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**Test conditions for numerically  
controlled turning machines and turning  
centres —**

**Part 4:  
Accuracy and repeatability of positioning  
of linear and rotary axes**

*Conditions d'essai des tours à commande numérique et des centres de  
tournage —*

*Partie 4: Précision et répétabilité de positionnement des axes linéaires  
et rotatifs*



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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.

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.

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 13041-4 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

ISO 13041 consists of the following parts, under the general title *Test conditions for numerically controlled turning machines and turning centres*:

- *Part 1: Geometric tests for machines with a horizontal workholding spindle*
- *Part 2: Geometric tests for machines with vertical workholding spindle*
- *Part 3: Geometric tests for machines with inverted vertical workholding spindle*
- *Part 4: Accuracy and repeatability of positioning of linear and rotary axes*
- *Part 5: Accuracy of feeds, speeds and interpolations*
- *Part 6: Accuracy of a finished test piece*
- *Part 7: Evaluation of contouring performance in the coordinate planes*
- *Part 8: Evaluation of thermal distortions*

## Introduction

The object of ISO 13041 is to supply information as wide and comprehensive as possible on geometric, positional, contouring, thermal and machining tests which can be carried out for comparison, acceptance, maintenance or any other purpose.

ISO 13041 specifies, with reference to the relevant parts of ISO 230, *Test code for machine tools*, tests for turning centres and numerically controlled turning machines with/without tailstocks standing alone or integrated in flexible manufacturing systems. ISO 13041 also establishes the tolerances or maximum acceptable values for the test results corresponding to general purpose and normal-accuracy turning centres and numerically controlled turning machines.

# Test conditions for numerically controlled turning machines and turning centres —

## Part 4: Accuracy and repeatability of positioning of linear and rotary axes

### 1 Scope

This part of ISO 13041 specifies, with reference to ISO 230-2, the tolerances which apply to the positioning tests for linear axes, up to 2 000 mm in length, and rotary axes of numerically controlled (NC) turning machines and turning centres.

It does not deal with environmental conditions, warm-up of the machine and measuring methods already described in ISO 230-2.

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

ISO 230-2:1997, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning numerically controlled axes*

ISO 230-2:1997/Cor.1:1999, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning numerically controlled axes — TECHNICAL CORRIGENDUM 1*

ISO 13041-1:2003, *Test conditions for numerically controlled turning machines and turning centres — Part 1: Geometric tests for machines with a horizontal workholding spindle*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13041-1 apply.

## 4 Preliminary remarks

### 4.1 Measuring units

In this part of ISO 13041, 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 arcseconds may be used for clarification purposes. The equivalence of the following expressions should always be kept in mind.

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

### 4.2 Reference to ISO 230-2

To apply this part of ISO 13041, reference shall be made to ISO 230-2, especially for the installation of the machine before testing, warming up of the machine, description of measuring methods, evaluation and presentation of the results.

### 4.3 Testing sequence

The sequence in which the tests are presented in this part of ISO 13041 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 part of ISO 13041. 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 13041 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.

### 4.5 Position of linear axes not under test

During the check of an axis, those of the basic linear axes not involved in the test shall be kept as far as possible in the middle of their working travel, or otherwise in a position such as to minimize deflections of elements affecting measurements. Sliding spindles, etc., when they are supplementary axes, shall be kept retracted.

## 5 Positioning of linear axes

### 5.1 Tolerances

Table 1 gives the positioning tolerances, as defined in Clause 2 of ISO 230-2:1997, for NC turning machines and turning centres of normal accuracy, relating to different measurement travels up to 2 000 mm. In addition, a graphical presentation of results should be provided as specified in ISO 230-2.

Table 1 — Positioning tolerances for axes up to 2 000 mm

Parameter		Measurement travel of the axis mm			
		≤ 500	> 500 ≤ 800	> 800 ≤ 1 250	> 1 250 ≤ 2 000
		Tolerances mm			
Bidirectional accuracy of positioning	A	0,022	0,025	0,032	0,042
Unidirectional repeatability of positioning	R↑ R↓	0,006	0,008	0,010	0,013
Reversal value	B	0,010	0,010	0,012	0,012
Unidirectional systematic deviation of positioning	E↑ E↓	0,010	0,012	0,015	0,018

## 5.2 Measuring instruments

A laser interferometer, or other measuring system with comparable accuracy may be used (see 5.1 of ISO 230-1:1996).

