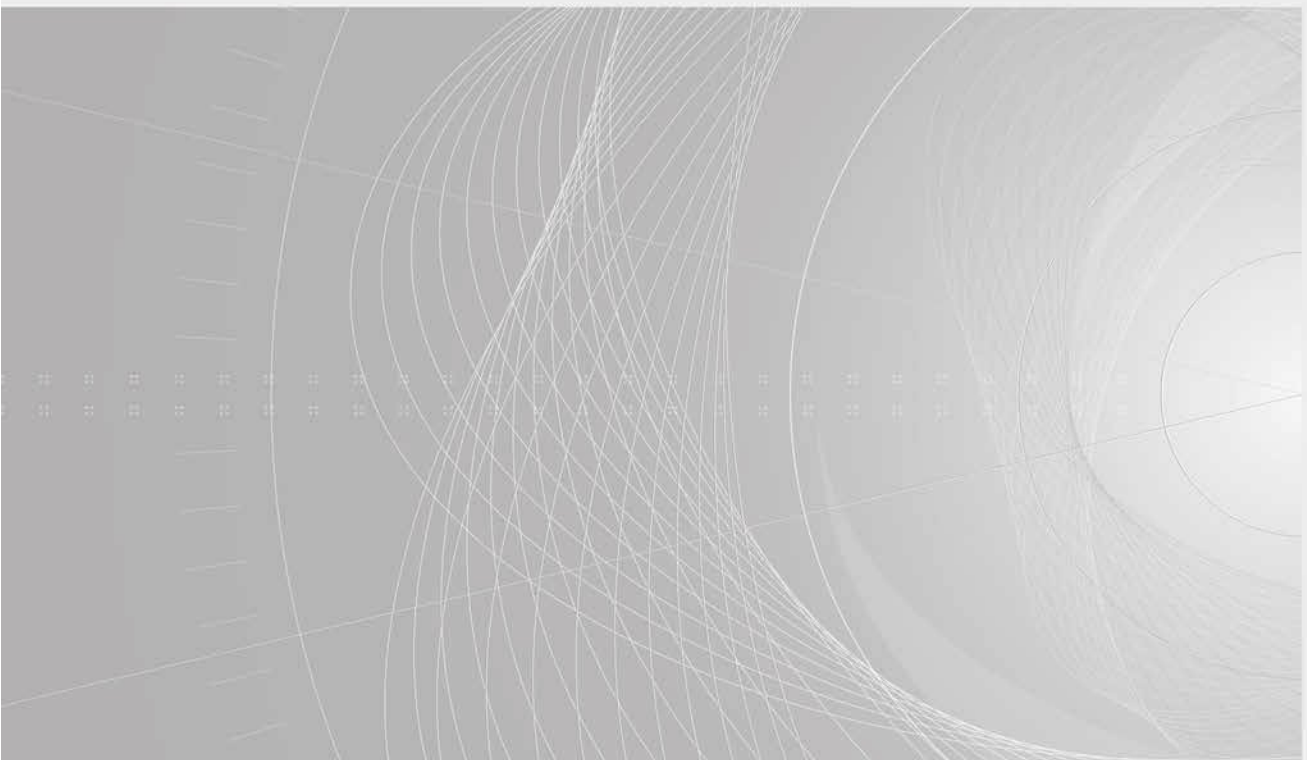


# INTERNATIONAL STANDARD



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





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# INTERNATIONAL STANDARD



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

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PRINTED ELECTRONICS –**

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

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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- withdrawn,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.

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## 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  $\mu\text{m}$  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**

