10 \times 10^{-6} = 10\ \mu\text{rad} \approx 2''$$

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 parts, description of measuring methods and recommended accuracy of testing equipment.

3.3 Testing sequence

The sequence in which the kinematic 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 applied 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 as well as the batch size to be used as a sample for the accuracy test 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 relevant sections are examples only. Other instruments measuring the same quantities and having at least the same accuracy and the same resolution may be used. Dial gauges shall have a resolution of 0,001 mm.

3.6 Diagrams

For reasons of simplicity, the diagrams in this part of ISO 10791 illustrate only some types of machines.

4 Kinematic tests

4.1 Speeds (K 1) and feeds (K 2)

The scope of these tests is to check the overall accuracy of all the electric, electronic and kinematic chain in the control system between the command on the keyboard and the physical movement of the component.

4.2 Linear interpolation (K 3)

The scope of this test is to check the coordinated motion of two linear axes while they are moving at the same feed rate (45° angle) and to check the behaviour of each one of them at very low feed rate (small angles), with the possible stick-slip motion.

4.3 Circular interpolation (K 4)

The scope of this test is to check the coordinated motion of two linear axes (generally X and Y) at variable feed rates, including points in which the feed of one axis slows down to zero and the direction of movement is reversed.

4.4 Angular interpolation (K 5)

The scope of this test, applicable to the 45° split universal heads, is to check the accuracy of a particular type of interpolation of the two rotary axes which allows, rotating axis D through 180° and axis B through 90°, to move the spindle from a vertical to a horizontal position, and/or vice versa, keeping it always parallel to the same plane.

If the structure of the head allows it, the extension of the test may be doubled, bringing the angle described by the spindle axis in a vertical (or even horizontal) plane to 180°.

4.5 Spherical interpolation of five axes (K 6)

The scope of this test, applicable to universal heads with two rotary axes (which can be perpendicular to each other or at 45°), is to check the accuracy of circular paths described by the spindle nose on the surface of a sphere to which it is kept perpendicular.

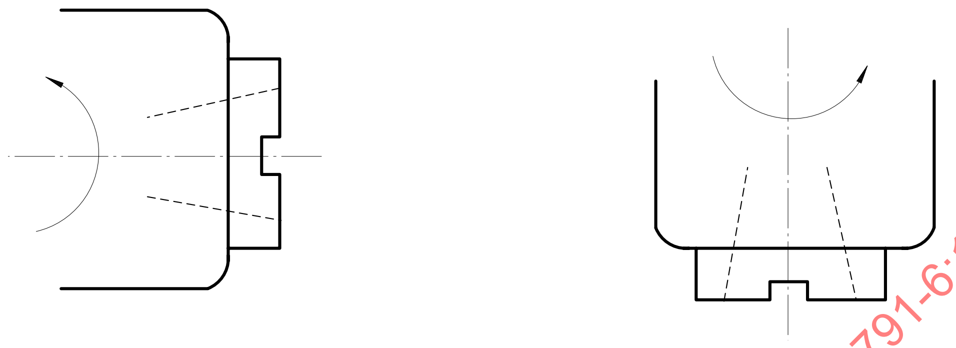
The test considered hereafter is limited to the upper front spherical octants, and involves the simultaneous movement of three axes at a time. It can anyway be extended to longer or differently oriented arcs and to different octants depending on the architecture of the machine and of the head.

K 1

Object

Checking of deviations in the spindle speed at 50 % and 100 % of the maximum speed of each range, clockwise and counter-clockwise directions of rotation.

Diagram



Tolerance

± 5 %

Measured deviation

Speed range	Direction of rotation	Programmed speed	Actual speed	Deviation %
	Counter-clockwise			
	Clockwise			
	Counter-clockwise			
	Clockwise			
	Counter-clockwise			
	Clockwise			
	Counter-clockwise			
	Clockwise			

Measuring instruments

Revolutions counter or stroboscope or others

Observations

If the instantaneous speed is read, five readings shall be taken and the average calculated. Readings shall be taken at constant speed, avoiding the acceleration/deceleration at start and stop. The override control shall be set at 100 %.

