IEC 62899-301-3

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INTERNATIONAL STANDARD

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Printed Electronics –
Part 301-3: Equipment – Contact printing – Rigid master – Method to measure the shape errors of printing plate rollers

IEC 62899-301-3:2024-09(en)

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CONTENTS

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PRINTED ELECTRONICS –

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The text of this International Standard is based on the following documents:

Draft	Report on voting
119/505/FDIS	119/511/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

The term "printed electronics" can be easily understood in that this industry involves electronic devices and products that are manufactured by using state-of-the-art printing techniques, otherwise known as additive processes. Printing methods have been widely used in textile and paper type substrates for centuries. In the past, the advent of mass producible printouts had a significant impact 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 resolution and functionality required makes the difference. Some of the widely used functional materials for printed electronics are, but 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 will necessarily be printed. Layer thickness and registration accuracy of printed products are closely related to the quality control of electronic devices with ink materials requiring a high level of quality. Overall, printing tolerance is much smaller in printed electronics.

There are two main categories in the printing process for printed electronics. One is a non-contact printing process, such as inkjet printing or an 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 the mass production of printed electronic devices, many companies, such as device manufacturers, printing master manufacturers and printing master manufacturing equipment vendors, are related to manufacturing and thus they will use a printing master and standardized measurement and assessment methods.

Printed electronics requires more precise dimensional control than conventional media printing as mentioned above. It means that the evaluation of printing plate rollers is critical to achieving the reliable production of high-resolution patterns and the reduction of printing registration errors. One of the most important performance parameters of the printing plate roller is the dynamic error in actual printing equipment during actual printing. The dynamic error of the printing plate roller causes the changes in the printing process condition, such as the printing pressure and the synchronization error between the roller and the substrate. Such a dynamic error results in printed linewidth variations and printing registration errors. The dynamic error is the combined results of the shape errors of the printing plate roller, the motion guiding error of the bearing assembly, and the unexpected deformation of the roller by the external load including self-gravity load. To reduce the occurrence of dynamic errors of the printing plate roller, each contributor to the dynamic error of the printing plate roller will be evaluated. For the first step to evaluate the dynamic error of the printing plate roller, this document focuses on measuring the shape errors of the printing plate roller.

PRINTED ELECTRONICS –

Part 301-3: Equipment – Contact printing – Rigid master – Method to measure the shape errors of printing plate rollers

1 Scope

This part of IEC 62899 defines measurement terms and methods related to the shape errors of printing plate rollers. Measurement terms include radius, total run-out, and three kinds of shape errors of printing plate rollers that are axial deviation, radial deviation, and cross-sectional deviation. The remaining shape error excluding the three errors mentioned above is defined as a residual shape error.

This document applies to printing plate rollers with or without patterns while excluding the pattern area for the measurement.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1101, *Geometrical product specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out*

ISO 12180-1:2011, *Geometrical product specifications (GPS) – Cylindricity – Part 1: Vocabulary and parameters of cylindrical form*

ISO 12180-2, *Geometrical product specifications (GPS) – Cylindricity – Part 2: Specification operators*

ISO 12181-2, *Geometrical product specifications (GPS) – Roundness – Part 2: Specification operators*

