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Flexible displays ~~devices~~ -
Part 6-22: Mechanical test methods - Crease and waviness measurement methods for foldable displays

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Flexible displays ~~devices~~ - Part 6-22: Mechanical test methods - Crease and waviness measurement methods for foldable displays

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IEC 62715-6-22 has been prepared by IEC technical committee 110: Electronic displays. It is an International Standard.

This second edition cancels and replaces the first edition published in 2023. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) addition of multiple-folding;

b) addition of new data analysis logic.

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

Draft	Report on voting
110/1841/FDIS	110/1852/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 62715 series, published under the general title *Flexible displays*, can be found on the IEC website.

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– reconfirmed,

– withdrawn, or

– revised.

INTRODUCTION

The market for foldable display devices is growing rapidly, as shown in the new form factors for portable devices. It is expected that various foldable display devices will be released in the near future.

Typically, the cover for rigid displays is made of glass. A rigid glass cover protects the display panel from external shock and produces a surface uniformity without visual distortion. In order to utilize a foldable display, a thin and flexible cover is preferred rather than the thick general rigid cover. Although cover materials like thin films or plastics can be flexible, their surface is rougher and can crease more easily. Based on this expectation, there is an anticipation to standardize the measurement of surface creasing and waviness due to folding in order to evaluate the surface quality of foldable displays.

There is a wide variety of ways to analyse the surface of an object, and many of them are already standardized, [1] to [9][1]. In this document, two of the non-contact methods and one contact method using a probe are described, and the manner in which to report the values of crease and waviness of foldable displays from the measured data is specified.

[1] Numbers in square brackets refer to the Bibliography.

1 Scope

This part of IEC 62715 specifies the standard measurement conditions and methods for determining the surface crease and waviness for the evaluation of foldable displays. The measurement methods are used to specify the extent of geometrical distortions in foldable display surfaces. This document applies to foldable display panels and modules ~~(e.g. in-folding and out-folding) with one axis~~. If the foldable display panel has two or more folding axes, this document applies only to the case that folding axes are parallel.

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.

IEC 60050-845, *International Electrotechnical Vocabulary (IEV) - Part 845: Lighting* (available at http://www.electropedia.org)

IEC 62341-1-2, *Organic light emitting diode (OLED) displays - Part 1-2: Terminology and letter symbols*

IEC 62341-6-2:2015, *Organic light emitting diode (OLED) displays - Part 6-2: Measuring methods of visual quality and ambient performance*

IEC 62715-5-3, *Flexible display devices - Part 5-3: Visual assessment of image quality and defects*

IEC 62715-6-1, *Flexible display devices - Part 6-1: Mechanical test methods - Deformation tests*

ISO 4287, *Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters*

ISO 16610-21, *Geometrical product specifications (GPS) - Filtration - Part 21: Linear profile filters: Gaussian filters*

ASME B46.1-2019, *Surface Texture (Surface Roughness, Waviness, and Lay)*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62341-1-2 and IEC 60050-845 and the following 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

3.1.1
crease
permanent or temporary linear visual distortion or deformation in the screen due to folding

3.1.2
waviness
long wavelength variation in a surface away from its basic form

Note 1 to entry: Within small areas of the display, distortions can occur in what should be nominally straight features in images, characters, and symbols. This measurement characterizes the deviations from straightness.

3.1.3
folding area
curved section of the panel due to folding

3.2 Abbreviated terms

CCD charge-coupled device
CMM coordinate measuring machine
CMOS complementary metal-oxide semiconductor
DUT device under test
LIDAR light detection and ranging
PMD phase measuring deflectometry
PSD position sensitive detector

4 Standard atmospheric conditions

The standard atmospheric conditions specified in IEC 62715-6-1 shall apply as follows, unless otherwise specifically agreed between customer and supplier:

– temperature: 25 °C ± 3 °C
– relative humidity: 25 % RH to 85 % RH
– atmospheric pressure: 86 kPa to 106 kPa

The temperature and humidity conditions shall be reported.

5 Preparation of specimen for measurement

5.1 General

In this document, the measurement object is called specimen, and the specimen consists of a foldable panel, modules, adhesive, base plate and jig. The description of the specimen's components and how to configure them is specified in 5.3. All measurements shall be performed under non-operating conditions.

5.2 Visual examination

The foldable display panel is subjected to visual and dimensional checks under non-operating conditions and a functional check under operating conditions specified as follows:

a) non-operating conditions: visual damage on the surface of the specimen shall be checked;
b) operating conditions: visual assessment shall be done by the methods specified in IEC 62715-5-3.

~~Unless otherwise specified,~~ Visual examination shall be performed under the conditions and methods specified in IEC 62341-6-2:2015, 5.2.2.1, unless otherwise specifically agreed between customer and supplier.

