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Test conditions for machining centres —
Part 8:
Evaluation of contouring performance in
the three coordinate planes

Conditions d'essai des centres d'usinage —

Partie 8: Évaluation des performances en contournage dans les trois plans de coordonnées

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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 3.

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.

Attention is drawn to the possibility that some of the elements of this part of ISO 10791 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10791-8 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 the thermal distortions*
- *Part 11: Evaluation of the noise emission*

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 8:

Evaluation of contouring performance in the three coordinate planes

1 Scope

This part of ISO 10791 specifies a method of checking the contouring performance of machining centres (or numerically controlled milling machines, etc., where applicable) by conducting circular tests in the three coordinate planes (XY, YZ and XZ) and by evaluating the radial deviation, F , and circular deviation, G , in accordance with ISO 230-4.

NOTE Measurements of circular movements can be carried out by different methods as described in 6.6 of ISO 230-1:1996. These methods consist of using a rotating one-dimensional probe and a test mandrel, a circular masterpiece and a two-dimensional probe, or a telescoping ball bar. Other test methods may be applied if the accuracy of the equipment is the same as (or better than) the accuracy of the methods described. Influences of typical machine deviations on circular paths are shown in annex B of ISO 230-4:1996.

The purpose of the checks by circular tests described in this part of ISO 10791 is to verify the circular movement

- only in one position per coordinate plane of the machine,
- at only one feed rate, and
- to repeat the test once in the opposite contouring direction.

The purpose of this part of ISO 10791 is not to provide a means of analysing the causes for the measured circular deviations, but to offer the user a method for periodic checking of the machine tool. It is recommended to carry out the tests of this part of ISO 10791 once the machine tool has satisfactorily undergone the acceptance tests and to use these results as a basis for comparison when carrying out periodic checks. Therefore, acceptable deviations from the initial results shall be decided by the user.

If the tests are used for machine acceptance purposes, the supplier/manufacturer and the user shall agree on specific diameters, feed rates and tolerances for the tests.

NOTE ISO 10791-6, which deals with the accuracy of feeds, speeds and interpolations, also includes as test K4 a circular test. Here, the purpose is to check the mutual behaviour of two linear axes (generally X and Y) at two defined feed rates for one defined diameter. This is more or less a diagnostic test with respect to the circular interpolation, whereas the circular tests of this part of ISO 10791 give information on the overall contouring performance of the machine.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10791. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10791 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC 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*.

ISO 10791-1:1998, *Test conditions for machining centres — Part 1: Geometric tests for machines with horizontal spindle and with accessory heads (horizontal Z-axis)*.

ISO 10791-3:1998, *Test conditions for machining centres — Part 3: Geometric tests for machines with integral indexable or continuous universal heads (vertical Z-axis)*.

ISO 10791-4:1998, *Test conditions for machining centres — Part 4: Accuracy and repeatability of positioning of linear and rotary axes*.

ISO 10791-6:1998, *Test conditions for machining centres — Part 6: Accuracy of feeds, speeds and interpolations*.

ISO 10791-7:1998, *Test conditions for machining centres — Part 7: Accuracy of a finished test piece*.

3 Preliminary remarks

3.1 Reference to ISO 230-1 and ISO 230-4

To apply this part of ISO 10791, reference shall be made to ISO 230-1 and ISO 230-4, especially for the installation of the machine before testing, for the warming up of the spindle and other moving components, for the description of measuring methods, as well as for the recommended accuracy of testing equipment.

3.2 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. With a view to making the mounting of instruments or gauging easier, tests may be performed in any order.

3.3 Tests to be performed

When testing a machine, it is not always necessary or 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 shall be clearly stated when ordering a machine. The 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 of the contracting parties.

3.4 Measuring instruments

The measuring instruments indicated in the tests described in clause 4 are examples only. Other instruments measuring the same quantities and having at least the same accuracy may be used.

4 Circular tests

See tests C1 to C3.

Object	C1
Checking of the radial deviation, F , or circular deviation, G , according to ISO 230-4 in the XY-plane over at least 190° for clockwise and for counter-clockwise contouring.	
Measuring conditions <p>diameter of nominal path feed rate location of measuring instrument — centre of circle (X/Y/X) — offset to tool reference (X/Y/Z) — offset to workpiece reference (X/Y/Z) temperatures — test environment temperature — temperature of measuring instrument — machine temperature data acquisition method — starting point — number of measuring points — data smoothing process compensation used positions of axis not under test</p>	Measured deviation angle over which the test is carried out = $F_{XY, \text{min}} =$ $F_{XY, \text{max}} =$ $F_{YX, \text{min}} =$ $F_{YX, \text{max}} =$ or $G_{XY} =$ $G_{YX} =$
Measuring instruments According to 6.63 of ISO 230-1:1996, that is rotating one-dimensional probe, or circular masterpiece and two-dimensional probe, or telescoping ball bar.	
Observations The following measuring conditions are recommended unless others are agreed upon by the supplier/manufacturer and user: choose a diameter that corresponds to about 2/3 of the shorter axis; choose any feed rate higher than 1/3 of the maximum feed rate. Measurement location: the axes are in the middle of the working part of their travel, irrespective of the region to where the table moves for tool/pallet change purposes Start the circular movement in one of the four quadrants, preferably not in one of the four reversal points, in order not to miss the performance of the machine at those points. If the diameter of the circular path is not 2/3 of the shortest axis or if the travels of the two axes differ by more than 50 %, more than one test per coordinate plane should be carried out at different positions of the circular path in order to check at least 2/3 of the travel of the axes. This test may be influenced by the following deviations : — straightness of linear motions [tests G1 a), G3 a) in ISO 10791-1:1998; tests G1 b), G2 b) in ISO 10791-3:1998]; — angular deviations of linear motions [tests G4, G6 in ISO 10791-1:1998, tests G4, G5 in ISO 10791-3:1998]; — squareness between linear motions [test G7 in ISO 10791-1:1998; test G9 in ISO 10791-3:1998]; — positioning of linear axes (ISO 10791-4); — linear and circular interpolation [tests K3 a), b), c) for vertical machines; and tests K3 e), f) for horizontal machines in ISO 10791-6:1998; test K4 in ISO 10791-6:1998]. NOTE As there is a good correspondence between machined circles and circular measurements, the circle machined by circular interpolation of the test piece as defined in ISO 10791-7 will show similar deviations as the circular measurements of this test.	