3 Terms and definitions

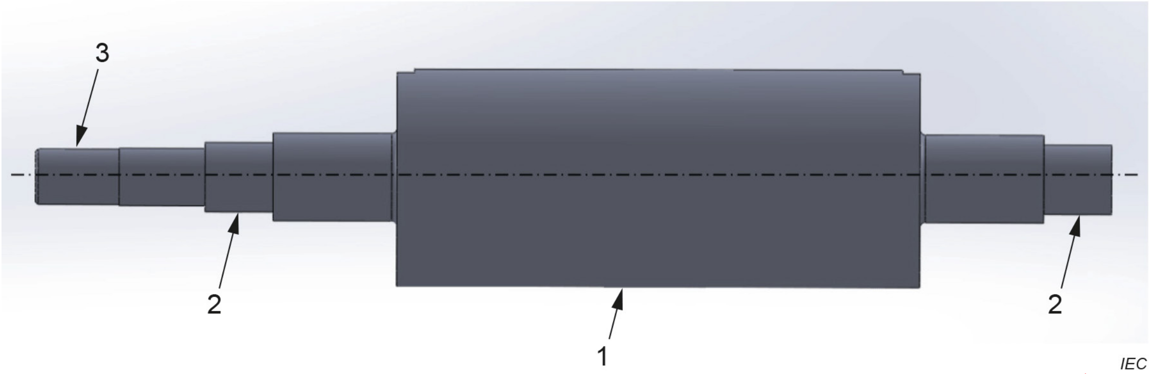
For the purposes of this document, the following terms and definitions apply.

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

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

3.1
printing plate roller
roller that carries the image to be printed and is composed of several sections including the printing cylinder, journal shaft, and driving shaft

SEE: Figure 1.



Key

1 printing cylinder

2 journal shaft

3 driving shaft

Figure 1 – General shape of printing plate roller

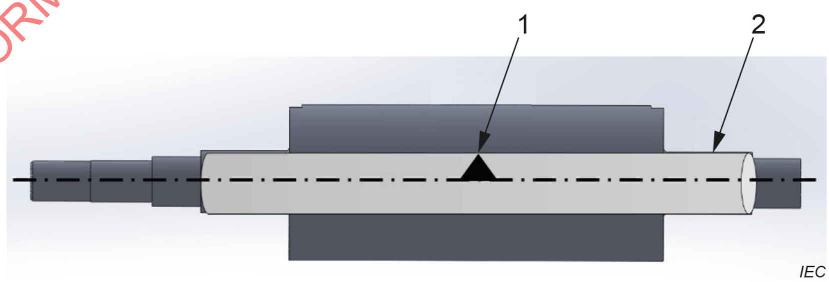
3.1.1
printing cylinder
main cylinder of the printing plate roller that carries the image to be printed on its cylindrical surface

3.1.2
journal shaft
shaft on which rotational bearings are attached

3.1.3
driving shaft
shaft on which driving force is exerted

3.1.4
datum axis of the printing plate roller
associated derived centre axis of the common least squares reference cylinder of two measured journal shafts, and considered as the rotation axis for the printing plate roller

SEE: Figure 2.



Key

1 datum axis

2 common least squares reference cylinder

Figure 2 – Datum axis of the printing plate roller for measuring shape errors of the printing cylinder

3.2
shape error of the printing cylinder
geometrical tolerance of a cylinder with respect to datum axis, defined as total runout in ISO 1101

Note 1 to entry: The total runout of a cylinder includes the various types of errors in the cylinder, such as cylindricity, roundness, and coaxiality (or straightness) as indicated in ISO 12181-1, ISO 12180-1, and ISO 12781-1, and reports only maximum deviation. In measuring the printing plate roller in printed electronics, it is important to know what kind of shape errors exist in the printing plate roller because each type of shape error has a different effect on the printing result (see Annex A). In Clause 3 three kinds of error shapes of the printing plate roller are defined in accordance with ISO 12180-1. The shape errors that are not included are considered residual shape errors.

3.2.1
axial deviation
deviation of the associated derived centers of measured least squares reference circles of the printing cylinder relative to the datum axis of the printing plate roller

Note 1 to entry: See ISO 12180-1:2011, 3.3.1.2 for a definition of least squares reference cylinder and Annex B.

SEE: Figure 3.

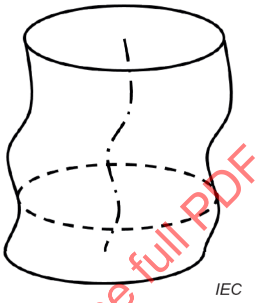


Figure 3 – Median line deviation of a cylinder

3.2.2
radial deviation
deviation of the extracted radius of the printing cylinder

Note 1 to entry: Refer to ISO 12180-1:2011, Annex B.