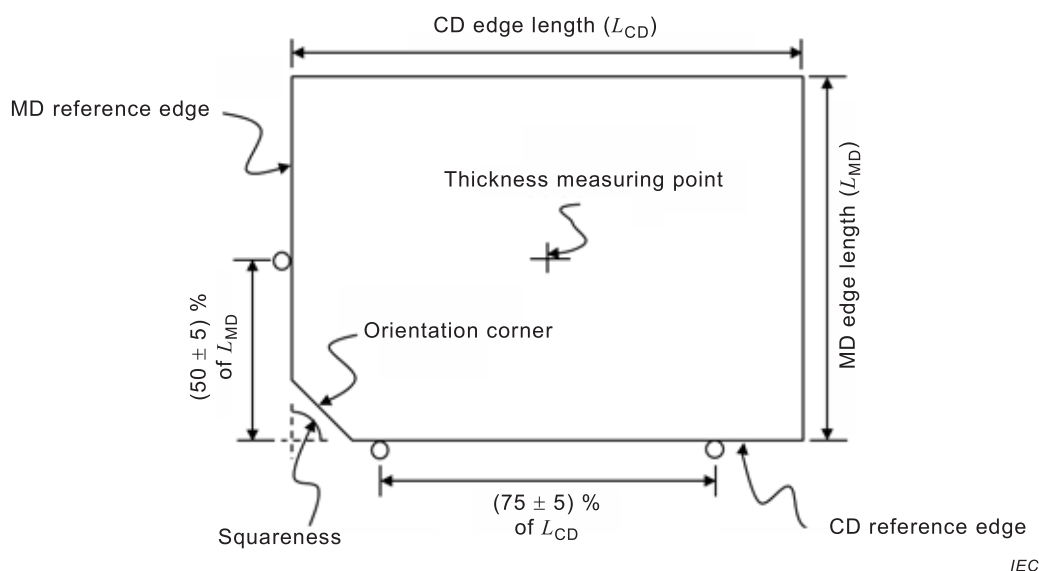
definition which is needed in order to determine the shape and size of the plate

##### 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 cross direction CD**

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**

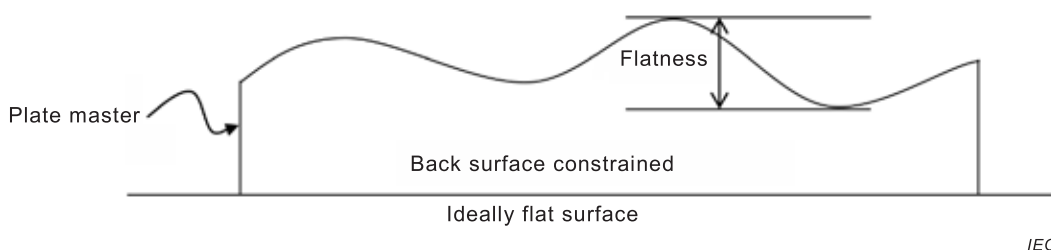
relative distance of the plate master from the bottom surface to the front surface at the center position in the normal direction of the reference plane

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.



IEC

**Figure 2 – Graphical illustration of flatness [1]<sup>1</sup>**

**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

<sup>1</sup> 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** $Z_{\text{rms}}$ 

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 repeatability

- 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**

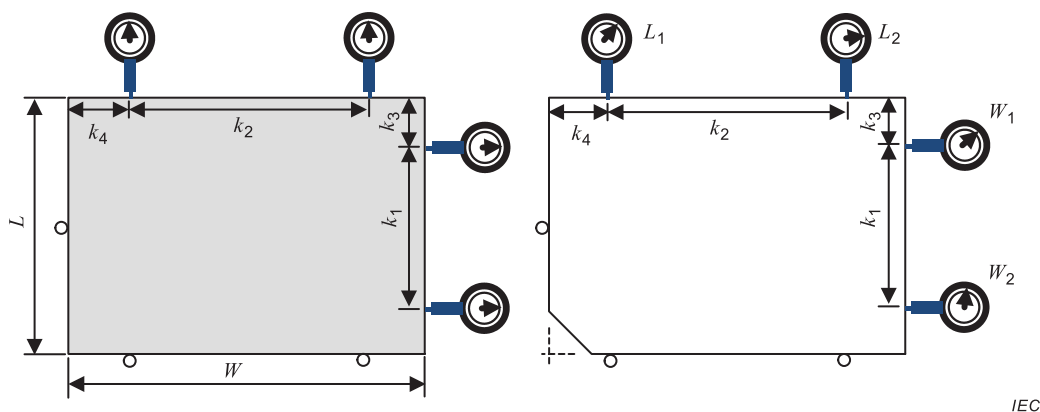
The procedure is as follows:

- 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**

$k_1 = (0,7 \pm 0,05) \times$  MD edge length

$k_2 = (0,7 \pm 0,05) \times$  CD edge length

$k_3 = (0,15 \pm 0,05) \times$  MD edge length

$k_4 = (0,15 \pm 0,05) \times$  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.