## 5.3 Observations and references to ISO 230-1 and ISO 230-2

When the laser interferometer is used, proper precautions shall be taken according to A.13 of ISO 230-1:1996.

As for the performance of the test, the procedures indicated in ISO 230-2:1997 shall be followed, in particular 4.3.2 for the full check up to 2 000 mm.

## 5.4 Calculation deviations

Table 2 provides an example of the format for the presentation of the results determined through the statistical analysis of the measurement data. In addition, a graphical presentation of results should be provided as specified in ISO 230-2.

Table 2 — Format for the presentation of the results of the full test up to 2 000 mm

Parameter	Axis name	Axis travel	Deviation mm
Bidirectional accuracy of positioning	A		
Repeatability of positioning (positive)	R↑		
Repeatability of positioning (negative)	R↓		
Reversal value	B		
Systematic deviation of positioning (positive)	E↑		
Systematic deviation of positioning (negative)	E↓		

## 6 Positioning of rotary axes

### 6.1 Tolerances

Table 3 gives the positioning tolerances, as defined in Clause 2 of ISO 230-2:1997, for NC turning machines and turning centres of normal accuracy, related to displacements up to 360°.

**Table 3 — Positioning tolerance for axes up to 360°**

Parametre		Tolerances arc seconds
Bidirectional repeatability of positioning	A	63
Unidirectional repeatability of positioning	R↑ R↓	25
Reversal value	B	25
Unidirectional systematic deviation of positioning	E↑ E↓	32

### 6.2 Measuring instruments

A laser angle interferometer with an indexing table, autocollimator with polygonal mirror, or other measuring system with comparable accuracy may be used.

### 6.3 Observations and references to ISO 230-1 and ISO 230-2

When the autocollimator is used, proper precautions shall be taken according to A.11 of ISO 230-1:1996.

As for the performance of the test, the procedures indicated in ISO 230-2:1997 shall be followed, in particular 4.3.4 for the full check up to 360°.

### 6.4 Calculated deviations

Table 4 provides an example of the format for the presentation of the results determined through the statistical analysis of the measured data. In addition, a graphical presentation of results should be provided as specified in ISO 230-2.

**Table 4 — Format for the presentation of the results of the full test up to 360°**

Parameter		Axis name	Deviation arc seconds
Bidirectional accuracy of positioning	A		
Repeatability of positioning (positive)	R↑		
Repeatability of positioning (negative)	R↓		
Reversal value	B		
Systematic deviation of positioning (positive)	E↑		
Systematic deviation of positioning (negative)	E↓		

## 7 Information to be recorded

### 7.1 General

To comply with this part of ISO 13041, the test report shall include the information in 7.2 to 7.4.



## 7.2 Data identifying the machine

- a) name of the manufacturer;
- b) year of construction, if available;
- c) type and serial number.

## 7.3 Data identifying the test

- a) date and place of test;
- b) company and name of inspector;
- c) list of testing equipment used, including manufacturer's name, type and serial number of the components (e.g. laser head, optics, temperature sensor).

## 7.4 Data on the test conditions

- a) machine component moving along or around the axis under test;
- b) feed rate;
- c) positions of the axis slides or moving components on the axes which are not under test;
- d) position of the measurement line;
- e) number and positions of temperature sensors;
- f) readings of the temperature sensors immediately before and after the test;
- g) expansion coefficient used for material compensation;
- h) if relevant, air temperature, pressure and humidity, immediately before and after the test;
- i) type of compensation applied to the machine axes;
- j) type of compensation applied to the measurement data.

## Bibliography

- [1] ISO 1708:1989, *Acceptance conditions for general purpose parallel lathes — Testing of the accuracy*
- [2] ISO 2806:1994, *Industrial automation systems — Numerical control of machines — Vocabulary*
- [3] ISO 6155:1998, *Machine tools — Test conditions for horizontal spindle turret and single spindle automatic lathes — Testing of the accuracy*



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