INTERNATIONAL STANDARD

ISO 230-4

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Test code for machine tools —

Part 4:

Circular tests for numerically controlled machine tools

Code d'essai des machines-outils —

Partie 4: Essais de circularité des machines-outils à commande numérique

Reference number
ISO 230-4:1996(E)

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 230-4 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal cutting machine tools*.

ISO 230 consists of the following parts, under the general title *Test code for machine tools*:

— *Part 1: Geometric accuracy of machines operating under no-load or finishing conditions*

— *Part 2: Determination of accuracy and repeatability of positioning of numerically controlled machine tools*

— *Part 3: Evaluation of thermal effects*

— *Part 4: Circular tests for numerically controlled machine tools*

— *Part 5: Noise emissions*

Annexes A to D of this part of ISO 230 are for information only.

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Test code for machine tools —

Part 4:
Circular tests for numerically controlled machine tools

1 Scope

This part of ISO 230 specifies methods of testing and evaluating the circular hysteresis and the circular and radial deviation of circular paths that are produced by the simultaneous movements of two linear axes. Relevant measuring instruments are described in 6.63 of ISO 230-1:1996.

The objective of this part of ISO 230 is to provide a method for the measurement of the contouring performance of a numerically controlled machine tool.

2 Normative references

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 230. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 230 are encouraged to investigate the possibility of applying the most recent edition of the standard 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.*

3 Definitions

For the purposes of this part of ISO 230 the following definitions apply:

3.1 nominal path: Numerically controlled and programmed circular path defined by its diameter (or radius), the position of its centre and its orientation in the working zone of the machine tool and which may be either a full circle or a partial circle of at least 90°.

3.2 actual path: Path produced by the machine tool when programmed to move on the nominal path.

3.3 circular hysteresis, H: Maximum radial difference between two actual paths, where one path is carried out by a clockwise contouring motion and the other one by an anticlockwise contouring motion (see figure 1).

NOTE 1 The reference for evaluation is the centre of the least squares circle of the two actual paths.

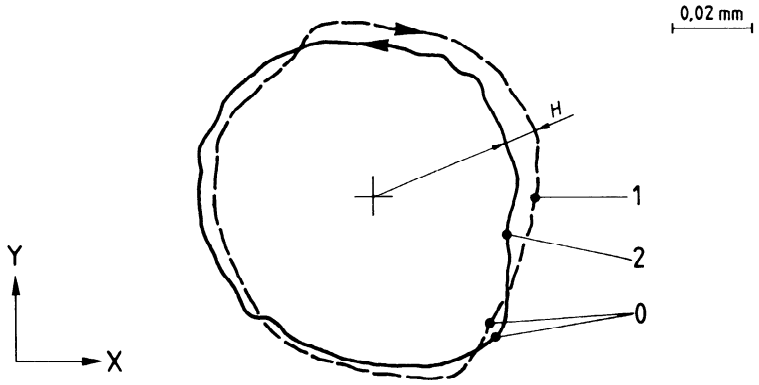
3.4 circular deviation, G: Minimum radial separation of two concentric circles enveloping the actual path (minimum zone circles) as shown in figure 2 and which may be evaluated as the maximum radial range around the least squares circle.

NOTES

2 Circular deviation does not include set-up errors, i.e. centring errors of the measuring instrument.

3 Circular deviation measurement does not require test equipment with calibrated length whereas radial deviation (3.5) does need that facility. For differences between the circular deviation G and the radial deviation F see annex A.

4 A line situated in a plane is said to be circular when all its points are contained between two concentric circles whose radial separation does not exceed a given value (see figure 2 and also 6.61 of ISO 230-1:1996).