SEE: Figure 4.

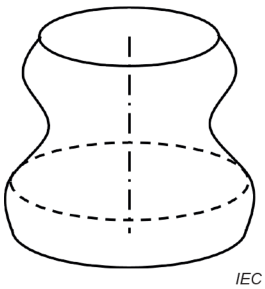


Figure 4 – Radius deviation of a cylinder

3.2.3
cross-section deviation
averaged roundness of the printing cylinder along the datum axis

Note 1 to entry: Refer to ISO 12180-1:2011, Annex B.

SEE: Figure 5.

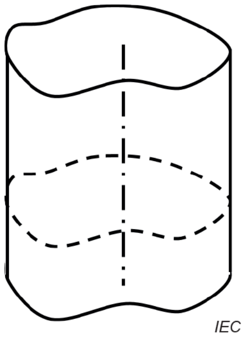


Figure 5 – Cross-sectional deviation of a cylinder

3.2.4
residual deviation
shape errors of the printing cylinder that cannot be described using the three types of shape errors as defined in 3.2.1 to 3.2.3

4 Measurement methods

4.1 General

Measuring the shape errors of the printing plate roller is highly recommended for the printing process in which the quality control of the printed patterns, such as the pattern resolution, linewidth variations, and printing registration accuracy, is important. The shape errors of the printing plate roller shall be measured using the following method.

4.2 Measuring instrument

The measuring instrument and its requirements comply with ISO 4291. The additional requirements are defined as follows.

a) Accuracy of the measuring instrument
   - Accuracy of the measuring instrument should be higher than the required accuracy of the printing plate roller.

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

c) Measurement conditions
   - Record the ambient temperature and any variations that occur during the measurement.

4.3 Measuring process

1) Locate the printing plate roller so that the datum axis is aligned vertically or horizontally in the measuring instrument.
   – The vertical setup has the benefit of reduced deflection due to gravity.
   – The measurement of a horizontally positioned roller is beneficial when evaluating the actual roller shape error in the actual printing condition because the printing plate roller is positioned horizontally in normal printing machines. The application of the measurement instrument can be limited in the horizontally positioned roller because the stylus of the measurement instrument cannot access the entire surface of the printing cylinder and journal shafts.

NOTE 1 The specimen will be stabilized to prevent swaying when measuring its shape and dimensions in an upright position.

2) Wait more than 30 min for temperature stabilization of the specimen to the measured room temperature after the specimen is loaded on the measurement instrument.

NOTE 2 The specimen will ideally be left in the measuring room condition for more than 24 h.

3) Measure the journal shaft using the circumferential method stated in ISO 12180-2. The measurement should contain more than two circumferences having more than 360 points (minimum sample points when the interested minimum undulation per revolution (UPR) is 50 according to ISO 12181-2) per journal shaft.

4) Calculate the cylinder axis, radius and cylindricity of two journal shafts as a single least square cylinder (see ISO 12180-1 and ISO 12180-2) and report the radius and cylindricity of the least square cylinder as the accuracy of the datum axis of the printing plate roller. The cylinder axis of journal shafts is the datum axis of the printing plate roller.

5) Align the z-axis of the measuring instrument to the datum axis of the printing plate roller.

6) Measure the printing cylinder using the circumferential method stated in ISO 12180-2. The measured circumferential lines locate equidistantly, and the measurement points of each circumferential line are sampled at equal angles.

   – It is recommended that at least five measured circumference lines are used to measure the typical shape errors of the printing plate roller, such as conical deviation, barrel deviation, and trumpet deviations. To include complex shape errors, the number of the measured circumferential lines shall be increased accordingly based on agreement between the user and supplier.

   – The number of sample points on each circumferential line follows the guidelines given in ISO 12181-2. The number of sample points shall be selected to fit the interested undulation per revolution (UPR) range as shown in Table 1.

