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Jawaharlal Nehru
“Step Out From the Old to the New”

Indian Standard

TEST CONDITIONS FOR MILLING MACHINES WITH TABLE OF VARIABLE HEIGHT — TESTING OF ACCURACY

PART 3 MACHINES WITH VERTICAL SPINDLE

ICS 25.080.20

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Price Group 7
NATIONAL FOREWORD

This Indian Standard (Part 3) which is identical with ISO 1701-3:1997 'Test conditions for milling machines with table of variable height — Testing of accuracy — Part 3: Machines with vertical spindle' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Machine Tools Sectional Committee and approval of the Basic and Production Engineering Division Council.

In order to align the numbering of Indian Standard with parts number of ISO standard, this edition of Indian Standard is now numbered as Part 3 of IS 2200, thus superseding IS 2201:1994 which was first published in 1962, subsequently revised in 1973 and 1994. Part 1 of this standard shall be published as and when Part 1 of ISO 1701 is published. Part 2 of IS 2200 is being processed for printing.

The text of the ISO Standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

<table>
<thead>
<tr>
<th>International Standard</th>
<th>Corresponding Indian Standard</th>
<th>Degree of Equivalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 1701-0:1984 Test conditions for milling machines with table of variable height with horizontal or vertical spindle — Part 0: General introduction</td>
<td>IS 13634 : 1993 General introduction for milling machines with table of variable height, with horizontal or vertical spindle</td>
<td>do</td>
</tr>
</tbody>
</table>

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2:1960 'Rules for rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
Indian Standard

TEST CONDITIONS FOR MILLING MACHINES WITH TABLE OF VARIABLE HEIGHT — TESTING OF ACCURACY

PART 3 MACHINES WITH VERTICAL SPINDLE

1 Scope

This part of ISO 1701 specifies, with reference to ISO 230-1, both geometric and machining tests on general purpose, normal accuracy, vertical spindle milling machines with table of variable height. It also specifies the applicable tolerances corresponding to the above-mentioned tests.

This part of ISO 1701 deals only with the verification of accuracy of the machine. It does not apply to the testing of the running of the machine (vibration, abnormal noise, stick-slip motion of components, etc.), nor to machine characteristics (such as speeds, feeds, etc.), which should generally be carried out before testing the accuracy.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 1701. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 1701 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.


ISO 1701-0:1984 1), Test conditions for milling machines with table of variable height with horizontal or vertical spindle — Part 0: General introduction.

3 Terminology and designation of axes

For axes of machines with vertical spindle, reference should be made to 4.2 and figure 5 of ISO 1701-0:1984

4 Preliminary remarks

4.1 Measuring units

In this part of ISO 1701, 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:

\[ 0.010/1000 = 10 \times 10^{-6} = 10 \mu\text{rad} = 2'' \]

1) See "Foreword"
4.2 Reference to ISO 230-1

To apply this part of ISO 1701, 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.

In the “Observations” block of the tests described in the following sections, the instructions are followed by a reference to the corresponding clause in ISO 230-1 in cases where the test concerned is in compliance with the specifications of that part of ISO 230.

4.3 Testing sequence

The sequence in which the tests are presented in this part of ISO 1701 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 1701. 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 1701 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 Measuring instruments

The measuring instruments indicated in the tests described in the following sections are examples only. Other instruments measuring the same quantities and having at least the same accuracy may be used. Dial gauges shall have a resolution of 0.001 millimetres or better.

4.6 Machining tests

Machining tests shall be made with finishing cuts only, not with roughing cuts which are liable to generate appreciable cutting forces.

4.7 Minimum tolerance

When the tolerance for a geometric test is established for a measuring length different from that given in this part of ISO 1701 (see 2.311 of ISO 230-1:1996), it shall be taken into consideration that the minimum value of tolerance is 0.005 mm.
5 Geometric tests

5.1 Axes of motion

Object

Checking of straightness of the vertical movement of the knee (W-axis):

a) in the vertical plane of symmetry of the machine (YZ plane);
b) in the plane perpendicular to the vertical plane of symmetry of the machine (ZX plane).