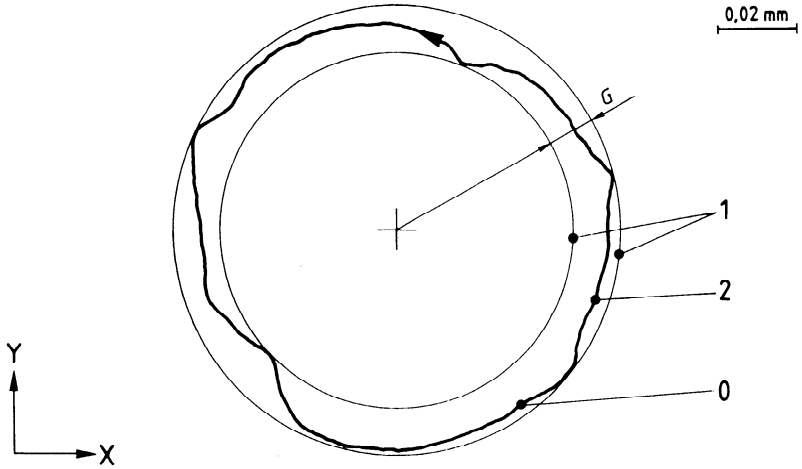


Key

+ centre of least squares circle of the two actual paths
0 starting point
1 actual path, clockwise
2 actual path, anticlockwise

circular hysteresis, H_{XY} = 0,008 mm

Figure 1 — Evaluation of circular hysteresis H



Key

+ centre of minimum zone circles
0 starting point
1 minimum zone circles
2 actual path

circular deviation, G_{XY} = 0,012 mm

Figure 2 — Evaluation of circular deviation G

3.5 radial deviation, F: Deviation between the actual path and the nominal path, where the centre of the nominal path is obtained either,

a) from the centring of the measuring instruments on the machine tool, or

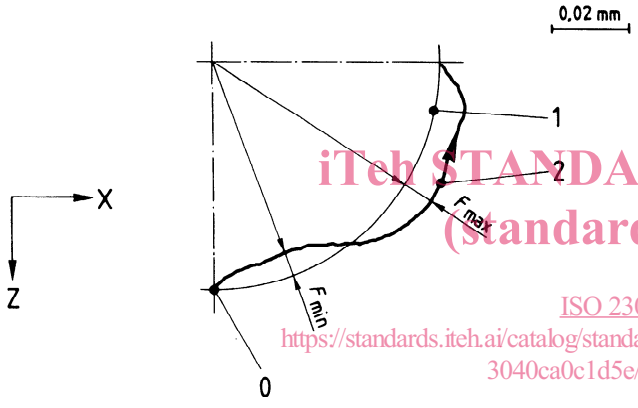
b) from the least squares centring analysis for a full circle only.

NOTES

5 Positive deviations are measured away from the centre of the circle and negative ones towards the centre of the circle (see figure 3). The radial deviation is given by the maximum value, F_{max}, and the minimum value, F_{min}.

6 Set-up errors may be included in the radial deviation F; this is applicable only to a) above.

7 For differences between the radial deviation F and the circular deviation G see annex A.



Key

+ centre of nominal circle
0 starting point
1 nominal path
2 actual path

radial deviation, $F_{ZX,max}$ = + 0,008 mm
$F_{ZX,min}$ = – 0,006 mm

Figure 3 — Evaluation of radial deviation F

3.6 identification of axes: Designation of the axes which are moved to produce the actual path.

3.7 sense of contouring: (clockwise or anticlockwise contouring, for circular deviation G and radial deviation F). Sense indicated by the sequence of the indices which identify the axes moved when the movement is from the axis' positive part indicated by the first index to the axis' positive part indicated by the second index; e.g. the circular deviation G produced by the X and Y axes in a clockwise movement is denoted as G_{YX}, in an anticlockwise movement as G_{XY}.

4 Test conditions

4.1 Environment

Where the temperature of the environment can be controlled it shall be set at 20 °C. Otherwise the output of the measuring instrument and the machine nominal readings shall be adjusted to yield results corrected to 20 °C (for radial deviation measurements only).

The machine and, if relevant, the measuring instrument, shall have been in the test environment long enough (preferably overnight) to have reached a thermally stable condition before testing. They shall be protected from draughts and external radiation such as sunlight, overhead heaters, etc.

4.2 Machine to be tested

The machine shall be completely assembled and fully operational. All necessary levelling operations and functional checks shall be completed before starting the tests for circular hysteresis and circular and radial deviation.