   – It is possible that the line interval and the sample interval will not be equal in case there are some areas that the stylus is unable to access on the printing cylinder.

   – The radius (d) of the stylus to the radius (r) of the printing cylinder shall meet the requirements given in ISO 12181-2 as shown in Table 1.

Table 1 – Guideline for the sample points on each circumferential measurement

Maximum interested UPR	Minimum sample points	Minimum d:r ratio
15	105	5
50	360	15
150	1 050	50
500	3 500	150
1 500	10 500	500

7) Calculate the total runout of the printing cylinder relative to the datum axis of the printing plate roller using the measured data in 6) and report the measured total runout of the printing cylinder (see ISO 1101).

8) Extract the least square reference circles for each measured circumference using the measured data in 6). Each least square reference circle has the information of the axial deviation and the radial deviation of the printing cylinder relative to the datum axis of the printing plate roller at the given cross-directional position. Report the radius, the axial deviations, and the radial deviations of the printing cylinder (see Clause B.1).

9) Remove the axial deviations and the radial deviations from the measured data in 6) (see Clause B.2). After this step, the measured data of each circumference in 6) are changed so as to have the same radius and zero axial deviations.

10) Calculate the cross-section deviations by averaging all circumferences in the data of 9) and report the cross-section deviations (see Clause B.3).

11) Calculate the residual shape errors of the printing plate roller by subtracting the cross-section deviation in 10) from the data in 9) (see Clause B.4).

4.4 Report

The report shall contain the following (refer to Annex C for the model reports):

– measuring instrument: manufacturer, model, and accuracy;

– measuring conditions: temperature with the variation during measurement and picture of measurement setup;

– datum axis: radius and cylindricity of two journal shafts as a single least square cylinder. (If the profile filter is applied, the filter type and the cut-off frequency should be specified);

– tolerance of the printing cylinder: total runout of the printing cylinder relative to the datum axis of the printing plate roller. (If the profile filter is applied, the filter type and the cut-off frequency shall be specified);

– shape errors of the printing cylinder: radius, axial deviations, radial deviations, cross-section deviations and residual deviations of the printing cylinder. (See Clause B.1, Clause B.3 and Clause B.4).

Annex A
(informative)

Printing force variation of the printing plate roller

The measured printing forces at both ends of the printing plate roller in two machines show the different trend in Figure A.1. In machine #1, the printing forces at both ends show the out-of-phase errors, which means the pressure changes at both ends have a phase difference of about 180°. However, there are also the in-phase printing force errors that show nearly zero phase differences at both ends in machine #2. This kind of printing force error can be explained by assuming that the main error source is the shape error of the printing plate roller. This means that the dominant shape error of the printing plate roller in machine #1 is axial deviation with a slope relative to the datum axis as shown in Figure A.2. On the other hand, it is likely that the axial deviation has an offset relative to the datum axis in Figure A.3. Alternatively, it can also be caused by cross-section deviation. This is the reason why the shape error of the printing plate roller should be measured accurately before using it in the printing machines. However, there are some other characteristics that cause printing force variation, not only by shape error, but also other error in the printing system, such as error in chassis, vibration, in bearings, non-roundness, or by dynamic balance of a roller itself, although there is no static shape error.

