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Test conditions for machining centres —

Part 6: Accuracy of speeds and interpolations

Conditions d'essai pour centres d'usinage —

Partie 6: Précision des vitesses et interpolations

[Revision of first edition (ISO 10791-6:1998) and ISO 10791-6:1998/Cor.1:2004]

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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ISO 10791-6 was prepared by Technical Committee ISO/TC 39, *Machine Tools*, Subcommittee SC 2, *Test conditions for machine tools*.

This second edition cancels and replaces the first edition which has been technically revised.

ISO 10791 consists of the following parts, under the general title *Machine Tools — 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 speeds and interpolations*
- *Part 7: Accuracy of a finished test piece*
- *Part 8: Evaluation of contouring performance in the three coordinate planes*
- *Part 9: Evaluation of the operating times of tool change and pallet change*
- *Part 10: Evaluation of thermal distortions*

Normative Annexes A, B, and C form an integral part of this part of ISO 10791. Annex D is informative.

Introduction

This International Standard is one of the series of parts of ISO 10791 concerned with methods of testing machining centres.

A machining centre is a numerically controlled machine tool capable of performing multiple machining operations, including milling, boring 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. 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.

In five-axis machining centres having three orthogonal linear axes and two rotary axes, there are such types as machines with two rotary axes in the spindle head (see Annex A), machines with tilting rotary table (see Annex B), and machines with a swivel head and a rotary table (see Annex C).

The annexes of this international standard specify the kinematic tests for five-axis machining centres.

Test conditions for machining centres —

Part 6: Accuracy of speeds and interpolations

1 Scope

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

This part of ISO 10791 applies to machining centres having three linear axes (X, Y and Z) up to 5 000 mm and additionally one or two rotary axes (A, B or C). 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 deals only with the verification of kinematic accuracy of the machine and does not apply to the testing of the machine operation, which should generally be checked separately.

The tests described in this part of ISO 10791 are also applicable, totally or partially, subject to specific agreement between manufacturer/supplier and user, to numerically controlled milling and boring machines, when their configuration, components and movements are compatible with the tests described herein.

2 Normative references

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

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

ISO 230-4:2005, *Test code for machine tools — Part 4: Circular tests for numerically controlled machine tools*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 230-1, ISO 230-4, ISO 230-7, ISO 841 and the following apply.

3.1 linear interpolation

an interpolation where relative motion between tool side and workpiece side of the machine tool is a straight line obtained by controlling multiple axes simultaneously

¹ Revision of ISO 230-1:1996, under preparation.

3.2**circular interpolation**

an interpolation where relative motion between tool side and workpiece side of the machine tool is a circular arc in a specific plane obtained by controlling multiple axes simultaneously

3.3**Tool Centre Point control function**

TCP control function

an advanced CNC control function that drives the linear axes of a numerically controlled machine tool, in order to maintain constant tool centre point coordinates, in the workpiece coordinate system, in response to instantaneous position variation of rotary axes

4 Preliminary remarks**4.1 Measurement 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 (e.g. 0,00x/1 000) as the primary method, but in some cases microradians or arcseconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind:

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

4.2 Reference to ISO 230

To apply this International Standard, 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. Circular interpolation motions shall be referred to ISO 230-4.

4.3 Testing sequence

The sequence in which the tests are presented in this International Standard in no way defines the practical order of testing. In order to make the mounting of instruments or gauging easier, tests may be performed in any order.

4.4 Tests to be performed

When testing a machine, it is not always necessary or possible to carry out all the tests described in this International Standard. 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. The mere reference to this International Standard for the acceptance tests, without specifying the tests to be carried out, and without agreement on the relevant expenses, can not be considered as binding for any contracting party.

4.5 Measuring instruments

The measuring instruments indicated in the tests described in Clause 5 and in Annexes A, B and C are examples only. Other instruments measuring the same quantities and having the same or smaller measurement uncertainty may be used. Linear displacement sensors shall have a resolution of 0,001 mm or better.

