INTERNATIONAL STANDARD

ISO 10791-7

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Test conditions for machining centres —

Part 7:
Accuracy of a finished test piece

Conditions d'essai pour centres d'usinage —

Partie 7: Précision d'une pièce d'essai usinée

Reference number
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Contents

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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 10791-7 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 universal heads with horizontal primary rotary axis (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*

— *Part 12: Evaluation of the vibration severity*

Annex A of this part of ISO 10791 is for information only.

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.

The object of ISO 10791 is to supply information as wide and comprehensive as possible on tests which can be carried out for comparison, acceptance, maintenance or any other purpose.

ISO 10791 specifies, with 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.

Test conditions for machining centres —

Part 7:
Accuracy of a finished test piece

1 Scope

This part of ISO 10791 specifies, with reference to ISO 230-1, series of cutting tests, under finishing conditions, of standard test pieces, as well as the characteristics and dimensions of the test pieces themselves. This part of ISO 10791 is intended to supply minimum requirements for assessing the cutting accuracy of the machine. Different, more severe or more expensive tests may be performed by agreement between supplier/manufacturer and user.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10791. 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 10791 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 230-1:1996, *Test code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or finishing conditions.*

ISO 6462:1983, *Face milling cutters with indexable inserts — Dimensions.*

3 Preliminary remarks

3.1 Measuring units

In this part of ISO 10791, all linear dimensions, deviations and corresponding tolerances are expressed in millimeters, 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:

$$0{,}010/1\,000 = 10 \times 10^{-6} = 10\ \mu\text{rad} \approx 2''$$

3.2 Reference to ISO 230-1

To apply this part of ISO 10791, 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.

3.3 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. In order to make the mounting of instruments or gauging easier, tests may be performed in any order.

3.4 Tests to be performed

When testing a machine, it is not always necessary nor 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 are to be clearly stated when ordering a machine. 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 contracting party.

3.5 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 millimeters or better.

4 Types of test piece

In this part of ISO 10791, the two following types of test piece are considered, each of them in two sizes. Types, sizes and corresponding designation of the particular test piece are shown in table 1.

Table 1 — Types, sizes and designation of the test pieces

Type	Nominal size	Designation
A Positioning and contouring test piece	160 320	Test piece ISO 10791-7-A160 Test piece ISO 10791-7-A320
B Face milling test piece	80 160	Test piece ISO 10791-7-B80 Test piece ISO 10791-7-B160

In principle, no more than one piece of each type should be machined for acceptance purposes. In case of special requirements, such as statistical assessment of the machine performance, the machining of more test pieces is to be subject to agreement between supplier/manufacturer and user.

5 Location of test pieces

Extreme location positions for the test piece should only be adopted by agreement between supplier/manufacturer and user. Unless otherwise specified, the test piece should be placed approximately at mid-travel of the X axis, and in positions along Y and Z axes suitable for the location of the test piece and/or fixture, and for the tool lengths.

6 Fixing of test pieces

The test piece shall be conveniently mounted on a proper fixture, such that maximum stability of tools and fixture is achieved. The mounting surfaces of the fixture and of the test piece shall be flat. Parallelism between the contouring plane and the fixturing surface for the test piece should be checked. It is recommended that a suitable means of fixturing should be used to allow for tool breakthrough and full length machining of the centre hole. It is further recommended to mount the test piece on the fixture with countersink/counterbored screws, such that subsequent machining does not interfere with the screws. Other methods are possible and may be selected. Overall height of the test piece depends on the selected method of fixing.

7 Material of test pieces, tooling and cutting parameters

The material and the tooling for the test piece and the consequent cutting parameters are subject to agreement between supplier/manufacturer and user, and shall be recorded. Suggested cutting parameters are contained in clauses 9 and 10.

8 Size of test pieces

If the contouring test piece is machined several times, with a consequent reduction of external dimensions and increase of hole diameters, it is recommended that the final contouring test piece, when used for acceptance purposes, comply with the dimensions specified in this part of ISO 10791, so as to represent the cutting accuracy of the machine.

If the contouring test piece comes from previous cutting tests and is reused, its characteristic dimensions should remain within ± 10 % of those indicated in this part of ISO 10791. When the test pieces are reused, a shallow cut shall be made to clean up all surfaces before new finishing test cuts are taken.