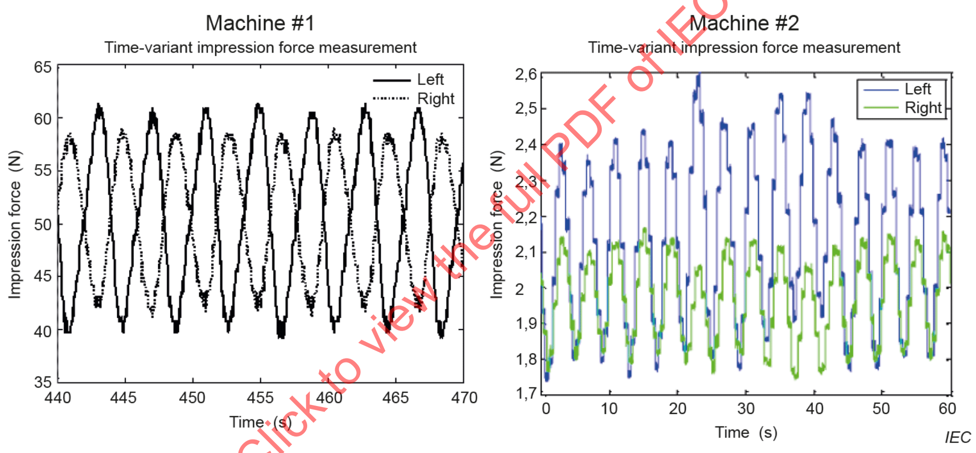


Figure A.1 – Printing force variations in two different cases

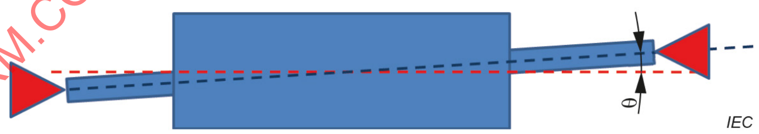


Figure A.2 – Axial deviation with a slope relative to the datum axis

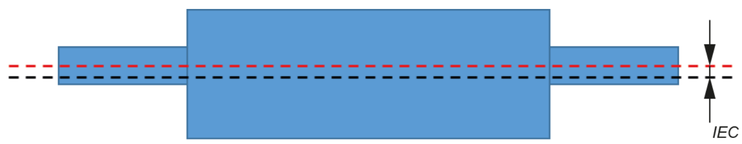


Figure A.3 – Axial deviation with an offset relative to the datum axis

Annex B
(normative)

Numerical procedures to extract the shape errors of the printing plate rollers

B.1 Extraction of the least square reference circle for each measured circumference of the printing cylinder

The printing cylinder is measured via a circumferential method as shown in Figure B.1 with n being the number of the measured circumferences. A least square reference circle is obtained from each measured circumference as shown in Figure B.2. The problem of least-square fitting is defined as follows.

Find C_x^i, C_y^i, R^i, to minimize $\sum_{j=1}^{m}\left\{\left(x_j^i - C_x^i\right)^2 + \left(y_j^i - C_y^i\right)^2 - R^{i2}\right\}$

where

m is the number of measured points in each measured circumference,

x_j^i is the measured x position of the j^{th} point in the i^{th} circumference,

y_j^i is the measured y position of the j^{th} point in the i^{th} circumference,

C_x^i is the axial deviation of the i^{th} circumference in the x-axis,

C_y^i is the axial deviation of the i^{th} circumference in the y-axis, and

R^i is the radius of the i^{th} circumference.

