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ISO 230-1

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Test code for machine tools —

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

Code d'essai des machines-outils —

Partie 1: Précision géométrique des machines fonctionnant à vide ou dans des conditions de finition

Reference number
ISO 230-1:1996(E)

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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.

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 230-1 was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 2, *Test conditions for metal-cutting machine tools*.

This second edition cancels and replaces the first edition (ISO 230-1:1986), which has been technically revised.

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 tool axes*

— *Part 3: Evaluation of thermal effects*

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

— *Part 5: Determination of noise emission*

Annexes A and B of this part of ISO 230 are for information only.

Introduction

After general considerations on definitions, test methods, use of measuring instruments and tolerances, this part of ISO 230 deals more thoroughly with preliminary operations, geometric and machining tests, and special tests.

Annex A provides additional information about the instruments and equipment used in these tests.

Geometric tests consist of the verification of dimensions, forms and positions of components and their displacement relative to one another. They comprise all the operations which affect the components of the machine (surface flatness, coincidence and intersection of axes, parallelism and perpendicularity of straight lines and of flat surfaces). They address only the sizes, forms, positions and relative movements which may affect the accuracy of the machine operation.

Practical tests consist of the machining of test pieces appropriate to the fundamental purposes for which the machine has been designed, and having predetermined limits and tolerances.

The clause numbering of the first edition ISO 230-1:1986 has been retained as far as possible. Clause numbering is changed only in 5.2 and 5.3 and former numbers are shown in parentheses at the corresponding entry of the contents list.

Test code for machine tools —

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

1 Scope

The aim of this part of ISO 230 is to standardize methods of testing the accuracy of machine tools, operating either under no-load or under finishing conditions, by means of geometric and machining tests. The methods may also be applied to other types of industrial machines where geometric and machining tests are concerned.

This part of ISO 230 covers power-driven machines, not portable by hand while working, which can be used for machining metal, wood, etc. by removal of chips or swarf or by plastic deformation.

This part of ISO 230 relates only to the testing of geometric accuracy. In particular, it deals neither with the operational testing of the machine tool (vibrations, stick-slip motion of components, etc.) nor with the checking of characteristics (speeds, feeds), as these checks should normally be carried out before testing of the accuracy of the machine tool.

When a measurement method not described in this standard can be shown to offer equivalent or better facilities for measuring the attributes to be studied, such a method may be used.

2 General considerations

2.1 Definitions relating to geometric tests

A distinction should be made between geometric definitions and those designated in this part of ISO 230 as metrological definitions.

Geometric definitions are abstract and relate only to imaginary lines and surfaces. From this it follows that geometric definitions sometimes cannot be applied in practice. They take no account of the realities of construction or the practicality of geometric verification.

Metrological definitions are real, as they take account of real lines and surfaces accessible to measurement. They cover in a single result all micro- and macro-geometric deviations. They allow a result to be reached covering all causes of error, without distinguishing among them. Such distinction should be left to the manufacturers.

Nevertheless, in some cases, geometric definitions [e.g. definitions of run-out (out-of-true running), periodic axial slip, etc.] have been retained in this part of ISO 230, in order to eliminate any confusion and to clarify the language used. However, when describing test methods, measuring instruments and tolerances, metrological definitions are taken as a basis.

2.2 Test methods and use of measuring instruments

During the testing of a machine tool, if the methods of measurement only allow verification that the tolerances are not exceeded (e.g. limit gauges) or if the actual deviation can only be determined by high-precision measurements for which a great amount of time would be required, it is sufficient, instead of measuring, to ensure that the limits of tolerance are not exceeded.

It should be emphasized that inaccuracies of measurement due to the instruments, as well as to the methods used, are to be taken into consideration during the tests. The measuring instrument should not cause any error of measurement exceeding a given fraction of the tolerance to be verified. Since the accuracy of the devices used varies from one laboratory to another, a calibration sheet should be available for each instrument.

Machines under test and instrumentation should be protected from draughts and from disturbing light or heat radiation (sunlight, electric lamps too close, etc.), and the temperature of the measuring instruments should be stabilized before measuring. The machine itself shall be suitably protected from the effects of external temperature variation.

A given measurement should preferably be repeated, the result of the test being obtained by taking the average of the measurements. However, the various measurements should not show too great deviations from one another. If they do, the cause should be sought either in the method or the measuring instrument, or in the machine tool itself.

For more precise indications, see annex A.

2.3 Tolerances

2.31 Tolerances on measurements when testing machine tools

Tolerances, which limit deviations to values which are not to be exceeded, relate to the sizes, forms, positions and movements which are essential to the accuracy of working and to the mounting of tools, important components and accessories.

There are also tolerances which apply only to test pieces.

