IEC 62899-301-1

Edition 1.0 2017-05

INTERNATIONAL STANDARD

colour inside

Printed electronics –
Part 301-1: Equipment – Contact printing – Rigid master – Measurement method of plate master external dimension

IEC 62899-301-1:2017-05(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

IEC 62899-301-1

Edition 1.0 2017-05

INTERNATIONAL STANDARD

Printed electronics –
Part 301-1: Equipment – Contact printing – Rigid master – Measurement method of plate master external dimension

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 19.080; 37.100.10

ISBN 978-2-8322-4302-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

PRINTED ELECTRONICS –

Part 301-1: Equipment – Contact printing – Rigid master – Measurement method of plate master external dimension

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62903-1 has been prepared by IEC technical committee:119: Printed electronics.

The text of this standard is based on the following documents:

FDIS	Report on voting
119/152/FDIS	119/162/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62899 series, published under the general title *Printed electronics*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

When dissecting the term “printed electronics”, it can be easily understood that this industry involves electronic devices and products that are made using some kind of printing technique. Printing methods have been widely used in textile and paper type substrates for centuries. In the past, the advent of mass producible printouts has brought huge impacts on how knowledge is stored, transferred and reproduced. At this current stage of technological development, printing on either rigid or flexible substrates is considered to supplement or replace traditional electronic device manufacturing processes. The difference between media printing and printed electronics stems from the fact that media print is used to convey information for humans to process using their eyes while printed electronics requires machines to process electronic information; the level of required resolution and functionality makes the difference. Some of the widely used functional materials for printed electronics are though not limited to: nano- or micro-size metal particles, semiconductive polymers, and dielectric materials. Due to the available and required readout resolution, small feature sizes below 20 μm need to be printed. Layer thickness and registration accuracy of printed products are closely related to the quality control of electronic devices and ink materials require a high level of quality. Overall, printing tolerance is much smaller in printed electronics.

There are two main categories in the printing process for the printed electronics. One is a non-contact printing process, such as inkjet printing and electrostatic discharge (ESD) printing process. The other is a contact printing process such as gravure printing, gravure offset printing, reverse offset printing and screen printing. This document provides a proposal for measuring and assessing the printing master, therefore the scope is limited to the printing process using the printing master.

The quality of the printing master is important because the ink is transferred from the printing master to the substrate directly in these processes, which means that the quality of the results of the printed circuit depends on the quality of the printing master. For a mass production of the printed electronic devices, many companies such as device manufacturers, printing master manufacturers and printing master manufacturing equipment vendors are related to manufacturing and they would be using the printing master and the standardized measurement and assessment methods.

PRINTED ELECTRONICS –

Part 301-1: Equipment – Contact printing – Rigid master – Measurement method of plate master external dimension

1 Scope

This part of IEC 62899 defines measurement terms and methods related to the external dimension of a rigid plate master.

Measurement terms include geometrical size such as edge length, edge squareness, edge straightness and thickness, flatness of plate master substrates, and surface roughness of plate master.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
plate master
device that carries the image to be printed

Note 1 to entry: The image on the plate may be raised above the surface (relief) or may be carved into the surface.

3.2
geometrical definition of plate master
definition which is needed in order to determine the shape and size of the plate

3.3
orientation corner
asymmetric corner specified for the purpose of mechanical orientation and the operator's visual confirmation of plate orientation

Note 1 to entry: This term is introduced graphically in Figure 1.