The spindle speed deviation shall be calculated using the following formula:

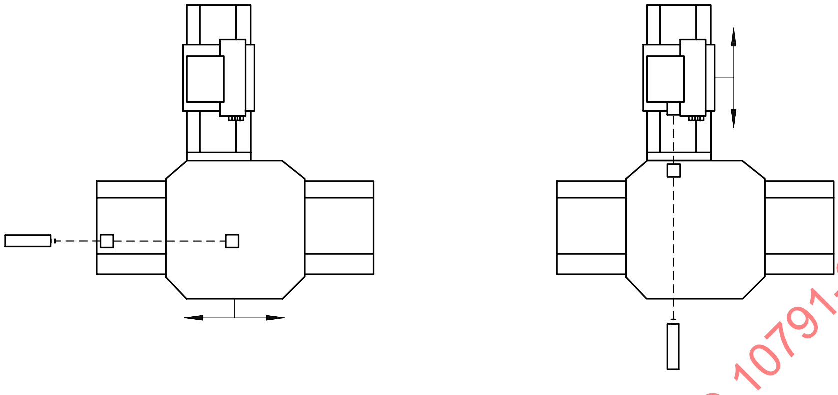
$$\%\ \text{deviation} = \frac{\text{actual speed} - \text{programmed speed}}{\text{programmed speed}} \times 100$$

Object

K 2

Checking of accuracy of the feed rate of the linear axes at the following feed rates:
a) 100 mm/min; b) 1 000 mm/min; c) maximum feed rate; d) rapid traverse.

Diagram



Tolerance

5 %

Measured deviation

Programmed feed rate	Direction	Axis X Actual feed	Axis X Deviation %	Axis Y Actual feed	Axis Y Deviation %	Axis Z Actual feed	Axis Z Deviation %	
100 mm/min	Positive							
	Negative							
1 000 mm/min	Positive							
	Negative							
Maximum feed rate .... mm/min	Positive							
	Negative							
Rapid traverse .... mm/min	Positive							
	Negative							

Measuring instruments

Laser interferometer or stopwatch

Observations

If a laser interferometer is used, which reads the instantaneous velocity, five readings shall be taken along the travel and the average calculated

If a stopwatch is used, the time shall be measured over a measuring length shorter than the programmed travel, in order to avoid the acceleration/deceleration at both ends.

The override control shall be set at 100 %.

The feed rate deviation shall be calculated using the following formula:

$$\% \text{ deviation} = \frac{\text{actual feed rate} - \text{programmed feed rate}}{\text{programmed feed rate}} \times 100$$

Object

K 3

Checking of accuracy of the path described by linear interpolation of two linear axes, over a measuring length of 100 mm to 300 mm.

Horizontal machining centres:

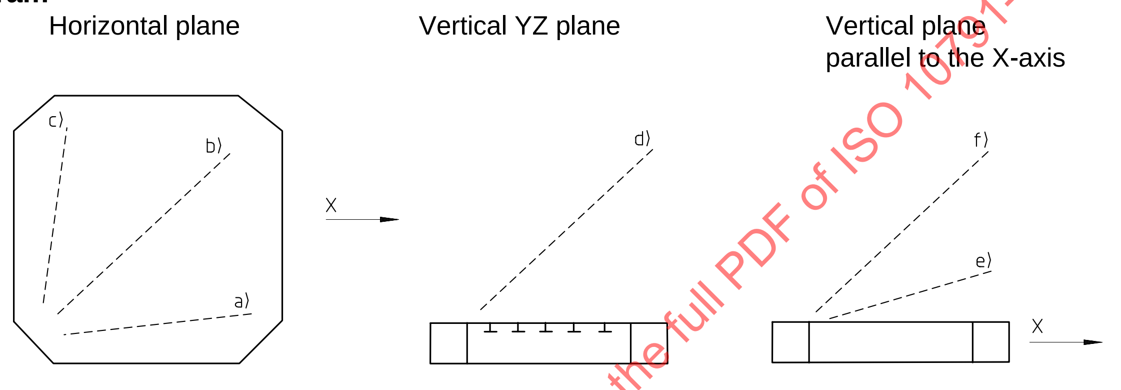
a) $\frac{dZ}{dX} = 0{,}05$; b) $\frac{dZ}{dX} = 1$; c) $\frac{dX}{dZ} = 0{,}05$; d) $\frac{dY}{dZ} = 1$; e) $\frac{dY}{dX} = 0{,}05$; f) $\frac{dY}{dX} = 1$.