2.311 Units of measurement and measuring ranges

When establishing tolerances, it is necessary to indicate:

a) the unit of measurement used;

b) the reference base and the value of the tolerance and its location to the reference base;

c) the range over which measurement is made.

The tolerance and the measuring range shall be expressed in the same unit system. Tolerances, particularly tolerances on sizes, shall be indicated only when it is impossible to define them by simple reference to International Standards for the components of the machine. Those relating to angles shall be expressed either in units of angle (degree, minute, second) or as tangent (millimetres per millimetres).

When the tolerance is known for a given range, the tolerance for another range comparable to the first one shall be determined by means of the law of proportionality. For ranges greatly different from the reference range, the law of proportionality cannot be applied: tolerances shall be wider for small ranges and narrower for large ranges than those which would result from the application of this law.

2.312 Rules concerning tolerances

Tolerances include inaccuracies inherent in the measuring instruments and test methods used. Inaccuracies of measurement should consequently be taken into account in the permitted tolerances (see 2.2).

EXAMPLE

Tolerance of run-out: x mm

Inaccuracy of instruments, errors of measurement: y mm

Maximum permissible difference in the readings during the test: $(x - y)$ mm

Errors due to inaccuracies arising from comparative laboratory measurements, inaccuracies of form of machine parts used as reference surfaces, including surfaces masked by styli or by support points of measuring instruments, should be considered.

The actual deviation should be the arithmetical mean of several readings taken, due to the above causes of error.

Lines or surfaces chosen as reference basis should be directly related to the machine tool (e.g. line between centres of a lathe, spindle of a boring machine, slideways of a planing machine, etc.). The direction of the tolerance shall be defined according to the rules given in 2.324.

2.32 Subdivisions of tolerances

2.321 Tolerances applicable to test pieces and to individual components of machine tools

It should be noted that the rules for indicating geometric tolerances on drawings given in ISO 1101 apply to the geometric accuracy of individual parts. These rules should be adhered to on manufacturing drawings.

2.321.1 Tolerances of dimension

The tolerances of dimension indicated in this part of ISO 230 relate exclusively to the dimensions of test pieces for machining tests and to the fitting dimensions of cutting tools and of measuring instruments which may be mounted on the machine tool (spindle taper, turret bores). They constitute the limits of permissible deviations from nominal dimensions. They shall be expressed in units of length (e.g. deviations of bearings and bore diameters, for the setting up and the centring of tools).

Deviations should be indicated numerically or by the symbols given in ISO 286-1.

EXAMPLE

$80\ ^{+0,012}_{-0,007}$ or 80j6

2.321.2 Tolerances of form

Tolerances of form limit the permissible deviations from the theoretical geometric form (e.g. deviations relative to a plane, to a straight line, to a revolving cylinder, to the profile of a thread or a gear tooth). They shall be expressed in units of length or of angle. Because of the dimensions of the stylus surface or of the support surface, only part of the error of form is detected. Therefore, where extreme accuracy is required, the area of the surface covered by the stylus or support shall be stated.

The stylus surface and shape should be suitable for the microgeometry of the surface to be measured (a surface plate and the table of a heavy planing machine are not measured with the same stylus surface).

2.321.3 Tolerances of position

Tolerances of position limit the permissible deviations concerning the position of a component relative to a line, to a plane or to another component of the machine (e.g. deviation of parallelism, perpendicularity, alignment, etc.). They are expressed in units of length or angle.

When a tolerance of position is defined by two measurements taken in two different planes, the tolerance should be fixed in each plane, when the deviations from those two planes do not affect the working accuracy of the machine tool in the same way.

NOTE 1 When a position is determined in relation to surfaces showing errors of form, these errors should be taken into account when fixing the tolerance of position.

2.321.4 Influence of errors of form in determining positional errors

When relative positional errors of two surfaces or of two lines (see figure 1, lines XY and ZT) are being determined, the readings of the measuring instrument automatically include some errors of form. It shall be laid down as a principle that checking shall apply only to the total error, including the errors of form of the two surfaces or of the two lines. Consequently, the tolerance shall take into account the tolerance of form of the surfaces involved. (If thought useful, preliminary checks may ascertain errors of form of lines and of surfaces, of which the relative positions are to be determined.)

When displayed in a graph (see figure 1) the different readings mn of the measuring instrument result in a curve, such as ab. It is to be accepted, as a rule, that the error be determined using line AB instead of this curve, as stated in 5.211.1.