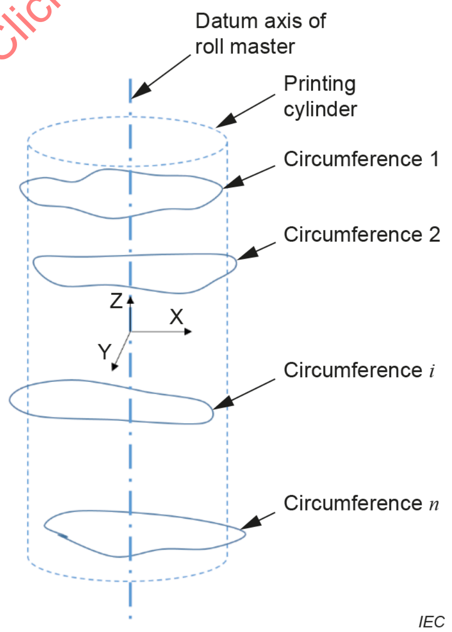


Figure B.1 – Measurement of the printing cylinder

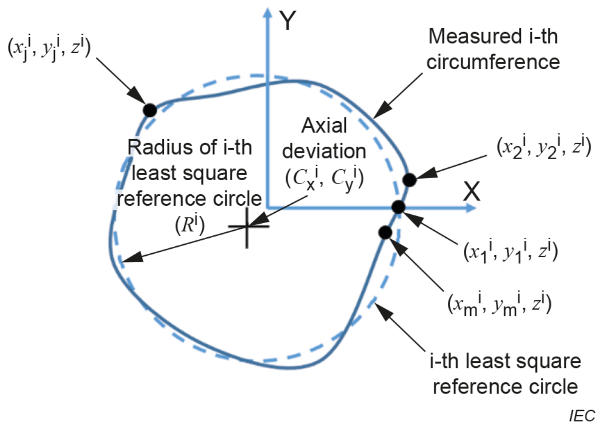


Figure B.2 – Least square reference circle of the i-th circumferential measurement

Include Table B.1 in the report. The mean radius (R_m) is the radius of all least-square circles.

Table B.1 – Report form for the axial deviations and radial deviations of the printing cylinder

Circumference index	**1**	**2**	**...**	***i***	**...**	***n***	**mean**
z^i							
C_x^i							
C_y^i							
R^i							

B.2 Remove the axial deviations and the radial deviations

Formula (B.1) and Formula (B.2) are applied to obtain the circumferential line profile of (xc_j^i, yc_j^i) to remove the axial deviations and the radial deviation from the original measured circumferential line profile of $\left(x_j^i, y_j^i\right)$.

$$xc_j^i = \frac{R_\mathrm{m}}{R^i}\sqrt{(y_j^i - C_y^i)^2 + (x_j^i - C_x^i)^2}\cos\left[\mathrm{atan}\left\{(y_j^i - C_y^i)/(x_j^i - C_x^i)\right\}\right] \qquad \text{(B.1)}$$

$$yc_j^i = \frac{R_\mathrm{m}}{R^i}\sqrt{(y_j^i - C_y^i)^2 + (x_j^i - C_x^i)^2}\sin\left[\mathrm{atan}\left\{(y_j^i - C_y^i)/(x_j^i - C_x^i)\right\}\right] \qquad \text{(B.2)}$$

In general, C_x^i and C_y^i are much less than R^i and the approximation below can be applied to obtain (xc_j^i, yc_j^i).

$$xc_j^i = x_j^i - C_x^i - \left(R^i - R_m\right)\cos\left[\text{atan}\left(y_j^i / x_j^i\right)\right] \qquad \text{(B.3)}$$

$$yc_j^i = y_j^i - C_y^i - \left(R^i - R_m\right)\sin\left[\text{atan}\left(y_j^i / x_j^i\right)\right] \qquad \text{(B.4)}$$

B.3 Calculate the cross-section deviations

The cross-section deviations of (xa_j , ya_j) are calculated by averaging the circumferential profiles of (xc_j^i , yc_j^i) using Formula (B.5) and Formula (B.6). The cross-section deviation is defined as the runout of (xa_j , ya_j).

$$xa_j = \frac{1}{n}\sum_{i=1}^{n} xc_j^i \qquad \text{(B.5)}$$

$$ya_j = \frac{1}{n}\sum_{i=1}^{n} yc_j^i \qquad \text{(B.6)}$$

B.4 Calculate the residual shape errors

The residual shape errors of the roll master of (xr_j^i , yr_j^i) are calculated using Formula (B.7) and Formula (B.8). The residual shape errors of the printing plate roller are defined as the total runout of (xr_j^i , yr_j^i).

$$xr_j^i = xc_j^i - xa_j \; \left(i = 1 \ldots n,\; j = 1 \ldots m\right) \qquad \text{(B.7)}$$

$$yr_j^i = yc_j^i - ya_j \; \left(i = 1 \ldots n,\; j = 1 \ldots m\right) \qquad \text{(B.8)}$$

Annex C[1]
(informative)

Examples of report

C.1 Example of report

Measuring instrument: Coordinate measuring machine (CMM)

- Manufacturer: Dukin
- Model: 121510
- Accuracy: 3,0 + L/300 µm (L is a measuring length in mm)

Measuring temperature: 20 °C ± 0,5 °C

Measurement setup with CMM is shown in Figure C.1.

