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Test conditions for machining centres —

Part 10: Evaluation of thermal distortions

Conditions d'essai des centres d'usinage —

Partie 10: Évaluation des déformations thermiques

Reference number
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Foreword

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

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

ISO 10791-10 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 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*

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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. Most machining centres have facilities for automatically changing the direction in which the workpieces are presented to the tool.

The purpose of ISO 10791 is to supply information as wide and comprehensive as possible on tests and checks which can be carried out for comparison, acceptance, maintenance or any other purpose.

ISO 10791 specifies, by 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.

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Test conditions for machining centres —

Part 10:
Evaluation of thermal distortions

1 Scope

This part of ISO 10791 specifies, with reference to ISO 230-3, tests for the evaluation of thermal distortions of the machine structure and positioning system, up to 2 000 mm in length, of machining centres. It gives three test methods:

— environmental temperature variation error;

— thermal distortion caused by a rotating spindle;

— thermal distortion caused by moving linear axes.

There is no intention of assigning any numerical tolerances associated with the tests specified.

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 230-3:2007, *Test code for machine tools — Part 3: Determination of thermal effects*

3 Preliminary remarks

3.1 Measuring units

In this part of ISO 10791, all linear dimensions and deviations are expressed in millimetres. All angular dimensions are expressed in degrees. Angular deviations are, in principle, expressed in ratios; however, in some cases, microradians or arcseconds may be used for classification purposes. The equivalent of the following expressions should always be kept in mind:

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

The temperatures are expressed in degrees Celsius (°C).

3.2 Reference to ISO 230

For the application of this part of ISO 10791, reference shall be made to ISO 230-3, especially for the installation of the machine before testing, description of measuring methods and presentation of the results.

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3.3 Measuring instruments

The measuring instruments recommended in this document are given only by way of examples. Other measuring instruments capable of measuring the same quantities and having the same or a smaller measurement uncertainty may be used.

3.4 Testing sequence

The tests given in this part of ISO 10791 may be used either singularly or in any combination. Before each test, the machine tool should be in equilibrium with the environment. Therefore, a sufficient cooling down period between tests, generally at least as long as the thermal test, where parts of the machine have been heated, shall be planned and respected.

3.5 Tests to be performed

When testing a machine, it is not always necessary or even possible to carry out all the tests given in this part of ISO 10791. When the tests are required for acceptance purposes, it is at the option of the user to choose, in agreement with the supplier/manufacturer, those tests relating to the components and/or the properties of the machine that 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 specification of the tests to be carried out, and without agreement on the relevant expenses, cannot be considered as binding for any contracting party.

4 Environmental temperature variation error (ETVE) test

4.1 General

ETVE tests are designed to reveal the effects of environmental temperature changes on the machine with respect to deflection or deformation of the machine or its parts. They shall not be used for machine comparison.

It is recommended that the supplier/manufacturer offer guidelines regarding the kind of thermal environment that should be acceptable for the machine to perform with the specified accuracy. It shall be the responsibility of the user to provide an acceptable thermal environment for the operation. However, if the user follows the guidelines provided by the machine supplier/manufacturer, the responsibility for machine performance according to the specification reverts to the machine supplier/manufacturer.

4.2 Test method

The test method shall be in accordance with ISO 230-3:2007, 5.2. Figure 1 shows a typical test set-up.

Axes might warm up when under NC “HOLD” mode, especially if they are in vertical direction. In such cases, it is recommended that the ETVE test be carried out with all controls on “OFF”. This shall be stated in the test report.

4.3 Measuring instruments

For this test, the required measuring instruments are the following:

— linear displacement sensors;

— temperature sensors;

— test mandrel;

— data acquisition equipment.