Vertical machining centres:

a) $\frac{dY}{dX} = 0{,}05$; b) $\frac{dY}{dX} = 1$; c) $\frac{dX}{dY} = 0{,}05$; d) $\frac{dZ}{dY} = 1$; e) $\frac{dZ}{dX} = 0{,}05$; f) $\frac{dZ}{dX} = 1$.

Instead of an angle equal to arctan 0,05 (= 2° 51' 45"), an angle of 3° may be chosen, depending on the programming facilities.

Diagram



Tolerance

0,020 for any length of 100

Measured deviation

Length ..... mm

a) b) c) d) e) f)

Measuring instruments

Straightedge or sine bar and dial gauge or electronic probe with graphic recorder

Observations

The measuring length shall be approximately in the middle of the table.

After choosing the angle and the length of travel, place a dial gauge[1)] on the spindle, if it can be locked, otherwise on the spindle head, reasonably perpendicular to the direction of movement.

Place the straightedge or the sine bar against the dial gauge and adjust its direction.

Then move the axes along the programmed path in both directions, with a feed rate of 250 mm/min, reversing the direction outside the measuring length, and note the difference between the maximum and the minimum reading separately for each direction.

The larger deviation and its direction shall be recorded.

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1) When possible, the use of an electronic probe connected with a graphic recorder is recommended, in order to have a hard copy of the measurement, which is easier to read.

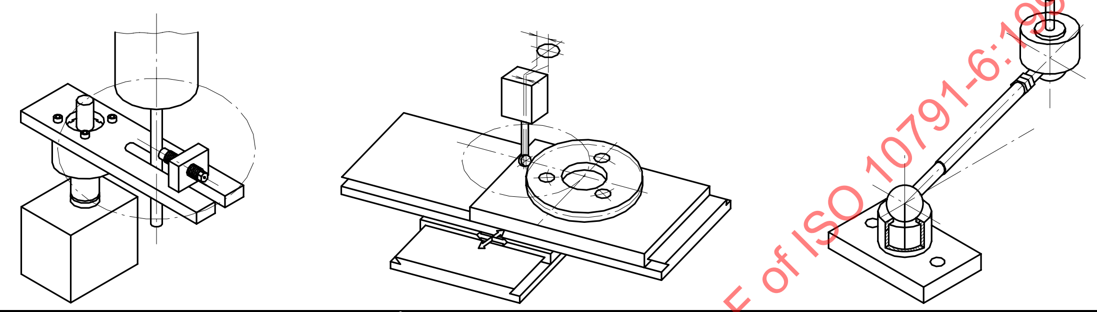
Object — **K 4**

Checking the circular deviation *G* and the circular hysteresis *H* of the path generated by circular interpolation of two linear axes (generally in the XY plane) over 360°, according to ISO 230-4, at one of the following diameters and at two feed rates, as follows:

1) 40 mm diameter	2) 80 mm diameter	3) 160 mm diameter	4) 320 mm diameter
a) 100 mm/min	a) 140 mm/min	a) 200 mm/min	a) 280 mm/min
b) 250 mm/min	b) 350 mm/min	b) 500 mm/min	b) 700 mm/min

The circular deviation *G* shall be checked for clockwise and counter-clockwise contouring motion.