It is also recommended that type and serial number of the machine, date of the test, and names and orientation of the axes are marked on the contouring test pieces, and that they are delivered with the machine, for reference purposes.

9 Positioning and contouring of test piece (Type A)

9.1 General

This test consists of positioning and boring of five holes and a series of finishing passes on different profiles, intended to check the performance of the machine under different kinematic conditions, i.e., one only axis feed, linear interpolation of two axes and circular interpolation.

This test is usually performed in the XY plane, and the indications shown below refer to this case, but can similarly be performed in the other planes when a universal head is available.

9.2 Dimensions

Two sizes of contouring test piece are considered in this part of ISO 10791, and their dimensions are shown in table 2.

Table 2 — Test piece dimensions

Dimensions in millimetres

Nominal size, *l*	*m*	*p*	*q*	*r*
320	280	50	220	100
160	140	30	110	52

The final shape of the test piece, as shown in figures 1 and 2, shall result from the following machining:

a) a through bored hole of diameter *p* located in the centre of the test piece;

b) an external square with side length *l* and a base square with side length *m*;

c) diamond (square inclined by 75°) with side length *q*, on the upper face of the square;

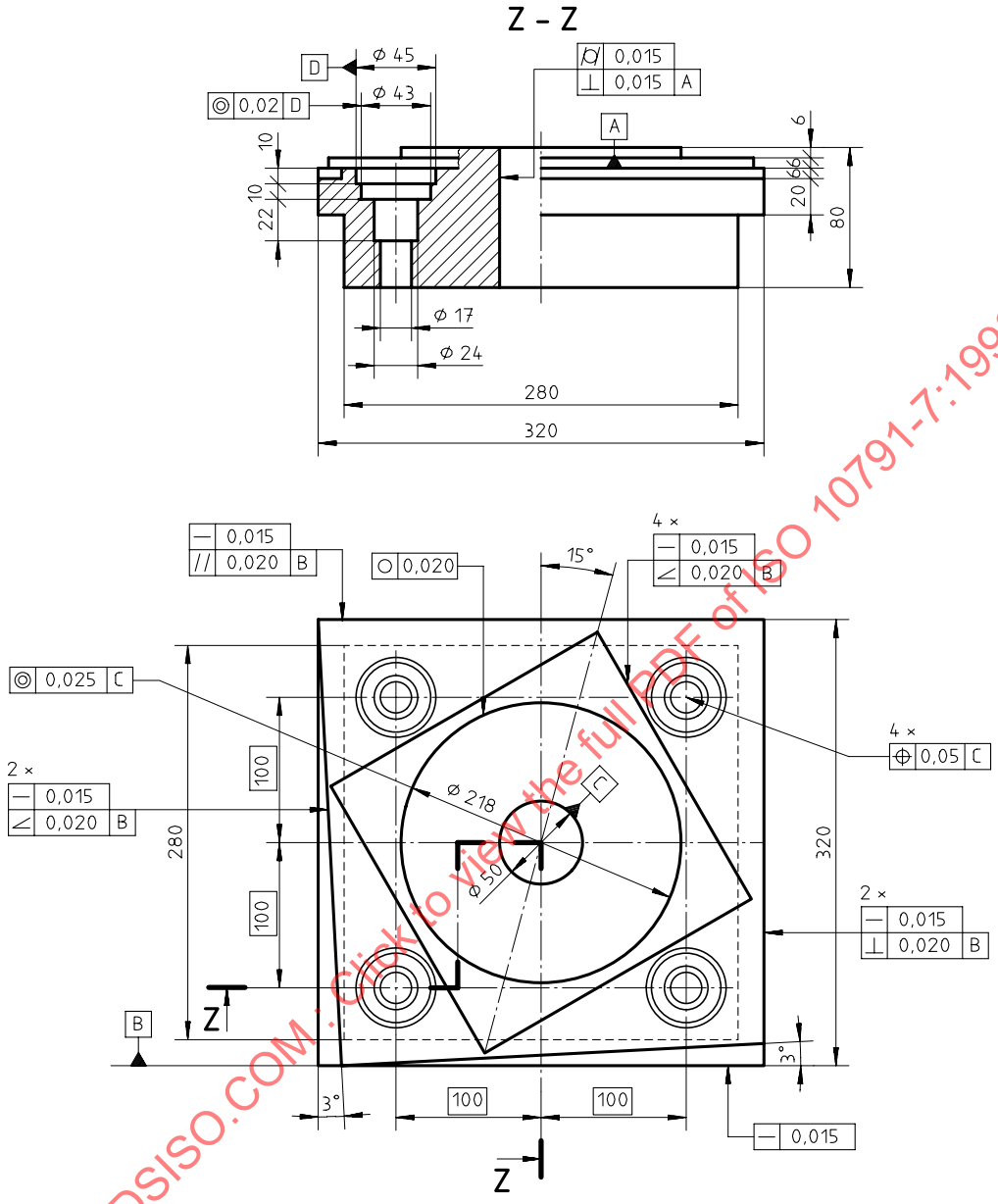
d) circle with a diameter of *q* – 2 mm and a depth of 6 mm, on the upper face of the diamond;