Figure C.1 – Measurement setup

Radius and cylindricity of two journal shafts: Radius 19,993 8 mm / Cylindricity ($^{7,7}_{-6,6}$ µm)

See Figure C.2.

NOTE 1 360 points are measured per each circumference and no profile filter is applied.

[1] Dukin and Kosakalab are examples of commercial manufacturers. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the companies or their products.

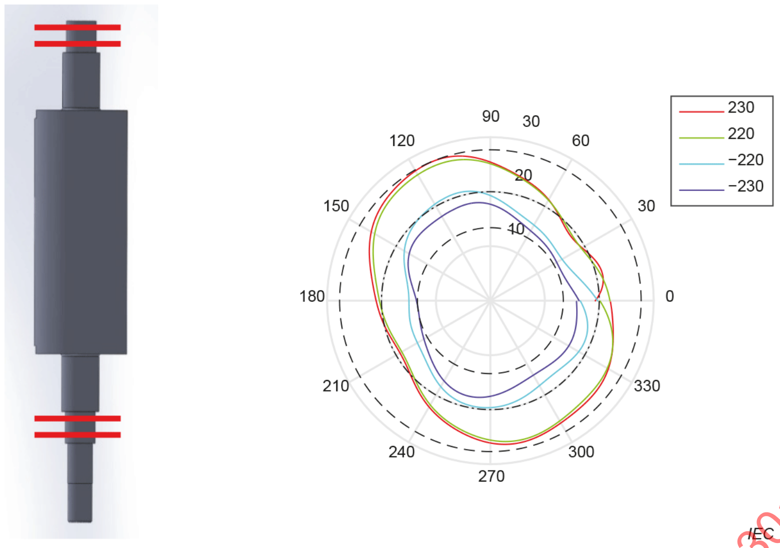


Figure C.2 – Measurement of the datum axis

Total runout of the printing cylinder with respect to the datum axis of the roll master: 22,3 µm.

See Figure C.3.

NOTE 2 360 points are measured per each circumference and no profile filter is applied.

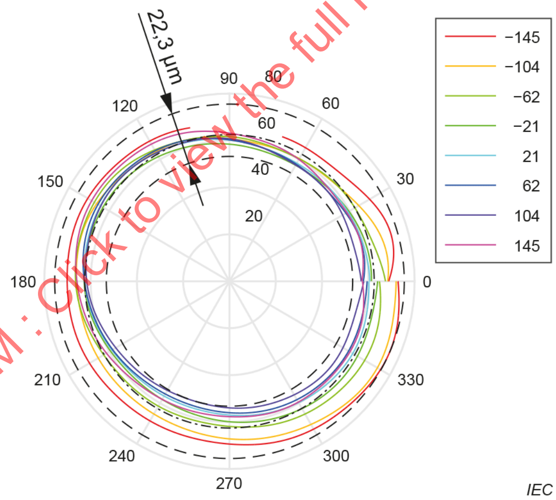


Figure C.3 – Measurement of the circumferences of the printing cylinder with the label meaning the z-axis position of each measured circumference

Axial deviation and radial deviation of the printing cylinder are reported in Table C.1 and Figure C.4.