Diagram

![Diagram showing the axes of motion](image)

Tolerance

a) and b)

0,020 for any measuring length of 300

(Measured deviation)

a)

Measuring instruments

Dial gauge and square.

Observations and references to ISO 230-1

5.232.11

Instead of a straigtedge, use the vertical arm of the square.

Adjust the square to obtain similar readings at both ends of its measuring length, then the maximum difference of dial gauge readings gives straightness deviation.

Table in central position:

a) cross slide (Y-axis) locked;
b) table (X-axis) locked.

If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on a fixed part of the machine.
Object

Checking of squareness between the transverse cross slide movement (Y-axis) and the longitudinal table movement (X-axis).

Diagram

![Diagram showing checking of squareness between Y-axis and X-axis](image)

<table>
<thead>
<tr>
<th>Tolerance (Measured deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02 for a measuring length of 300</td>
</tr>
</tbody>
</table>

Measuring instruments

Straightedge, dial gauge and square.

Observations and references to ISO 230-1

5.522.4

Knee (W-axis) locked.

a) The straightedge shall be set parallel to the longitudinal table movement (X-axis); then the square shall be placed against the straightedge. The table shall then be locked in the central position. This test can also be performed without the straightedge, aligning the long arm of the square parallel to the X-axis.

b) The transverse cross slide movement (Y-axis) shall then be checked.

If the spindle can be locked, then the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on a fixed part of the machine.
**Object**

Checking of angular deviation of the table in its longitudinal movement (X-axis):
- a) in the vertical YZ plane perpendicular to the table movement (roll EAX);
- b) in the vertical ZX plane parallel to the table movement (pitch EBX).

**Diagram**

![Diagram showing the table and reference levels in X-axis movement.](image)

**Tolerance**

<table>
<thead>
<tr>
<th>a)</th>
<th>b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04/1000 (or 40 microrad or 8&quot;)</td>
<td>X ≤ 1000 0.08/1000 (or 80 microrad or 16&quot;)</td>
</tr>
<tr>
<td>X ≤ 1000 0.12/1000 (or 120 microrad or 24&quot;)</td>
<td></td>
</tr>
</tbody>
</table>

**Measured deviation**

<table>
<thead>
<tr>
<th>a)</th>
<th>b)</th>
</tr>
</thead>
</table>

**Measuring instruments**

Precision level

**Observations and references to ISO 230-1 5.232.2**

These tests should only be performed when the knee (W-axis) is clamped on the column.

The level shall be placed in centre of the table
- a) transversely;
- b) longitudinally.

The reference level shall be located on the spindle head, and the spindle head shall be in the middle of the travel range.

When X-axis motion causes an angular movement of both spindle head and work holding table, differential measurements of the two angular movements shall be made and this shall be stated.

Measurements shall be taken at several positions moving the table by 200 or 250 mm steps.

The difference between the maximum and the minimum readings (excluding the above angular contribution) of both directions of movement shall not exceed the tolerance.
5.2 Table

Object
Checking of flatness of the table surface.

Diagram

<table>
<thead>
<tr>
<th>Tolerance (Measured deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04 for a measuring length up to 1000 (concave only)</td>
</tr>
<tr>
<td>For each 1000 mm increase in table length, add 0.005</td>
</tr>
<tr>
<td>Maximum tolerance: 0.05</td>
</tr>
<tr>
<td>Local tolerance: 0.02 for any measuring length of 300</td>
</tr>
</tbody>
</table>

Measuring instruments
Precision level or straightedge and slip gauges.

Observations and references to ISO 230-1 5.322 and 5.323
Table (X-axis) and cross slide (Y-axis) in the central position, table not locked, knee and cross slide locked.

NOTE — The alphabetical references on the diagram correspond to those used in figure 41 of ISO 230-1:1996.
Object

Checking of parallelism between the table surface and:
   a) the transverse cross slide movement (Y-axis), in the vertical YZ plane;
   b) its longitudinal movement (X-axis), in the vertical ZX plane.