All circular tests shall be carried out with the machine in the unloaded condition, i.e. without a workpiece.

4.3 Machine warm-up

The tests shall be preceded by an appropriate warm-up procedure as specified by the manufacturer of the machine and/or agreed between the supplier/manufacturer and the user.

If no other conditions are specified, the preliminary movements shall be restricted to only those necessary to set up the measuring instrument.

4.4 Test parameters

Parameters of the test are:

a) diameter (or radius) of the nominal path;

b) contouring feed;

c) contouring direction (clockwise or anticlockwise) as indicated according to 3.7;

d) machine axes moved to produce the actual path;

e) location of the measuring instrument in the machine tool working zone;

f) temperature (environment temperature, measuring instrument temperature, machine temperature) for radial deviation measurement only;

g) data acquisition method (data capture range if different from 360°, starting and stop points of the

actual movement, number of measuring points taken for digital data acquisition, and whether a data smoothing process is applied or not);

h) any machine compensation routines used during the test cycle;

i) positions of slides or moving elements on the axes which are not being tested.

4.5 Test instrument calibration

For the checking of radial deviation the reference dimension of the test instrument shall be known.

5 Test procedure

To determine circular hysteresis, H, two actual paths have to be measured consecutively: one in a clockwise contouring direction and the other in an anticlockwise contouring direction.

All measured data corresponding to the actual path (including any peaks at reversal points) shall be used in the evaluation.

NOTE 8 For radial deviation, F, of a partial circle, set-up errors should be minimized.

6 Presentation of results

A graphical method of presenting results is preferred with the following test result data specified numerically:

a) circular hysteresis, H;

b) circular deviations G, for clockwise and anticlockwise contouring;

c) radial deviations, F_{max} and F_{min}, for clockwise and anticlockwise contouring, corrected to 20 °C.

Typical examples of presentation of test results are shown in figures 4, 5 and 6.

The test report shall give the following:

— date of test;

— name of machine;

— measuring equipment;

— test parameters (see 4.4).

Magnification scale of the graphical presentation shall be stated.

7 Points to be agreed between supplier/manufacturer and user

The points to be agreed between the supplier/manufacturer and the user are as follows:

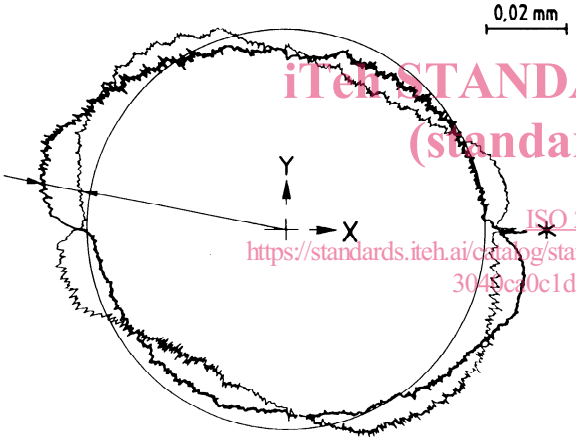
a) warm-up procedure prior to testing the machine (see 4.3);

b) test parameters (see 4.4);

c) which test result data for the circular hysteresis H, the circular deviation G and/or the radial deviation F [from 6a), 6b), 6c)] are required and shall be presented.

Date of test: yy/mm/dd Name of machine: xyz Measuring instrument: abc	
Test parameters	
diameter of nominal path:	40 mm
contouring feed:	500 mm/min
contouring direction:	—
machine axes under test (X, Y, Z):	XY
Location of measuring instrument	
— centre of circle (X/Y/Z):	250/250/100 mm
— offset to tool reference (X/Y/Z):	0/0/– 80 mm
— offset to workpiece reference (X/Y/Z):	0/0/30 mm
Data acquisition method	
— starting point:	4th quadrant
— stop point:	4th quadrant
— number of measuring points (digital only):	1 500
— data smoothing process:	none
Compensation used:	none
Positions of axes not under test	Z = 150 mm