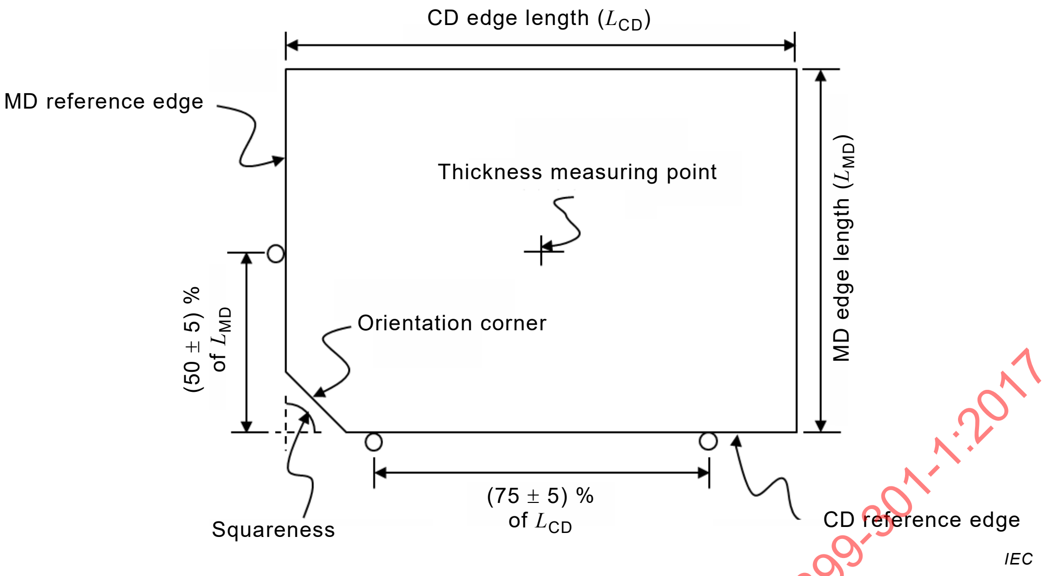


Figure 1 – Illustration of the terms defined for measuring the geometrical size of a plate master

3.4
machine direction
MD
direction in which the stock flows

Note 1 to entry: It can also mean circumferential direction of a roll of substrate.

3.5
CD
cross direction
direction at right angles to the machine direction of a substrate

3.6
reference edges
two edges adjacent to the orientation corner which are used for referencing the position of the plate master

Note 1 to entry: This term is introduced graphically in Figure 1.

3.7
MD reference edge
reference edge parallel with the MD

Note 1 to entry: This term is introduced graphically in Figure 1.

3.8
CD reference edge
reference edge parallel with the CD

Note 1 to entry: This term is introduced graphically in Figure 1.

3.9
edge length
length and width of edges in a rectangular plate master

Note 1 to entry: This term is introduced graphically in Figure 1.

Note 2 to entry: L_{MD} and L_{CD} are the edge length of the MD reference edge and CD reference edge, respectively.

3.10
edge squareness
angular variation of MD reference edge relative to straight lines drawn between the ends of, and perpendicular to, the CD reference edge of the plate master

Note 1 to entry: This term is introduced graphically in Figure 1.

3.11
edge straightness
S_t
deviation of an edge relative to a straight line

3.12
reference plane
user-defined flat plane approximating the front surface of a plate master and containing a coordinate system

Note 1 to entry: The same definition is applied for the measurement of flatness and surface roughness.

3.13
thickness of the plate master
relative distance of the plate master from the bottom surface to the front surface at the center position in the normal direction of the reference plane

Note 1 to entry: This term is introduced graphically in Figure 1.

3.14
flatness of plate master substrate
thickness variation of the entire plate master front surface relative to a reference plane when the substrate back surface is constrained against an ideally flat surface

Note 1 to entry: This term is introduced graphically in Figure 2.

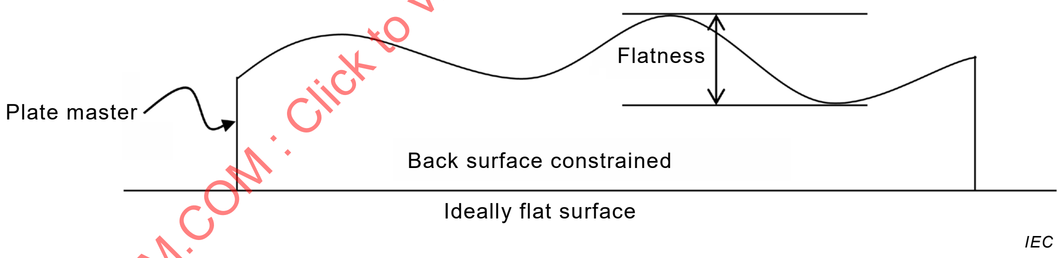


Figure 2 – Graphical illustration of flatness [1][1]