4.6 Diagrams

For reasons of simplicity, the diagrams in this part of ISO 10791 illustrate only one type of machines in each annex.

4.7 Position of axes not under test

Linear and/or rotary axes which are not relating with the test, should be located nearest to the middle of their working travel, or in the position that will minimize deflections of the machine components affecting the measurement.

4.8 Software compensation

When software facilities are available for compensating some geometric errors, based on an agreement between the manufacturer/supplier and user, the relevant test may be carried out with these compensations. When the software compensation is used, this shall be stated in the test report.

5 Kinematic tests

5.1 General

The scope of spindle speed tests (K1) and feed speed tests (K2) is to check the overall accuracy of all the electric, electronic and kinematic chain in the control system between the command and the physical movement of the component.

The purpose of linear interpolation motion tests (K3) is to check the coordinated motion of two linear axes in the following two conditions:

- While these axes are moving either at the same speed (45°) or
- While one of these axes is moving at a significantly lower speed than the other (small angles).

The purpose of circular interpolation motion tests (K4) is to check the coordinated motion of two linear axes along a circular path, including points in which the motion of one axis slows down to zero and the direction of movement is reversed. During these tests, axes will move with variable speeds.

The test for checking circular interpolation involving more than two linear axes, including rotary axes, are described in Annexes A, B, and C.

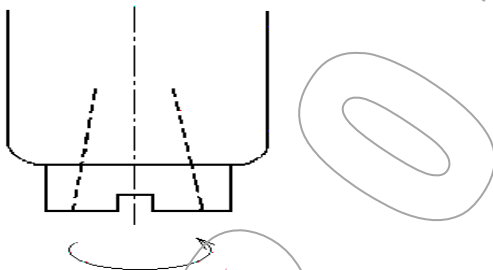
Tests described in Annexes A to C:

In Annex A, AK1 measures the deviations of the tool centre point trajectory with the rotation of B-axis. AK2 measures them with the rotation of C-axis. AK3 and AK4 measure them with the simultaneous interpolation with both B- and C-axes. Similarly, in all of Annexes A to C, each test describes a test for each rotary axis or the combination of two rotary axes.

Alternative tests in Annexes A and C:

In Annex A, AK1, AK2, and AK4 measure the deviations of the tool centre point trajectory in the workpiece coordinate system (the coordinate system attached to the work table). On the other hand, their alternative tests (AK1(alternative), AK2(alternative), and AK4(alternative)) measure them in radial, parallel, and tangential directions of the rotary axis of interest. In other words, these alternative tests measure the deviations in the coordinate system attached to the rotary axis of interest. Tests CK1 and CK1 (alternative) follow the same principle.