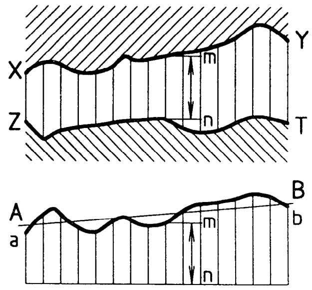

Figure 1

2.321.5 Local tolerances

Tolerances of form and position are usually related to the form or position as a whole (e.g. 0,03 per 1 000 for straightness or flatness). However, it may be desirable to limit the permissible deviation over a partial length to a different value. This is achieved by establishing a local tolerance related to a portion of the total length.

The local deviation is the distance between two lines parallel to the general direction of the part of the line or trajectory of the component which contains the maximum deviations of the partial length (see figure 2).

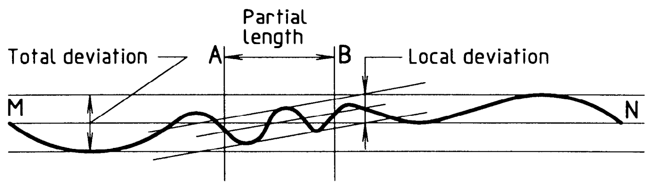

Figure 2

The value of the local tolerance (T_{local}) should be established:

— from the standard relating to a machine tool and for each particular test,

or

— as a proportion of the total tolerance (T_{total}), provided that it does not fall below a minimum value (normally 0,001 mm) (see figure 3).

In practice, local defects are generally imperceptible, as they are covered by the supporting or the detecting surfaces of the measuring instruments. However, when the detecting surfaces are relatively small (styli of dial gauges or micro-indicators), the measuring instrument should be such that the styli follow a surface of high-grade finish (straightedge, test mandrel, etc.).

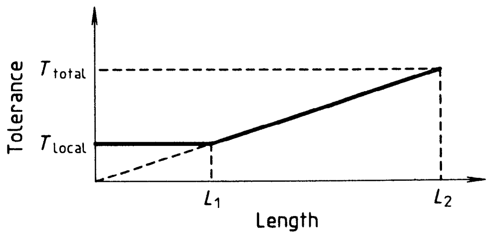

Figure 3

$$T_{local} = \frac{T_{total}}{L_2} \times L_1$$

EXAMPLE

T_{total} = 0,03 mm
L_2 = 1 000 mm
L_1 = 100 mm

Then

$$T_{local} = \frac{0,03}{1\ 000} \times 100$$
$$= 0,003 \text{ mm}$$

2.322 Tolerances applicable to the displacement of a component of a machine tool

NOTE 2 Positioning accuracy and repeatability of numerically controlled machine tools shall be referred to ISO 230-2.

2.322.1 Tolerances of positioning

Tolerances of positioning limit the permissible deviation of the position reached by a point on the moving part from its target position after moving.

EXAMPLE 1 (see figure 4)

At the end of the travel of a slide, the deviation d is the distance between the actual position reached and the target position. The tolerance of positioning is p.

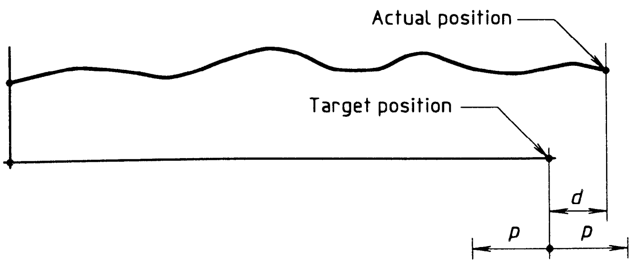

Figure 4

EXAMPLE 2

Angle of rotation of a spindle relative to the angular displacement of a dividing plate coupled to it (see figure 5). The tolerance of positioning is p.

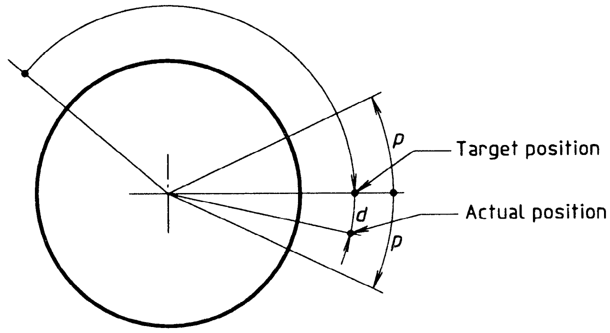

Figure 5

2.322.11 Tolerances of repeatability

Tolerances of repeatability limit the spread of deviations, when repeating movements approach the target in the same or opposite direction.

2.322.2 Tolerances of the form of trajectory

Tolerances of the form of trajectory limit the deviation of the actual trajectory of a point on the moving component relative to the theoretical trajectory (see figure 6). They shall be stated in units of length.