Table C.1 – Report for the axial deviations and radial deviations of the printing cylinder fitted from measured circumferences given in Figure C.3

Circumference index	1	2	3	4	5	6	7	8	mean
z^i (mm)	-145	-104	-62	-21	21	62	104	145	-
$C_x^{\ i}$ (µm)	1,13	1,86	-0,16	0,11	-0,86	-1,84	-2,31	-3,45	-0,69
$C_y^{\ i}$ (µm)	-1,94	-3,46	-0,29	-0,63	1,57	2,38	3,31	2,82	0,47
R^i (mm)	62,534 4	62,530 7	62,528 4	62,525 2	62,524 6	62,524 1	62,522 6	62,526 0	62,527 0

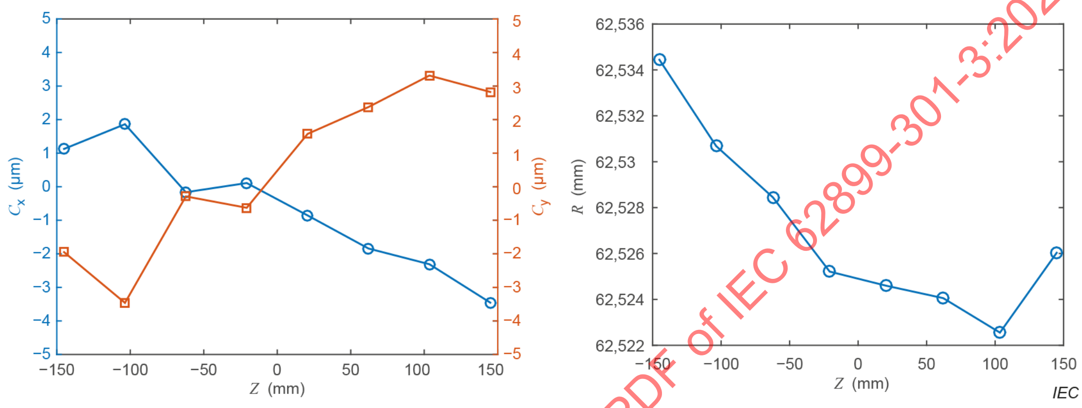


Figure C.4 – Graphical report of Table C.1

Radius of the printing cylinder: 62,527 0 mm

Cross-section variation: 6,1 µm

See Figure C.5.

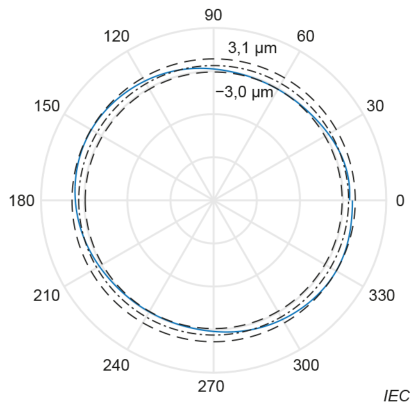


Figure C.5 – Extracted cross-section variation

Residual shape errors of the roll master: 5,9 µm

See Figure C.6.

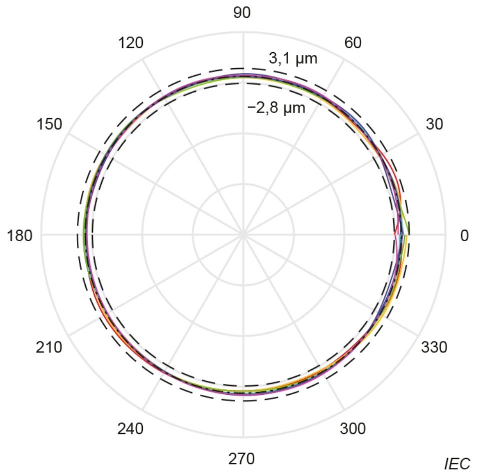


Figure C.6 – Residual shape errors

C.2 Example of report 2

Measuring instrument: Roundness tester

– Manufacturer: Kosakalab
– Model: EC3600A
– Rotational accuracy of the rotary table: (0,1 + 0,000 6) H µm (H is the height from the table in mm)
– Straightness accuracy of the vertical column: 1,5 µm/200 mm (4 µm/1 400 mm)
– Parallelism of the vertical column: 5 µm/1 400 mm

Measuring temperature: 20 °C±0,5 °C

A picture of measurement setup in a roundness tester is shown in Figure C.7.