3.14.1
flatness cut-off wavelength
wavelength at which the attenuation ratio of its amplitude becomes a standard value when the traced profile is passed through the filter which eliminates the roughness element

3.14.2
profile
positive and negative vertical deviations measured from the reference plane

1 Numbers in square brackets refer to the Bibliography.

3.14.3
traced length
total traversing length of the measurement probe in the apparatus to measure the flatness profile

3.14.4
height of point
Z_i
height of any point in the profile from the reference plane

3.14.5
***z* direction**
direction perpendicular to the reference plane

3.15
profile parameter
parameter for evaluating the flatness in a single profile

3.15.1
R_a
average deviation from the mean of all the heights over the length of the profile

3.15.2
R_{max}
maximum height difference between the highest and lowest points on a profile over the length of the profile or in the region of interest (ROI)

3.15.3
R_z
average difference in height between the five highest peaks and the five lowest valleys over the length of the profile or in the region of interest (ROI)

3.16
flatness parameter
parameter for evaluating the flatness in all profiles

3.16.1
mean flatness
average deviation from the mean of all heights in all profiles

3.16.2
maximum flatness
maximum height difference between the highest and lowest points in all profiles

3.17
surface roughness of plate master
surface irregularities with a spatial wavelength smaller than the roughness cut-off wavelength

3.17.1
roughness cut-off wavelength
wavelength at which the attenuation ratio of its amplitude becomes a standard value when the traced profile is passed through the filter which eliminates flatness and waveness elements

3.17.2
raster scan
repetitive scanning in the CD direction while moving stepwise in the MD direction

3.17.3
region of interest
ROI
area in which the surface parameters are calculated

3.17.4
surface roughness parameters
parameters for evaluating the surface roughness over the ROI

3.17.5
RMS surface roughness
$Z_{\mathbf{rms}}$
height deviation by calculating the root-mean-square method in the ROI

4 Measurement methods for geometrical size of plate master

4.1 General

Two types of measurement methods are specified. A simple test method with a comparator such as a dial gauge is defined in procedure A (4.2) and a precise test method with a coordinate measuring machine (CMM) is specified in procedure B (4.3).

4.2 Procedure A

4.2.1 Measuring instrument

The instrument is a comparator method measuring instrument with a standard specimen.

a) Comparator repeatablity
   - Less than 10 % of the tolerance specification of each measurement term. The specification is outside the scope of this document.

b) Standard specimen
   - The accuracy of the standard specimen should be less than 10 % of the tolerance specification of each measurement term.

c) Calibration
   - Calibration should be carried out periodically in accordance with the guidelines of the instrument manufacturer.
   - It is recommended that standard specimens are certified to a recognized industry standard.

d) Measurement condition
   - It is recommended that the measurement is carried out at the temperature of 20 °C which is specified as the standard reference temperature in ISO 1 [7].

4.2.2 Measurement of edge length

4.2.2.1 Procedure

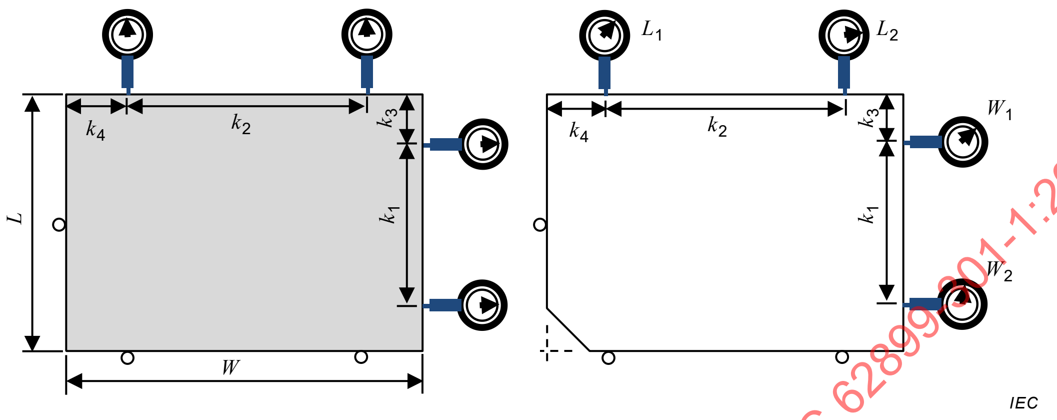
The procedure is as follows:

a) Put the length standard specimen on the flat surface with a 3-pin alignment.
b) Two comparators (e.g. dial gauges) are inserted into the specimen as shown in Figure 3.
c) Adjust the dial gauges to zero and remove the standard specimen.
d) Put the plate master on the flat surface with the same 3-pin alignment as given in item a).
e) Read four dial gauge values (L_1, L_2, W_1, W_2) (see Figure 3).

f) Calculate the CD edge length and MD edge length using Formula (1).

$$L_{MD} = L + \frac{1}{2}(L_1 + L_2), L_{CD} = W + \frac{1}{2}(W_1 + W_2) \quad (1)$$

NOTE W and L are the width and length of the standard specimen which represent the CD and MD edge lengths respectively.



Key

k_1= (0,7 ± 0,05) × MD edge length

k_2= (0,7 ± 0,05) × CD edge length

k_3= (0,15 ± 0,05) × MD edge length

k_4= (0,15 ± 0,05) × CD edge length

Figure 3 – Measurement procedure of edge length

4.2.2.2 Report

The report should contain the following:

- Provide the measured CD and MD edge lengths.
- Show the results in units of 0,1 mm.
- Specify the accuracy of the standard specimen and the repeatability of the measurement instrument.
- Specify the measurement temperature and temperature variation during the measurement.

4.2.3 Edge squareness [1][2]

4.2.3.1 Procedure

The procedure is as follows:

a) Put the squareness standard specimen on the flat surface with a 3-pin alignment.

b) Two comparators (e.g. dial gauges) are inserted into the specimen as shown in Figure 4.

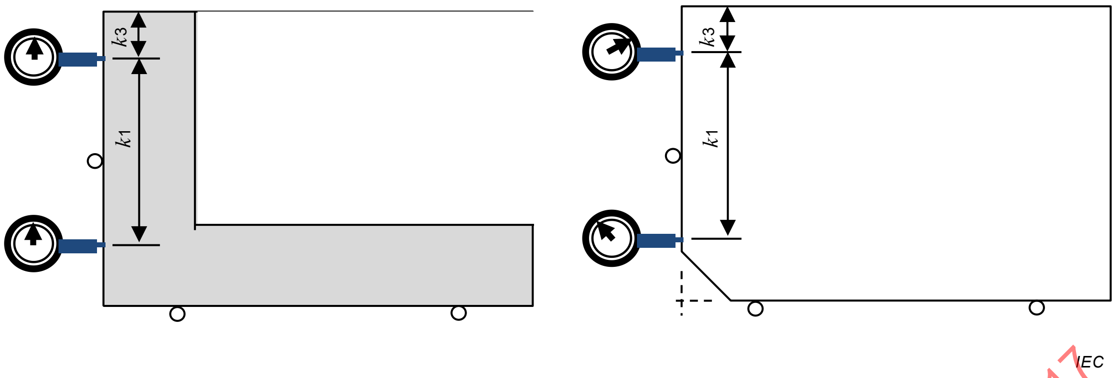
c) Adjust the dial gauges to zero and remove the standard specimen.

d) Put the plate master on the flat surface with a 3-pin alignment.

e) Read the two dial gauge values (S_1, S_2).

f) Calculate the edge squareness (S) using Formula (2).

$$S = \frac{S_2 - S_1}{k_1} \quad (2)$$



Key

k_1 = (0,7 ± 0,05) × MD edge length

k_3 = (0,15 ± 0,05) × MD edge length

Figure 4 – Measurement procedure of edge squareness

4.2.3.2 Report

The report should contain the following:

- Provide the measured edge squareness.
- Show the results in units of 0,1°.
- Specify the accuracy of the standard specimen and the repeatability of the measurement instrument.
- Specify the measurement temperature and temperature variation during the measurement.