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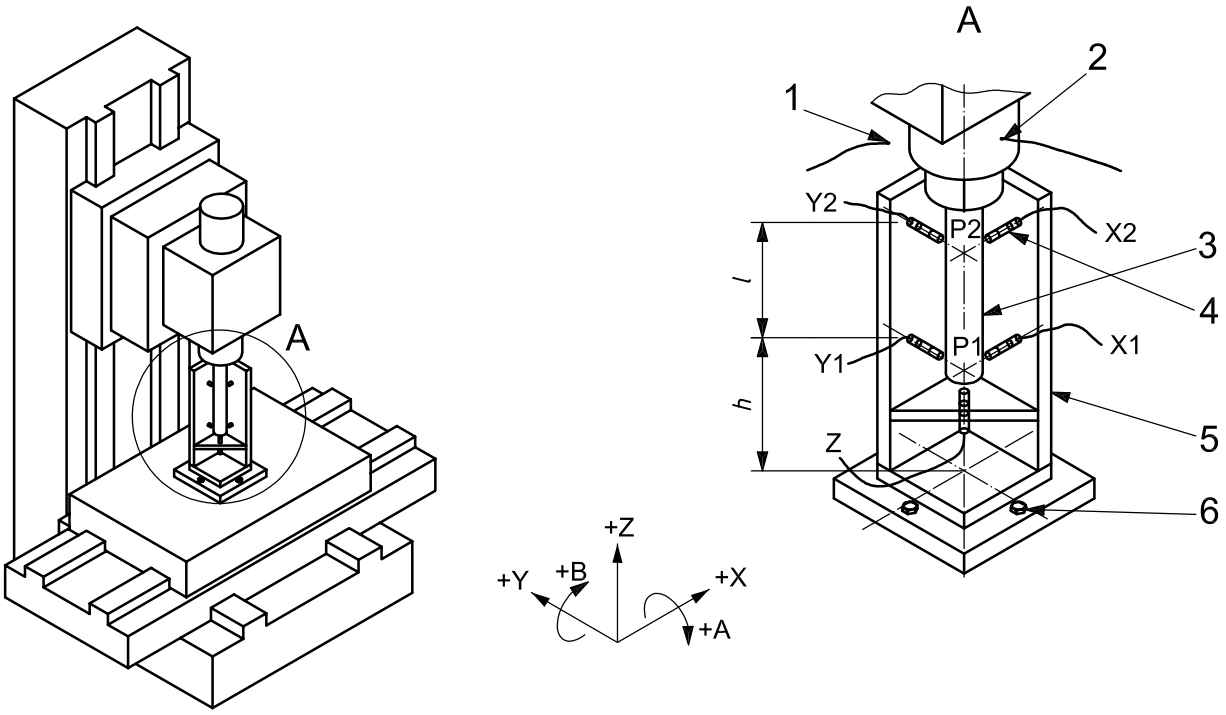

Key

X1, X2, Y1, Y2, Z linear displacement sensors

1 ambient air temperature sensor

2 spindle bearing temperature sensor

3 test mandrel

4 linear displacement sensors

5 fixture

6 fixture bolted to table

Figure 1 — Typical set-up for ETVE and thermal distortion caused by rotating spindle tests

4.4 Presentation of results

Table 1 provides an example format for the presentation of the results; in addition, a graphical presentation of results should be provided in accordance with ISO 230-3:2007, 5.4.

Table 1 — Format for presentation of ETVE results

Parameter		Results
Time	min	
$ETVE_X$	mm	
$ETVE_Y$	mm	
$ETVE_Z$	mm	
$ETVE_A$	arcsec	
$ETVE_B$	arcsec	

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4.5 Information to be recorded

The following information shall be recorded:

a) machine brand and model name;

b) year of construction of machine, if available;

c) machine serial number;

d) time and date of test;

e) location of the measurement set-up;

f) location of temperature sensors;

g) type of sensors;

h) design and material of the test mandrel and fixture;

i) thermal compensation procedure;

j) any special test procedures;

k) machine preparation procedure prior to testing;

l) control ON or OFF;

m) positive direction of drift (if different from coordinate system).

5 Thermal distortion caused by rotating spindles

5.1 Requirement

One test per spindle shall be carried out.

5.2 Test method

The test method shall be in accordance with of ISO 230-3:2007, 6.2. Figure 1 shows a typical test set-up. User and manufacturer/supplier shall agree as to whether a constant spindle speed or a variable speed spectrum is used. For the case of constant spindle speed, they also shall agree on the spindle speed to be used. For the variable speed spectrum, they shall agree on the spindle speeds and time interval durations.

NOTE A possible speed spectrum cycle would be a percentage of the maximum spindle speed for a set time, followed by a spindle stop for another fixed time (e.g. 70 % maximum spindle speed for 3 min, followed by a 1 min stop). This cycle would then be repeated for the complete test duration. The exact details of the speed spectrum would need to be discussed between the user and manufacturer/supplier.

The test shall last for 4 h plus 1 h with the spindle stopped.

5.3 Measuring instruments

For this test, the required measuring instruments are the following:

— linear displacement sensors;

— temperature sensors;

— test mandrel;

— data acquisition equipment.

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5.4 Presentation of results

Table 2 provides an example of the format for the presentation of the results; in addition, a graphical presentation of results should be provided, in accordance with ISO 230-3:2007, 6.4.

Table 2 — Format for presentation of results of thermal effects caused by rotating spindle C

	X1 mm	**Y1** mm	**Z** mm	**A** arcsec	**B** arcsec
During first 60 mm	$d\,(\mathrm{EXC})_{\mathrm{P,60}} = ...$	$d\,(\mathrm{EYC})_{\mathrm{P,60}} = ...$	$d\,(\mathrm{EZC})_{60} = ...$	$d\,(\mathrm{EAC})_{60} = ...$	$d\,(\mathrm{EBC})_{60} = ...$
After end of period $t = ...$	$d\,(\mathrm{EXC})_{\mathrm{P1},t} = ...$	$d\,(\mathrm{EYC})_{\mathrm{P1},t} = ...$	$d\,(\mathrm{EZC})_{t} = ...$	$d\,(\mathrm{EAC})_{t} = ...$	$d\,(\mathrm{EBC})_{t} = ...$
Distance, $l = ...$					

5.5 Information to be recorded

The following information shall be recorded:

a) machine brand and model name;

b) year of construction, if available;

c) machine serial number;

d) time and date of test;

e) location of the measurement set-up;

f) location of temperature sensors;

g) type of sensors;

h) design and material of the test mandrel and fixture;

i) thermal compensation procedure;

j) any special test procedures;

k) machine preparation procedure prior to testing.

l) spindle speed regime;

m) positive direction of drift (if different from coordinate system);

n) relative position of the spindle during measurement.