Diagram

Tolerance

<table>
<thead>
<tr>
<th>a) and b)</th>
<th>(Measured deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.025 for any measuring length of 300</td>
<td>a)</td>
</tr>
<tr>
<td>Maximum tolerance: 0.05</td>
<td>b)</td>
</tr>
</tbody>
</table>

Measuring instruments

Straightedge and dial gauge.

Observations and references to ISO 230-1 5.422.21

The stylus of the dial gauge shall be placed approximately at the working position of the tool.

The measurement may be made on a straightedge laid parallel to the table surface.

If the table length is greater than 1600 mm, carry out the inspection by successive movements of the straightedge.

Knee (W-axis) locked:
   a) table (X-axis locked);
   b) cross slide (Y-axis) locked.

If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on a fixed part of the machine.
Object

Checking of squareness between the table surface and the vertical movement of the knee (W-axis) (in three positions: in the middle and near the extremities of travel):

a) in the vertical plane of symmetry of the machine (YZ plane);

b) in the plane perpendicular to the vertical plane of symmetry of the machine (ZX plane).

Diagram

Tolerance

<table>
<thead>
<tr>
<th>Measured deviation</th>
<th>Measured deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 0.025 for a measuring length of 300 with $\alpha \leq 90^\circ$</td>
<td>a) 0.025 for a measuring length of 300</td>
</tr>
<tr>
<td>b) 0.025 for a measuring length of 300</td>
<td>b)</td>
</tr>
</tbody>
</table>

Measuring instruments

Dial gauge and square.

Observations and references to ISO 230-1

Table in central position, knee (W-axis) locked when taking measurements;

a) cross slide (Y-axis) locked;

b) table (X-axis) locked.

If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on a fixed part of the machine.
Object

Checking of squareness between the table surface and the vertical movement of the spindle head slide (Z-axis):
   a) in the vertical plane of symmetry of the machine (YZ plane);
   b) in the plane perpendicular to the vertical plane of symmetry of the machine (ZX plane).

Diagram

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>(Measured deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 0,025 for a measuring length of 300 with ( \alpha \leq 90^\circ )</td>
<td>a)</td>
</tr>
<tr>
<td>b) 0,025 for a measuring length of 300</td>
<td>b)</td>
</tr>
</tbody>
</table>

Measuring instruments

Dial gauge and square.

Observations and references to ISO 230-1 5.522.2

Table in central position, knee (W-axis) locked;
Spindle head slide (Z-axis) locked when taking measurements;
   a) cross slide (Y-axis) locked;
   b) table (X-axis) locked.

If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on the spindle head slide of the machine.
Object
Checking of straightness of the median or reference T-slot of the table.

Diagram

Tolerance

<table>
<thead>
<tr>
<th>Measured deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,01 for a measuring length of 500</td>
</tr>
<tr>
<td>Maximum tolerance: 0,03</td>
</tr>
</tbody>
</table>

Measuring instruments
Straightedge and dial gauge or gauge blocks, or taut wire and microscope, or autocollimator.

Observations and references to ISO 230-1
5.212, 5.212.1 and 5.212.23

The straightedge may be placed directly on the table.
Object

Checking of parallelism between the median or reference T-slot and the longitudinal movement of the table (X-axis).

Diagram

Tolerance

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>(Measured deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,015 for a measuring length of 300</td>
<td>0,04</td>
</tr>
</tbody>
</table>

Measuring instruments

Dial gauge.

Observations and references to ISO 230-1

5.422.1 and 5.422.21

Cross slide (Y-axis) and knee (W-axis) locked.

If the spindle can be locked, the dial gauge may be mounted on it. If the spindle cannot be locked, the dial gauge shall be placed on a fixed part of the machine.
5.3 Spindle

Object

Checking of:
  a) run-out of the external centring surface on the spindle nose (for machines having this feature);
  b) periodic axial slip;
  c) camming of the face of the spindle nose (including periodic axial slip).