4.2.4 Measurement of edge straightness

4.2.4.1 General

The edge straightness should be measured because the measurement accuracy of edge length and edge squareness is affected by edge straightness. More generally, the straightness of the two reference edges is important because they are used as the position reference of the plate master.

4.2.4.2 Procedure

The procedure illustrated in Figure 5 is as follows:

a) Set up a comparator (e.g. dial gauge) in a linear guided stage system.

b) Put the straightness standard specimen against the comparator in parallel with the motion direction of the linear stage system.

c) Measure the value of the comparator (y_i) at each x_i position of the linear stage. The x_i is distributed equidistantly with the interval of Δx.

d) Remove the standard specimen.

e) Put the measured edge of the plate master against the comparator in parallel with the motion direction of the linear stage system.

f) Measure the value of the comparator (Δy_i) at each x_i position of the linear stage.

g) Calculate an approximation line (line of best fit using the least square method) of the edge from the data set of $\{(x_1, y_{1,2}\text{-}y_{1,1}),\ldots, (x_i, y_{i,2}\text{-}y_{i,1}),\ldots(x_n, y_{n,2}\text{-}y_{n,1})\}$.

$$y = mx + b \tag{3}$$

h) Obtain the data set of the edge point deviation $\{\Delta y_1, \Delta y_2, \ldots, y_n\}$.

$$\Delta y_i = (y_{i,2} - y_{i,1}) - mx_i - b \quad (i = 1, 2, \ldots, n) \tag{4}$$

i) Calculate the edge straightness.

$$S_t = P_1 - V_1 \tag{5}$$

where

P_1 is the highest peak among Δy_i

V_1 is the deepest valley among Δy_i

j) Repeat procedures b) to i) for the other edges.

4.2.4.3 Report

The report should contain the following:

- Provide the measured edge straightness with the measurement interval of Δx and the total measured length of $(x_n - x_1)$.
- Show the results in units of 0,1 mm.
- Specify the accuracy of the standard specimen and the repeatability of the measurement instrument.
- Specify the measurement temperature and temperature variation during the measurement.

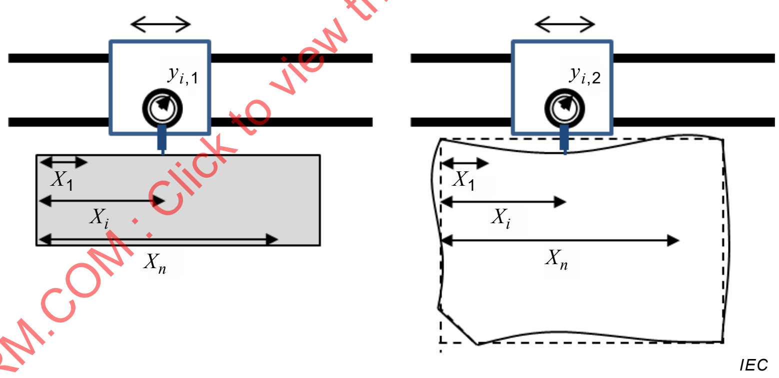


Figure 5 – Measurement procedure of edge straightness

4.2.5 Thickness

4.2.5.1 Procedure

The procedure is as follows:

a) Place and clamp the thickness standard specimen on the flat surface: the edge length of the thickness standard does not need to be equal to that of the plate master.

b) Locate a dial gauge $L/2$ away from the MD reference edge and $W/2$ away from the CD reference edge to measure the z direction of the thickness standard.

c) Adjust the dial gauges to zero and remove the standard specimen.

d) Place and clamp the plate master on the flat surface with a 3-pin alignment.

e) Read the dial gauge value (T_1).