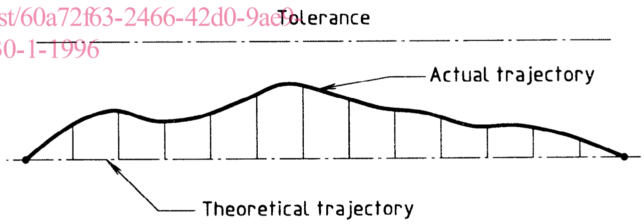

Figure 6

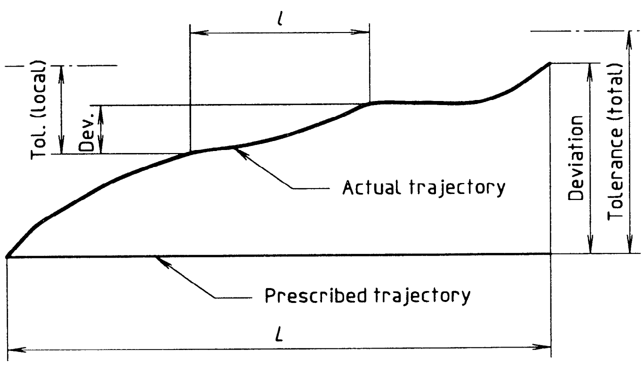

Figure 7

2.322.3 Tolerances of relative position of straight-line motion (see figure 7)

The tolerances of relative position of straight-line motion limit the permissible deviation between the trajectory of a point of the moving component and the prescribed direction (for example deviation of parallelism or perpendicularity between the trajectory and a line or a surface). They are expressed in units of length for the total length L or any measuring length of l.

2.322.4 Local tolerance of displacement of a component

Tolerances of positioning, form of the trajectory and direction of straight-line motion are also related to the total length of displacement of a component. When local tolerance is required, definition and establishment of the local tolerance value are similar to 2.321.5.

2.323 Overall or inclusive tolerances

The overall tolerances are intended to limit the resultant of several deviations which may be determined by a single measurement, without it being necessary to know each deviation.

EXAMPLE (see figure 8)

The deviation for the run-out of a shaft is the sum of the deviation of form (out-of-round of the circumference ab with which the stylus is in contact), the deviation of position (the geometric axis and the axis of rotation of the shaft do not coincide) and the deviation of out-of-round of the bore of the bearing.

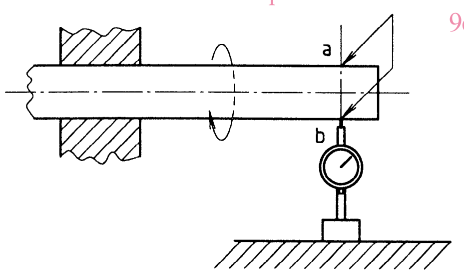

Figure 8

2.324 Symbols and positions of tolerances for relative angular positions of axes, slideways, etc.

When the position of the tolerance in relation to the nominal position is symmetrical, the sign ± may be used. If the position is asymmetrical, it shall be stated precisely, in words, either in relation to the machine or to one of the components of the machine.

2.325 Conventional definition of the axes and of the movements

In order to avoid using the terms transversal, longitudinal, etc., which are liable to create confusion, the axes of the displacements and rotations of the machine parts are designated by letters (e.g. X, Y, Z, etc.) and signs, in accordance with ISO 841.

3 Preliminary operations

3.1 Installation of the machine before test

Before proceeding to test a machine tool, it is essential to install the machine upon a suitable foundation and to level it in accordance with the instructions of the manufacturer.

3.11 Levelling

The preliminary operation of installing the machine shall involve (see 3.1) its levelling and is essentially determined by the particular machine concerned.

The aim of the levelling is to obtain a position of static stability of the machine which will facilitate subsequent measurements, especially those relative to the straightness of certain components.

3.2 Conditions of the machine before test

3.21 Dismantling of certain components

As the tests are carried out, in principle, on a completely finished machine, dismantling of certain components should only be carried out in exceptional circumstances, in accordance with the instructions of the manufacturer (e.g. dismantling of a machine table in order to check the slideways).

3.22 Temperature conditions of certain components before test

The aim is to evaluate the accuracy of the machine under conditions as near as possible to those of normal functioning as regards lubrication and warm-up. During the geometric and practical tests, components such as spindles, which are liable to warm up and consequently to change position or shape, shall be brought to the correct temperature by running the machine idle in accordance with the conditions of use and the instructions of the manufacturer.

Special conditions may be applied to high-precision machines and some numerically controlled machines for which temperature fluctuations have a marked effect on the accuracy.

It is necessary to consider how much the machine alters in dimensions during a normal working cycle from ambient to working temperature. The preliminary warm-up sequence and the ambient temperature at which the machine is to be tested should be the subject of agreement between the manufacturer and the user.