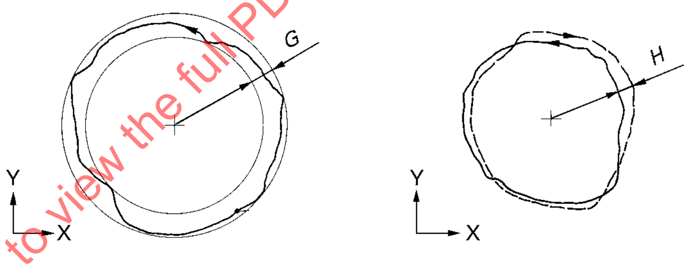
Diagram



Tolerance

a) G_{XY} = 0,03 mm
G_{YX} = 0,03 mm
H_{XY} = 0,02 mm

b) G_{XY} = 0,05 mm
G_{YX} = 0,05 mm
H_{XY} = 0,04 mm



Measured deviation

a) feed rate = ...
G_{XY} = ...
G_{YX} = ...
H_{XY} = ...

b) feed rate = ...
G_{XY} = ...
G_{YX} = ...
H_{XY} = ...

diameter of nominal path ....
location of measuring instrument
— centre of circle (X/Y/Z) ....
— offset to tool reference (X/Y/Z) ....
— offset to workpiece reference (X/Y/Z) ....
data acquisition method
— starting point ....
— number of measuring points ....
— data smoothing process ....
compensation used ....
positions of axes not under test ....

Measuring instruments

Test mandrel, special rotary fixture and electronic probe, or circular masterpiece and bidimensional probe, or telescopic ball bar

References and observations

Diameters may differ from the above values by a maximum of 25 %. In such cases, the feed rate has to be adjusted according to annex C of ISO 230-4:1996.

Zero the axes in a position in which the test mandrel is on the axis of rotation of the rotary fixture or the bidimensional probe is in the centre of the masterpiece.

Start the interpolation in one of the four quadrants, possibly not in one of the four reversal points, in order not to miss the performance of the machine at those points.

When using the rotary fixture, if a deviation appears on the graph, whose wavelength is 360°, the fixture position shall be better adjusted or, vice versa, the axes shall be reset in a better position.

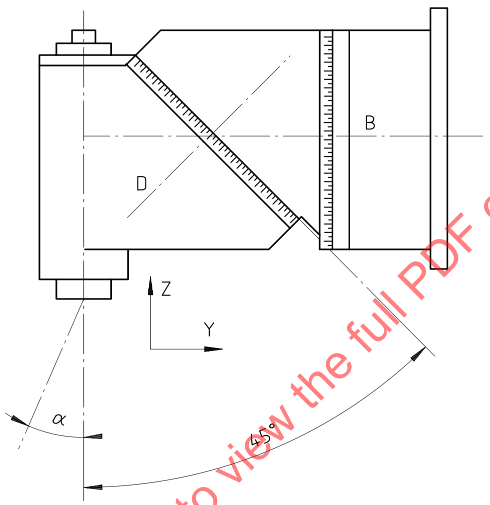
Object | **K 5**

Checking of parallelism between the spindle axis and the vertical YZ plane in four positions of the path described by angular interpolation of two axes, according to the following formula:

$$\tan B = \frac{\sqrt{2}\sin D}{1 + \cos D}$$

a)	b)	c)	d)
$B = 0°$	$B = 54° 44' 8''$	$B = 74° 27' 28''$	$B = 90°$
$D = 0°$	$D = 90°$	$D = 137° 3' 31''$	$D = 180°$
$\alpha = 0°$	$\alpha = 30°$	$\alpha = 60°$	$\alpha = 90°$

Diagram



Tolerance

To be agreed between the supplier/manufacturer and the user.

a) b) c) d)

Measured deviation

a) b) c) d)

Measuring instruments

Test mandrel and dial gauge

References and observations

X axis locked during the measurements, if possible.

Check a) before starting the movement, with two readings, respectively close to the spindle nose and at a distance of 300 mm, rotating manually the spindle so as to minimize the contribution of the run-out.

Mark the angular position on the mandrel.

Then start the movement and stop at the programmed positions.

In any of the b), c) and d) positions touch the test mandrel close to the spindle nose in the same point previously marked. Lock the X-axis, if possible, and zero the dial gauge. Moving Y- and Z-axes only, touch the test mandrel at 300 mm from the spindle nose and note the deviation.