NOTE The purpose of 5.2 is to check the surface damage or failure of the DUT before performing the measurement.

5.3 Specimen preparation

The conditions for the preparation of the specimen (e.g. plate, jig), the number of cyclic folding tests, the folding duration time, and the size of the specimen shall be determined between the supplier and customer. If a mechanical test (e.g. cyclic folding test) is performed in the process of preparing the specimen, the mechanical test method and condition shall be determined between the supplier and customer before the preparation of the specimen. This mechanical test specified in IEC 62715-6-1 and the test method and condition shall be reported.

NOTE 1 If the mechanical test is not performed in the process of preparing the specimen, the corresponding content in Table 1 will be empty.

The temperature, humidity, storage time prior to testing, and the delayed time between the specimen preparation and measurement can affect the crease and waviness, so the specimen preparation condition and delayed time shall be controlled and reported.

NOTE 2 If the foldable display panel is unfolded and the time is delayed, the measurement result of the crease and waviness can be smaller or alleviated due to the resilience of the panel. Therefore, the delayed time will be reported as illustrated in Table 1.

The order and process of preparing the specimen are described as illustrated in Figure 1, Figure 2, Figure 3, and Figure 4.

Step 1: Preparing the components of the specimen: the foldable display panel should be unfolded after a specific duration under the conditions outlined in Table 1. The base plate shall be flat and larger than the foldable display panel. The jig with a flat surface should be fixed to the base plate and have an adhesive on the top to attach to the back of the panel. The panel holder ~~is used to prepare the out-folding type panel. It~~ is a tool to maintain the flatness of the panel while the jig is attached to the back of the panel in step 2 and step 3. The height of the panel holder should be ~~high enough~~ sufficient to ensure that the folding area does not touch the ground when the ~~out-folding type~~ panel is placed on it. When the foldable panel has N folding axes, N+1 sets of jig/adhesive/panel holder are required. Figure 1 is an example of the components for a specimen with two folding axes.

NOTE 3 Once the jig and the panel are attached, the panel holder is no longer necessary.

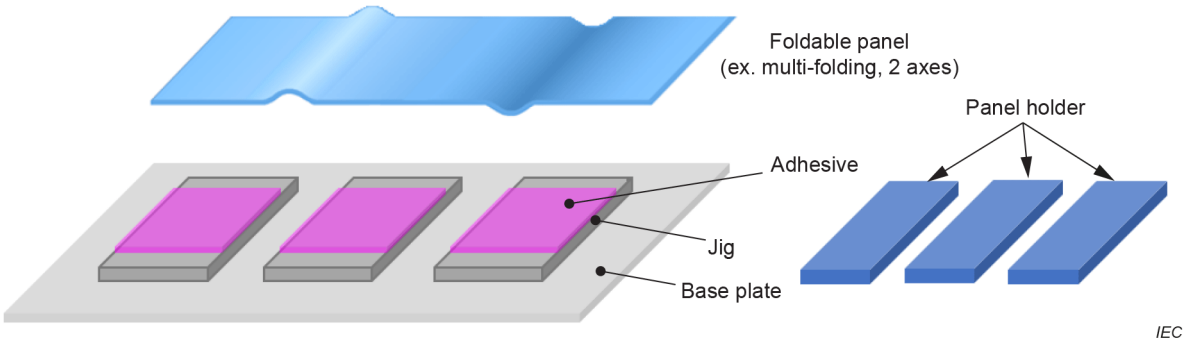


Figure 1 – Step 1: Preparing the components of the specimen

Step 2: Turning the back of the panel to face upward: the method and location of the attachment should not affect the measurement. In order to eliminate the influence of tensile tension that can occur in the process of attaching the panel to the jig, the foldable panel shall be flipped so that the back of the panel faces upward. In other words, as shown in Figure 2, the light-emitting surface of the panel is placed downward. It shall be placed on the panel holder and the folding axis is positioned between the panel holders.