NOTE The thickness variation will be handled in the measurement of the flatness.

4.2.5.2 Report

The report should contain the following:

- Provide the measured thickness value: $T + T_1$ (T: thickness of standard specimen).
- Show the results in units of 0,1 mm.
- Specify the accuracy of the standard specimen and the repeatability of the measurement instrument.
- Specify the measurement temperature and temperature variation during the measurement.

4.3 Procedure B

4.3.1 Measuring instrument

The measuring instrument is a coordinate measuring machine:

a) Accuracy of the measuring instrument
   - Less than 10 % of the tolerance specification of each measurement term. The specification is outside the scope of this document.

b) Calibration
   - Calibration should be carried out periodically in accordance with the guidelines of the instrument manufacturer.

c) Measurement condition
   - It is recommended that the measurement is carried out at the temperature of 20 °C which is specified as the standard reference temperature in ISO 1 [7].

4.3.2 Procedure

The procedure is as follows:

a) Place and clamp the plate master on the flat surface so that the CD reference edge is parallel to the x-axis of the CMM.

b) Measure the edge positions of more than two points on each edge as shown in Figure 6. It is recommended that the distance (k_2) between the farthest two measured points on the CD edges be larger than half of the CD edge length, and that the distance (k_1) between the farthest two measured points on the MD edges be larger than half of the MD edge length. To measure the edge straightness, more than three points in each edge should be measured.

c) Calculate the line equations of four edges in the CMM coordinate by the least square fitting.

d) Calculate squareness (S) using Formula (2) from two line equations of the reference edges.

e) Calculate the edge straightness using the method given in 4.2.4.

f) Calculate four vertices of the master plate in the CMM coordinate.

g) Calculate the CD edge length (L_{CD}) and the MD edge length (L_{MD}) from three vertices.

h) Measure the height (H_P) of the plate master at center position: the center position can be determined by procedures a) to f). The MD center line is determined by the two line equations of the vertical edges and the CD center line is determined by the two line equations of the horizontal edges. The center point is obtained by the cross point of the two center lines.

i) Remove the plate master and measure the height (H_F) of flat plane at the same position used in procedure h).

j) Calculate the thickness of the master plate by subtracting H_F from H_P.

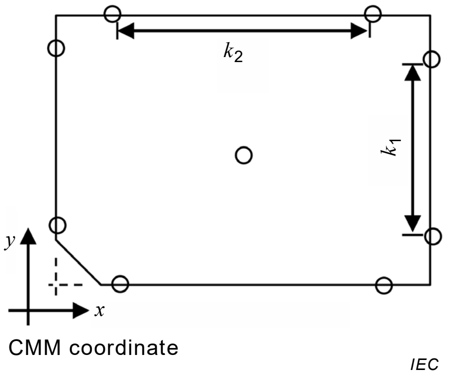


Figure 6 – Measurement locations for geometrical size of plate using CMM

4.3.3 Report

The report should contain the following:

- Provide the measured CD edge length and MD edge length in units of 0,1 mm.
- Provide the measured edge squareness in units of 0,1°.
- Provide the measured edge straightness in units of 0,1 mm.
- Provide the measured thickness of the master plate in units of 0,01 mm.
- Specify the accuracy of the measurement instrument.
- Specify the measurement temperature and temperature variation during the measurement.

5 Measurement method for flatness of plate master substrate [4]

5.1 Measuring instrument

5.1.1 Method

Mechanical or optical stylus measuring instrument.

5.1.2 Mechanical stylus measuring instrument

The mechanical stylus measuring instrument is as follows:

- Shape of tip: Sphere.
- Tip radius: To be agreed upon between user and supplier.
- Measuring force: To be agreed upon between user and supplier.
- Repeatability: Less than 10 % of the tolerance specification of the flatness.