Diagram

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>(Measured deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 0,01</td>
<td>b) 0,01</td>
</tr>
<tr>
<td>c) 0,02</td>
<td>a)</td>
</tr>
</tbody>
</table>

Measuring instruments

Dial gauge.

Observations and references to ISO 230-1

a) 5.612.2

b) 5.622.1 and 5.622.2
   A force $F$, specified by the supplier/manufacturer of the machine, can be exerted by pressing towards the housing during tests b) and c).

c) 5.632
   The distance $A$ of the dial gauge c) from the spindle axis shall be as large as possible.
Object

Checking of the run-out of the internal taper of the spindle:
   a) at the spindle nose;
   b) at a distance of 300 mm from the spindle nose.

Diagram

Tolerance | (Measured deviation)
---|---
a) 0.01 | a) b)
b) 0.02

Measuring instruments

Dial gauge and test mandrel.

Observations and references to ISO 230-1 5.612.3
Object

Checking of squareness between the spindle axis and the table surface:
  a) in the vertical plane of symmetry of the machine (YZ plane);
  b) in the plane perpendicular to the vertical plane of symmetry of the machine (ZX plane).

Diagram

Tolerance  

| a) 0,025/300 with $\alpha \leq 90^\circ$ | (Measured deviation) |
| b) 0,025/300 |  |

Measuring instruments

Dial gauge and test mandrel.

Observations and references to ISO 230-1

5.512.1 and 5.512.42

Table (X-axis), cross slide (Y-axis), spindle head slide (Z-axis) and knee (W-axis) locked.
Machining tests

Milling of surface A by automatic longitudinal movement of the table and manual transverse movement of the cross slide, in two cuts overlapping by about 5 to 10 mm.


Diagram Dimensions in millimetres

L is the length of the test piece or distance between the opposite faces of two test pieces, and is equal to 1/4 the longitudinal travel. I is equal to \( h \), and corresponds to 1/8 of the longitudinal travel.

\[ \text{If } L \leq 100 \text{ mm}, \quad I = 50 \text{ mm} \]
\[ \text{If } 100 < L \leq 1000 \text{ mm}, \quad I = 100 \text{ mm} \]
\[ \text{If } L > 1000 \text{ mm}, \quad I = 200 \text{ mm} \]

NOTES

1. Longitudinal travels \( \leq 400 \) mm: one or two test pieces, machined in the longitudinal direction over a length at each end, can be used.

2. Longitudinal travels of \( > 400 \) mm: one test piece, machined over its entire length, shall be used.


Cutting conditions

a) With a shell end mill
b) Slab milling with the same cutter

Checks to be applied

a1) Surface A on each block shall be flat.

a2) The height \( H \) of the block(s) shall be constant.

b) The planes containing the surfaces B, C and D shall be perpendicular to each other and each one perpendicular to the surface A.

Tolerance (Measured deviation)

\[ a1) \quad 0,02 \]
\[ a2) \quad 0,03 \]
\[ b) \quad 0,02 \quad 100 \]

Measuring instruments

a1) Straightedge and gauge block or amplifier

a2) Micrometer callipers

b) Square and gauge blocks

Observations and references to ISO 230-1 4.1 and 4.2

Before beginning the test, surface E shall be flat.

Test pieces shall be placed along the longitudinal axis of the table so that the length \( L \) is equally distributed on either side of the table centre.

NOTE — Subject to agreement between the user and the supplier/manufacturer, the form of the test piece shown in the diagram may be replaced by a simpler form of test piece having sides of full width, in which case tests carried out using this form will be at least as severe as those carried out using the form in the diagram.

The cutter when mounted, should conform to the following tolerances:

1) run-out: \( \leq 0,02 \text{ mm} \)

2) camming: \( \leq 0,03 \text{ mm} \).

All non-operating slides shall be locked during cutting.
Annex A
(informative)

Bibliography

[1] ISO 841:— 2), Industrial automation systems — Physical device control — Coordinate system and motion nomenclature


2) To be published. (Revision of ISO 841:1974)
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Amendments Issued Since Publication

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