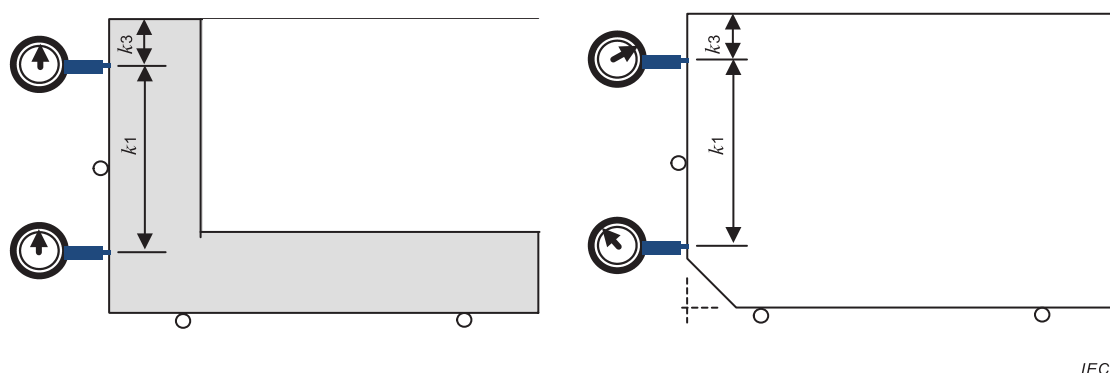
**4.2.3 Edge squareness [1][2]**

**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**

$$k_1 = (0,7 \pm 0,05) \times \text{MD edge length}$$

$$k_3 = (0,15 \pm 0,05) \times \text{MD edge length}$$

**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  $0,1^\circ$ .
- 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:

- Set up a comparator (e.g. dial gauge) in a linear guided stage system.
- Put the straightness standard specimen against the comparator in parallel with the motion direction of the linear stage system.
- 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  $\Delta x$ .
- Remove the standard specimen.
- Put the measured edge of the plate master against the comparator in parallel with the motion direction of the linear stage system.
- Measure the value of the comparator ( $\Delta y_i$ ) at each  $x_i$  position of the linear stage.
- Calculate an approximation line (line of best fit using the least square method) of the edge from the data set of  $\{(x_1, y_{1,2}-y_{1,1}), \dots, (x_i, y_{i,2}-y_{i,1}), \dots, (x_n, y_{n,2}-y_{n,1})\}$ .

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

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

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

i) Calculate the edge straightness.

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

where

$P_1$  is the highest peak among  $\Delta y_i$

$V_1$  is the deepest valley among  $\Delta y_i$

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  $\Delta x$  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.

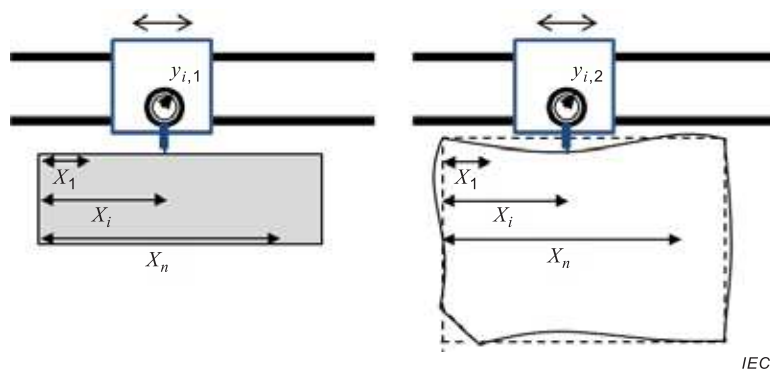


Figure 5 – Measurement procedure of edge straightness

#### 4.2.5 Thickness

##### 4.2.5.1 Procedure

The procedure is as follows:

- 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.
- 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.
- Adjust the dial gauges to zero and remove the standard specimen.
- Place and clamp the plate master on the flat surface with a 3-pin alignment.
- 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:

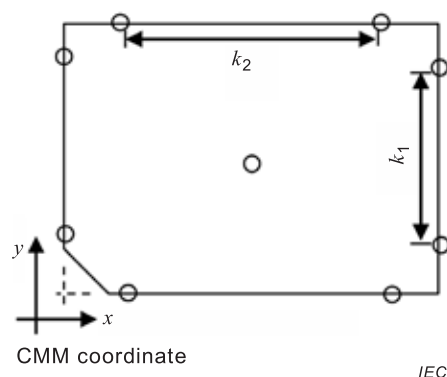
- a) Accuracy of the measuring instrument
  - Less than 10 % of the tolerance specification of each measurement term. The specification is outside the scope of this document.
- b) Calibration
  - Calibration should be carried out periodically in accordance with the guidelines of the instrument manufacturer.
- 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.

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

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

$$R_{\max} = P_1 - V_1 \tag{8}$$

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  $i^{\text{th}}$  highest peak over the profile length,

$V_i$  is the  $i^{\text{th}}$  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  $\mu\text{m}$  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 #*	** $\mu\text{m}$	** $\mu\text{m}$	** $\mu\text{m}$
CD scan #**	** $\mu\text{m}$	** $\mu\text{m}$	** $\mu\text{m}$
MD scan #*	** $\mu\text{m}$	** $\mu\text{m}$	** $\mu\text{m}$

- b) Show the flatness measurement results in  $\mu\text{m}$  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	** $\mu\text{m}$	** $\mu\text{m}$	** $\mu\text{m}$

- 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.

## **6 Measurement method for surface roughness of plate master substrate [5]**

### **6.1 Measuring instrument**

#### **6.1.1 Method**

Mechanical or optical stylus measuring instrument.

#### **6.1.2 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 surface roughness.

#### **6.1.3 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 surface roughness.

#### **6.1.4 Calibration**

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

#### **6.1.5 Environment control**

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

#### **6.1.6 Measurement conditions**

The measurement conditions are as follows:

- Target surface: Pattern surface.
- 2D filter: To be agreed upon between user and supplier.
- Scan area: To be agreed upon between user and supplier.
- ROI: To be agreed upon between user and supplier.
- Sampling interval: To be agreed upon between user and supplier.
- Roughness 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].

#### **6.1.7 Measurement location**

The measurement location is as follows:

- a) To be agreed upon between user and supplier.
- b) Describe the measurement location in the report, for example, measure the following two locations:
  - The center of the specimen.
  - The point which is 20 mm inside both edges of the orientation corner.

## 6.2 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 probe on the plate master and measure a real profile parallel to the reference edges using a raster scan by tracing the surface.
- c) Apply the 2-dimensional high-pass cut-off length filter to the real profile and get the surface roughness profiles.
- d) Calculate the surface roughness parameters ( $Z_{rms}$ ,  $R_{max}$ ,  $R_z$ ).

$$Z_{rms} = \left[ \left( \frac{1}{N_t} \right) \sum_{i=1}^{N_t} (Z_i - \bar{Z})^2 \right]^{1/2} \quad (9)$$

$$R_{max} = P_1 - V_1 \quad (10)$$

$$R_z = \frac{1}{5} \left( \sum_{i=1}^5 P_i + \sum_{i=1}^5 V_i \right) \quad (11)$$

where

$Z_i$  is the height of points  $(x,y)$  over the ROI,

$i$  is the number of the measurements in the ROI,

$N_t$  is the number of data points over the ROI,

$P_i$  is the  $i^{\text{th}}$  highest peak over the ROI,

$V_i$  is the  $i^{\text{th}}$  deepest valley over the ROI.

- e) Change the measurement location and repeat procedures b) to d).

## 6.3 Report

The report should contain the following:

- a) Show the surface roughness measurement results in nm (see Table 3).

**Table 3 – Example of surface roughness measurement results**

Measured location	$Z_{rms}$	$R_{max}$	$R_z$
Center	** nm	** nm	** nm
Corner	** nm	** nm	** nm

- b) Specify the measurement instrument and measurement conditions:
  - Measurement instrument: Type of instrument, name of maker and model, tip radius, and measuring force
  - Measurement conditions: 2D filter, roughness cut-off length, measurement location, ROI, sampling interval, measurement temperature and temperature variation during measurement
- c) Provide the surface plot of each measurement.

## Bibliography

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