5.1.3 Optical stylus measuring instrument

The optical stylus measuring instrument is as follows:

- Diameter of spotlight: To be agreed upon between user and supplier.
- Repeatability: Less than 10 % of the tolerance specification of the flatness.

5.1.4 Calibration

Calibration should be carried out periodically in accordance with the guidelines of the instrument manufacturer.

5.1.5 Environment control

Temperature control and acoustic/vibration isolation are to be provided as necessary to obtain an artifact-free profile.

5.1.6 Measurement conditions

The measurement conditions are as follows:

- Target surface: The pattern surface of the master plate.
- Profile filter: To be agreed upon between user and supplier.
- Traced length: To be agreed upon between user and supplier.
- Sampling interval: To be agreed upon between user and supplier.
- Flatness cut-off wavelength: To be agreed upon between user and supplier.
- Measurement temperature: It is recommended that the measurement be carried out at the temperature of 20 °C which is specified as the standard reference temperature in ISO 1 [7].

NOTE The traced length, sampling interval and flatness cut-off length can be varied according to the size difference of the master plate.

5.1.7 Measurement location

The measurement location has the following characteristics:

- At least 5 lines parallel to CD reference edge. The lines are distributed equidistantly and cover the entire surface area of the plate master. Traced length is recommended to be larger than 95 % of L_{CD}.
- At least 5 lines parallel to the MD reference edge. The lines are distributed equidistantly and cover the entire surface area of the plate master. Traced length is recommended to be larger than 95 % of L_{MD}.
- The patterned area should be avoided.

5.2 Procedure

The procedure is as follows:

a) Put the plate master on the instrument with the constraining back surface of the plate and leave for 5 min or more to condition the plate master to room temperature.

b) Put the stylus on the plate master and measure a real profile parallel to two reference edges by tracing the surface: the measurement location is defined in the measurement condition.

c) Apply the filter using the flatness cut-off wavelength to the real profile and get the flatness profile by removing the roughness component.

d) Remove the plate master.

e) Repeat procedures b) to c) on the instrument plane on which the plate master is constrained.

f) Calculate the compensated profiles of the plate master by subtracting the surface profile of the reference plane from the surface profile.

g) Calculate the profile parameters (R_a, R_z, R_{max}) for each profile.

$$R_a = \left(\frac{1}{N}\right)\sum_{i=1}^{N}\left|Z_i - \overline{Z}\right| \tag{6}$$

$$R_Z = \frac{1}{5}\left(\sum_{i=1}^{5} P_i + \sum_{i=1}^{5} V_i\right) \quad (7)$$

$$R_{max} = P_1 - V_1 \quad (8)$$

where

Z_i is the height of points (x,y) over a single profile,

i is the number of measurements in a single profile,

N is the number of data points over a single profile,

P_i is the i^{th} highest peak over the profile length,

V_i is the i^{th} deepest valley over the profile length.

If the reference plane is regarded as ideally flat, which means that all profile parameters of each line in procedure f) are smaller than 10 % of the profile parameters of each line in procedure d), the procedures e) to f) can be omitted.

5.3 Report

The report should contain the following:

a) Show the profile measurement results in µm and round-off to a fraction of 0,5 (see Table 1).

Table 1 – Example of profile measurement results

Measured location	R_a	R_{max}	R_z
CD scan #*	** µm	** µm	** µm
CD scan #*	** µm	** µm	** µm
MD scan #*	** µm	** µm	** µm

b) Show the flatness measurement results in µm and round-off to a fraction of 0,5 (see Table 2).

Table 2 – Example of flatness measurement results

	R_a	R_{max}	R_z
Flatness	** µm	** µm	** µm

c) Specify the measurement instrument and measurement conditions

- Measurement instrument: Type of instrument, name of maker and model, tip radius, and measuring force.
- Measurement condition: Profile filter, flatness cut-off length, measurement location, traced length, sampling interval, measurement temperature and temperature variation during measurement.

d) Provide the profile plot of each line.