e) sloping faces, on full length of the two sides of the external square, with an angle of 3° or providing a tangent of 0,05 and a depth of 6 mm on the top of the external square sides;

f) four bored holes of diameter 26 mm (or 43 mm on the larger test piece) and four bored holes of diameter 28 mm (or 45 mm on the larger test piece); the holes of diameter 26 mm shall be approached in positive direction of the axes, the holes of diameter 28 mm in the negative direction. The location of these bores *r* from the centre of the part.

Since the different contouring surfaces are machined at different axial heights, face contact should be avoided by keeping the tool a fraction of millimeter apart from the lower plane surface. The overall height of the test piece depends on the selected method of fixing.

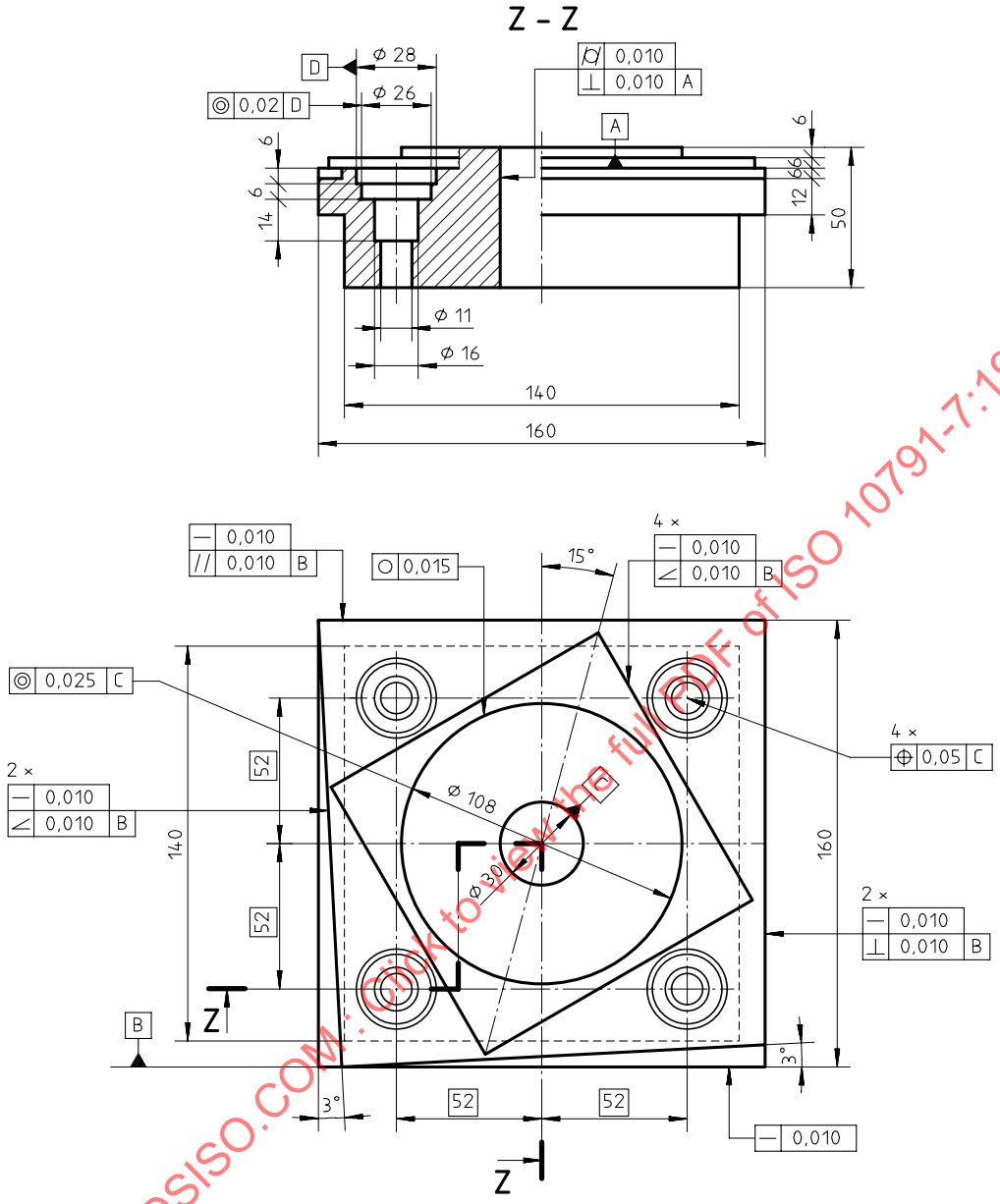
Dimensions in millimetres



NOTE — Fixing dimensions are related to M16 cap screws

Figure 1 — Large size contouring test piece

Dimensions in millimetres



NOTE — Fixing dimensions are related to M10 cap screws

Figure 2 — Small size contouring test piece

9.3 Tooling

The same tool can be used to machine all the contouring test surfaces; it can be an end mill with a cutting edge 35 mm long and 30 mm in diameter.

9.4 Cutting parameters

With reference to 9.3, the following cutting parameters are recommended.

9.4.1 Cutting speed

It should be about 50 m/min for cast iron and 300 m/min for aluminum.

9.4.2 Feed rate

It should be about 0,05 mm/tooth to 0,1 mm/tooth.

9.4.3 Depth of cut

It should be 0,2 mm in the radial direction for all the milling operations, and about 6 mm in the axial direction for the slab milling operations b), c) and d) of 9.2.

9.5 Blank and preliminary operations

The blank shall be provided with a square base on the lower face, with side length *m* and with appropriate depth depending on the selected method of fixing.