Object	C2
Checking of the radial deviation, F , or circular deviation, G , according to ISO 230-4 in the YZ-plane over at least 190° for clockwise and counter-clockwise contouring.	
Measuring conditions	Measured deviation
diameter of nominal path feed rate location of measuring instrument — centre of circle (X/Y/X) — offset to tool reference (X/Y/Z) — offset to workpiece reference (X/Y/Z) temperatures — test environment temperature — temperature of measuring instrument — machine temperature data acquisition method — starting point — number of measuring points — data smoothing process compensation used positions of axis not under test	
angle over which the test is carried out = $F_{YZ, \min} =$ $F_{YZ, \max} =$ $F_{ZY, \min} =$ $F_{ZY, \max} =$ or $G_{YZ} =$ $G_{ZY} =$	
Measuring instruments	
According to 6.63 of ISO 230-1:1996, that is rotating one-dimensional probe, or circular masterpiece and two-dimensional probe, or telescoping ball bar.	
Observations	
The following measuring conditions are recommended unless others are agreed upon by the supplier/manufacturer and user : choose a diameter that corresponds to about 2/3 of the shorter axis; choose any feed rate up to a maximum of 1/3 of the maximum feed rate.	
Measurement location: the axes are in the middle of the working part of their travel, irrespective of the region to where the table moves for tool/pallet change purposes.	
Start the circular movement in one of the four quadrants, preferably not in one of the four reversal points, in order not to miss the performance of the machine at those points.	
If the diameter of the circular path is not 2/3 of the shorter axis or if the travels of the two axes differ by more than 50%, more than one test per coordinate plane should be carried out at different positions of the circular path in order to check at least 2/3 of the travel of the axes.	
This test is influenced by the following deviations:	
— straightness of linear motions [tests G2 a), G3 b) in ISO 10791-1:1998 and in ISO 10791-3:1998]; — angular deviations of linear motions [tests G5, G6 in ISO 10791-1:1998 and in ISO 10791-3:1998]; — squareness between linear motions [test G8 in ISO 10791-1:1998 and in ISO 10791-3:1998]; — positioning of linear axes (ISO 10791-4); — linear interpolation [test K3 d) in ISO 10791-6:1998].	
NOTE As there is a good correspondence between machined circles and circular measurements, the circle machined by circular interpolation of the test piece as defined in ISO 10791-7 will show similar deviations as the circular measurements of this test.	

Object	C3
Checking of the radial deviation, F , or circular deviation, G , according to ISO 230-4 in the ZX-plane over at least 190° for clockwise and counter-clockwise contouring.	
Measuring conditions	Measured deviation
diameter of nominal path feed rate location of measuring instrument — centre of circle (X/Y/X) — offset to tool reference (X/Y/Z) — offset to workpiece reference (X/Y/Z) temperatures — test environment temperature — temperature of measuring instrument — machine temperature data acquisition method — starting point — number of measuring points — data smoothing process compensation used positions of axis not under test	angle over which the test is carried out = $F_{ZX, \text{min}} =$ $F_{ZX, \text{max}} =$ $F_{XZ, \text{min}} =$ $F_{XZ, \text{max}} =$ or $G_{ZX} =$ $G_{XZ} =$
Measuring instruments	
According to 6.63 of ISO 230-1:1996, that is rotating one-dimensional probe, or circular masterpiece and two-dimensional probe, or telescoping ball bar.	
Observations	
The following measuring conditions are recommended unless others are agreed upon by the supplier/manufacturer and user: choose a diameter that corresponds to about 2/3 of the shorter axis; choose any feed rate up to a maximum of 1/3 of the maximum feed rate.	
Measurement location: axes are in the middle of the working part of their travel, irrespective of the region to where the table moves for tool/pallet change purposes.	
Start the circular movement in one of the four quadrants, preferably not in one of the four reversal points, in order not to miss the performance of machine at those points.	
If the diameter of the circular path is not 2/3 of the shorter axis or if the travels of the two axes differ by more than 50 %, more than one test per coordinate plane should be carried out at different positions of the circular path in order to check at least 2/3 of the travel of the axes.	
This test is influenced by the following deviations:	
— straightness of linear motions [tests G1 b), G2 b) in ISO 10791-1:1998; tests G1 a), G3 a) in ISO 10791-3:1998]; — angular deviations of linear motions [tests G4, G5 in ISO 10791-1:1998; tests G4, G6 in ISO 10791-3:1998]; — squareness between linear motions [test G9 in ISO 10791-1:1998; test G7 in ISO 10791-3:1998]; — positioning of linear axes (ISO 10791-4); — linear interpolation (tests K3 e), f), for vertical machines, and tests K3 a), b), c) for horizontal machines in ISO 10791-6:1998].	
NOTE As there is a good correspondence between machined circles and circular measurements, the circle machined by circular interpolation of the test piece as defined in ISO 10791-7 will show similar deviations as the circular measurements of this test.	