Date of test: yy/mm/dd Name of machine: xyz Measuring instrument: abc	
Test parameters	
diameter of nominal path:	250 mm
contouring feed:	1 000 mm/min
contouring direction:	+ X to + Y
machine axes under test (X, Y, Z):	XY
Location of measuring instrument	
— centre of circle (X/Y/Z):	250/250/300 mm
— offset to tool reference (X/Y/Z):	0/0/– 80 mm
— offset to workpiece reference (X/Y/Z):	0/0/230 mm
Data acquisition method	
— starting point:	4th quadrant
— stop point:	4th quadrant
— number of measuring points (digital only):	1 800
— data smoothing process:	none
Compensation used:	none
Positions of axes not under test	Z = 350 mm



Key:

\+ centre of least squares circle of the two actual paths

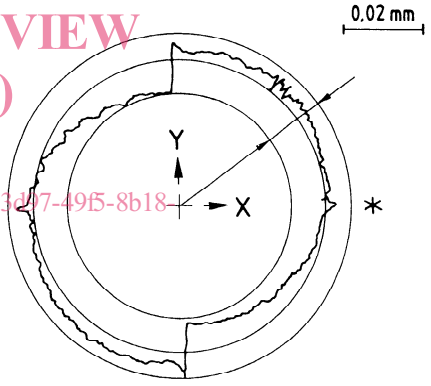
* starting point

heavy trace actual path, from + Y to + X

light trace actual path, from + X to + Y

circular hysteresis, H_{XY} = 0,014 mm

Figure 4 — Example of data presentation for circular hysteresis H



Key:

\+ centre of minimum zone circles

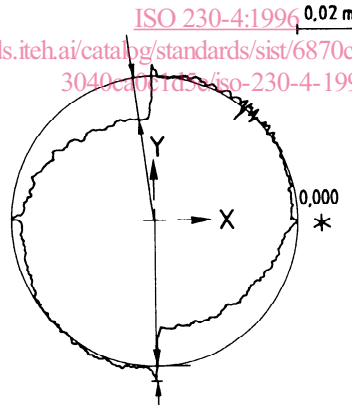
* starting point

circular deviation, G_{XY} = 0,018 mm

Figure 5 — Example of data presentation for circular deviation G

Date of test: yy/mm/dd Name of machine: xyz
Measuring instrument: abc

Test parameters	
diameter of nominal path:	150 mm
contouring feed:	300 mm/min
contouring direction:	+ Y to + X
machine axes under test (X, Y, Z):	XY
Location of measuring instrument	
— centre of circle (X/Y/Z):	250/250/100 mm
— offset to tool reference (X/Y/Z):	0/0/– 80 mm
— offset to workpiece reference (X/Y/Z):	0/0/30 mm
Temperature	
— environment temperature:	22 °C
— temperature of the measuring instrument:	22 °C
— machine temperature:	22 °C
Data acquisition method	
— starting point:	4th quadrant
— stop point:	4th quadrant
— number of measuring points (digital only):	1 800
— data smoothing process:	none
Compensation used:	temperature
Positions of axes not under test:	Z = 150 mm



Key:

+	centre of least circle
*	starting point
0,000	nominal path
radial deviation:	$F_{YX,max}$ = + 0,005 mm
	$F_{YX,min}$ = – 0,013 mm

Figure 6 — Example of data presentation for radial deviation F

Annex A
(informative)

Differences between circular deviation G and radial deviation F

Table A.1 shows the differences between circular deviation G and radial deviation F.

Table A.1

Influences	Circular deviation G	Radial deviation F
deviation of form[1)]	included	included
deviation of diameter[2)]	not included, as the diameters of the minimum zone circles are not evaluated	included
deviation of position[3)]	not included, as the position of the minimum zone circles is defined by the actual path only	included for a partial circle, not included for a full circle

1) Deviation between a circle and the shape of the actual path (e.g. elliptical form deviation).

2) Deviation between the diameter of the nominal path and the diameter of the actual path.

3) Deviation between the position of the centre of the nominal path and the centre of the actual path (e.g. deviations in the X and Y positions).