5.2 Spindle speeds and feeds

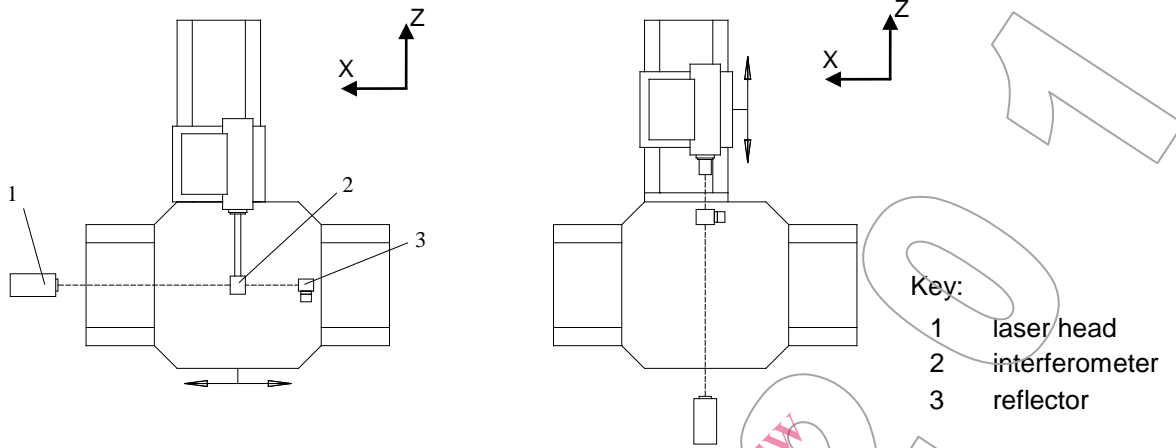
<p>Object and test conditions</p> <p>Checking the deviations in the spindle speed at the mid point and at the maximum of each speed range for clockwise and counter-clockwise directions of rotation. This test shall be carried out for each speed range, where applicable.</p>	<p>K1</p>																																							
<p>Diagram</p> <div style="text-align: center;">  <p>The diagram shows a cross-section of a spindle with a tool bit. A vertical dashed line indicates the axis of rotation. Two curved arrows, one pointing clockwise and one counter-clockwise, indicate the directions of rotation. A large '0' is drawn next to the diagram.</p> </div>																																								
<p>Tolerance</p> <p style="text-align: center;">±5 %</p>																																								
<p>Measured deviations</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 15%;">Speed range</th> <th style="width: 20%;">Direction of rotation</th> <th style="width: 25%;">Programmed speed</th> <th style="width: 20%;">Actual speed</th> <th style="width: 20%;">Deviation %</th> </tr> </thead> <tbody> <tr> <td rowspan="4"></td> <td>counter-clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td>clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td>counter-clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td>clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td rowspan="4"></td> <td>counter-clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td>clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td>counter-clockwise</td> <td></td> <td></td> <td></td> </tr> <tr> <td>clockwise</td> <td></td> <td></td> <td></td> </tr> </tbody> </table>		Speed range	Direction of rotation	Programmed speed	Actual speed	Deviation %		counter-clockwise				clockwise				counter-clockwise				clockwise					counter-clockwise				clockwise				counter-clockwise				clockwise			
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<p>Measuring instruments</p> <p>Revolutions counter or stroboscope or others</p>																																								
<p>Observations</p> <p>A dummy tool may be clamped in the spindle.</p> <p>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 %.</p> <p>The spindle speed deviation shall be calculated using the following formula:</p> $D = \frac{A_s - P_s}{P_s} \times 100$ <p>where D is the deviation %, A_s is the actual speed in min^{-1}, and P_s is the programmed speed in min^{-1}</p>																																								

Object and test conditions

K2

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

Diagram



Tolerance

±5 %

Measured deviations

Programmed feed speed	Direction	Axis					
		X		Y		Z	
		Measured avg feed speed	Deviation%	Measured avg feed speed	Deviation%	Measured avg feed speed	Deviation %
a) 100 mm/min	Forward						
	Backward						
b) 1 000 mm/min	Forward						
	Backward						
c) Max. feed speedmm/min	Forward						
	Backward						
d) Rapid traversemm/min	Forward						
	Backward						

Measuring instruments

Laser interferometer

Observations

Align the laser interferometer (setup for positioning deviation) with the motion of the axis under test. Axis shall be commanded to execute a simple motion with two end points specified. Travel distance of about half the axis travel range (or 500 mm whichever is shorter) to allow the axis to accelerate, then move at constant speed, and then to decelerate to stop shall be selected. Same travel distance shall be used for all feed speeds. The tests shall be carried out for both directions of travel (forward and backward). Speed data should be sampled with a minimum frequency of 100 Hz, no smoothing or averaging shall be allowed. The override control shall be set at 100 %. For each direction, calculate the average feed speed as the average of all measured constant feed speed values (minimum 1 000 sampled points) for a given test.

The feed speed deviations shall be calculated using the following formula:

$$D_f = \frac{A_f - P_f}{P_f} \times 100$$

where D_f is the deviation %, A_f is the measured average feed speed in mm/min, and P_f is the programmed feed speed in mm/min