The counterbored holes for the fixing screws shall be located in the areas between the diamond sides and the corners of the square base, as shown in figures 1 and 2.

Preliminary cuts shall be taken in order to make the depth of cut as constant as possible.

9.6 Tests and tolerances

The tests and tolerances which apply to the test pieces machined in compliance with this part of ISO 10791 are given in table 3.

Table 3 — Contouring test piece geometric tests

Dimensions in millimetres

Object	Tolerances Nominal size *l* 320	 160	Measuring instruments
Central hole			
a) Cylindricity	0,015	0,010	CMM [1)]
b) Squareness between the hole axis and the basis A	0,015	0,010	CMM
Square			
c) Straightness of the sides	0,015	0,010	CMM or straightedge and dial gauge
d) Squareness of the adjacent sides to basis B	0,020	0,010	CMM or square and dial gauge
e) Parallelism of the opposite side to basis B	0,020	0,010	CMM or height gauge or dial gauge
Diamond			
f) Straightness of the sides	0,015	0,010	CMM or straightedge and dial gauge
g) Accuracy of 75° angles to basis B	0,020	0,010	CMM or sine bar and dial gauge
Circle			
h) Circularity	0,020	0,015	CMM or dial gauge or roundness measuring instruments
i) Concentricity of the external circle and the internal bored hole C	0,025	0,025	CMM or dial gauge or roundness measuring instruments
Sloping faces			
j) Straightness of the faces	0,015	0,010	CMM or straightedge and dial gauge
k) Accuracy of the angles to basis B	0,020	0,010	CMM or sine bar and dial gauge
Bored holes			
n) Position of the holes with respect to internal bored hole C	0,05	0,05	CMM
o) Concentricity of inner hole to outer hole D	0,02	0,02	CMM or dial gauge or roundness measuring instruments

1) Coordinate measuring machine.

NOTES

1 If possible, take the test piece to a coordinate measuring machine (CMM) and take the required measurements.

2 For the straight sides (or the square, diamond and sloping faces), touch the measured surface by the probe at least at ten points in order to obtain the straightness, squareness and parallelism deviations.