6 Thermal distortion caused by linear motion of components

6.1 Test method

The test method shall be in accordance with ISO 230-3:2007, 7.2. Figure 2 shows a typical test set-up.

In practice, there should be different feedrates for principal and for auxiliary axes.

EXAMPLE A feedrate set for principal axes at 50 %, and one for auxiliary axes set at 20 %, of f_{max}.

The test cycle shall be made up of two time periods: 4 h of warming up the axis and 1 h for cooling it down. The measurements shall be interrupted when the distortion change noted during the final 60 min is less than 15 % of the distortion registered over the initial 60 min of the test.

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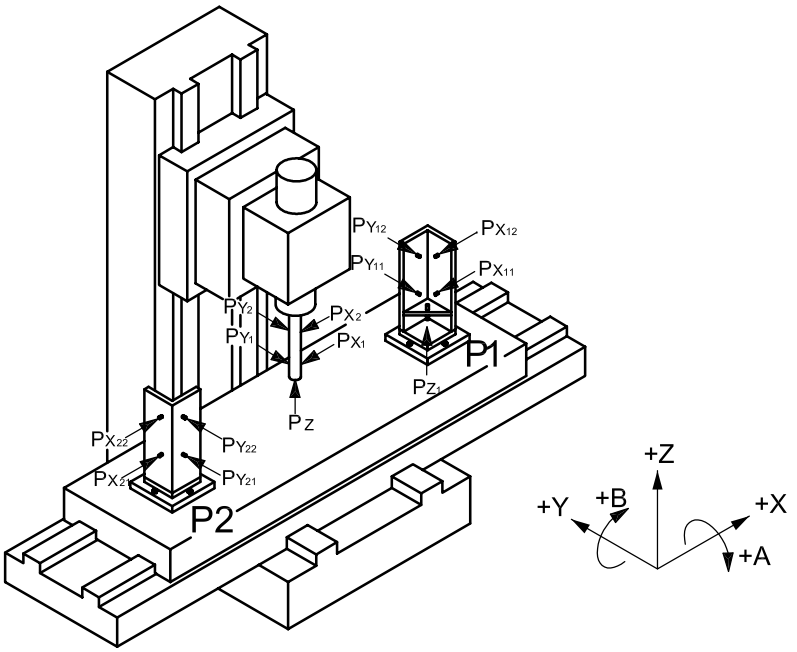

Figure 2 — Typical test set-up for measuring thermal distortions due to linear motion of components

6.2 Measuring instruments

For this test, the required measuring instruments are the following:

— linear displacement sensors;

— temperature sensors;

— special test mandrel;

— data aquisition equipment.

6.3 Presentation of results

For each axis of the machine, the following plots versus time should be presented (e.g. for Figure 2 test set-up):

— two position plots of the target positions, one with $d(\mathrm{EXX})_{\mathrm{P1}}$, $d(\mathrm{EYX})_{\mathrm{P1}}$, $d(\mathrm{EZX})_{\mathrm{P1}}$, and the other with $d(\mathrm{EXX})_{\mathrm{P2}}$, $d(\mathrm{EYX})_{\mathrm{P2}}$, $d(\mathrm{EZX})_{\mathrm{P2}}$;

— two pitch plots of the target positions, one with $d(\mathrm{EBX})_{\mathrm{P1}}$, and the other with $d(\mathrm{EBX})_{\mathrm{P2}}$;

— two roll plots of the target positions, one with $d(\mathrm{EAX})_{\mathrm{P1}}$, and the other with $d(\mathrm{EAX})_{\mathrm{P2}}$;

— temperature plots of environment and machine during tests versus time.

6.4 Information to be recorded

The following information shall be recorded:

a) machine brand and model name;

b) year of construction, if available;

c) machine serial number;

d) time and date of test;

e) location of measurement line;

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f) location of temperature sensor;
g) traverse rate;
h) dwell times;
i) start and end positions;
j) compensation capabilities and facilities;
k) instruments used;
l) coefficient of thermal expansion used;
m) warm up procedures;
n) temperature of the measured object at start and end of test;
o) positive direction of position drift (if different from co-ordinate system).

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Bibliography

[1] ISO 1:2002, *Geometrical Product Specifications (GPS) — Standard reference temperature for geometrical product specification and verification*

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

[3] ISO 230-2:2006, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning numerically controlled axes*

[4] ISO 2806:1994, *Industrial automation systems — Numerical control of machines — Vocabulary*

[5] ISO/TR 16015:2003, *Geometrical product specifications (GPS) — Systematic errors and contributions to measurement uncertainty of length measurement due to thermal influences*

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