3 For the circularity (or cylindricity) test, if the measurement is not continuous, check at least fifteen points (for cylindricity in each measured plane). For circularity, continuous measurements with no filtering is recommended.

9.7 Information to be recorded

For tests made according to the requirements of this part of ISO 10791, the following information shall be compiled as completely as possible and included in the test report:

a) material and designation of the test piece;

b) material and dimensions of the tool;

c) cutting speed;

d) feed rate;

e) depth of cut;

f) choice between 3^{o} and tangent 0,05 for the sloping faces.

10 Face milling test piece

10.1 General

The purpose of this test is to check the flatness of a surface machined by a finish face milling operation performed by two cuts overlapping by about 20 % of the cutter diameter. Usually the test is performed by a longitudinal movement along the X axis and a transverse movement along the Y axis, but can be performed otherwise, subject to agreement between supplier/manufacturer and user.

10.2 Dimensions

A choice of two sets of dimensions for test piece and relevant tooling is left to agreement between the supplier/manufacturer and the user.

In table 4 below, the face width of the test piece is related to the cutter diameter in order to maintain a ratio of 1:1,6, which provides two cuts as wide as 80 % of the cutter diameter.

In order to have almost the same width of cut during the two cuts, in the first cut the cutter shall protrude from the face of the test piece by about 20 % of its diameter. In the second cut, the cutter shall protrude from the other side by about 1 mm (see figure 3). The length of the test piece should be 1,25 times to 1,6 times the face width.

Table 4 — Cutting parameters

Face width *W* mm	**Face length** *L* mm	**Cut width** *w* mm	**Cutter diameter** mm	**Number of teeth**
80	100 to 130	40	50	4
160	200 to 250	80	100	8

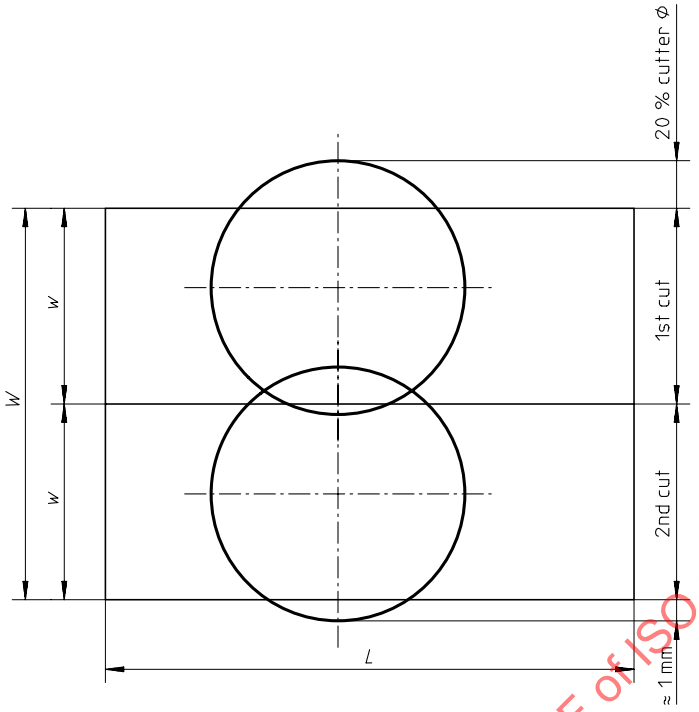


Figure 3 — Pattern of the face milling test

10.3 Tooling

Face milling cutter with indexable inserts (see ISO 6462).

10.4 Cutting parameters

Although the material of the test piece has not been specified, if cast iron is used, table 4 can supply a guide for the dimensions and cutting parameters to be adopted.

With a feed rate of 300 mm/min, the feed per tooth is almost constant and close to 0,12 mm. The depth of cut should not exceed 0,5 mm. The axis square to the machined surface (usually Z) should be locked during cutting, if possible.

10.5 Blank and preliminary operations

The blank shall be provided with a base suitable for being fastened to the work holding table/pallet or to a fixture, providing a sufficient stiffness both for horizontal and vertical machines. Preliminary cuts should be taken in order to make the depth of cut as constant as possible.

When mounted, the cutter shall conform to the following tolerances:

a) run-out $\leqslant$ 0,02 mm;

b) camming $\leqslant$ 0,03 mm.