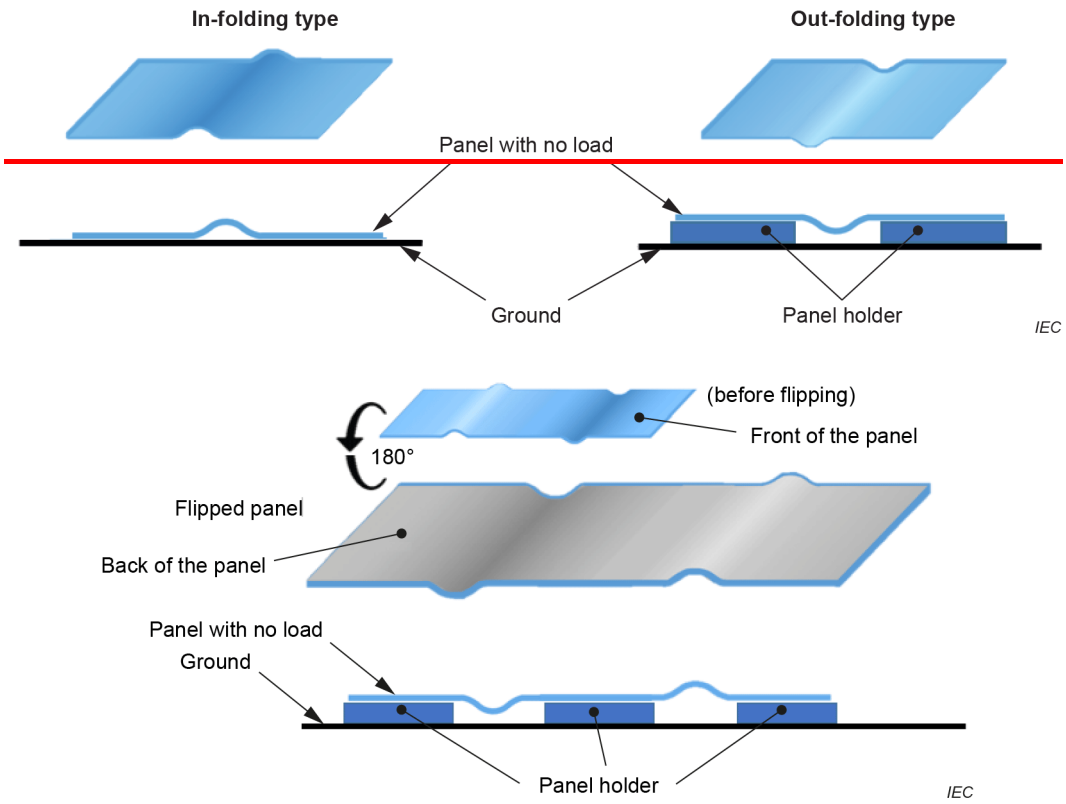


Figure 2 – Step 2: Turning the back of the panel to face upward

Step 3: Turning over the base plate and attaching it to the back of the panel: the base plate shall also be flipped so that the adhesive surface faces downward. Then, lower the base plate from the top down and attach it to the back of the panel. The folding axis should be located in the centre between the jigs as shown in Figure 3.

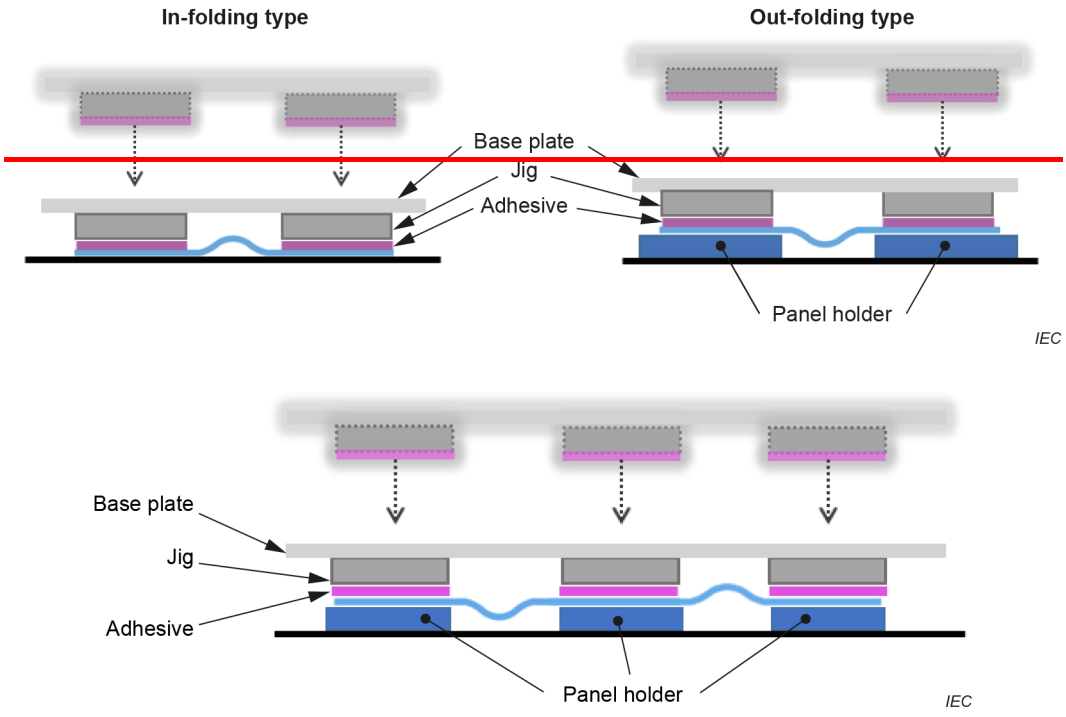
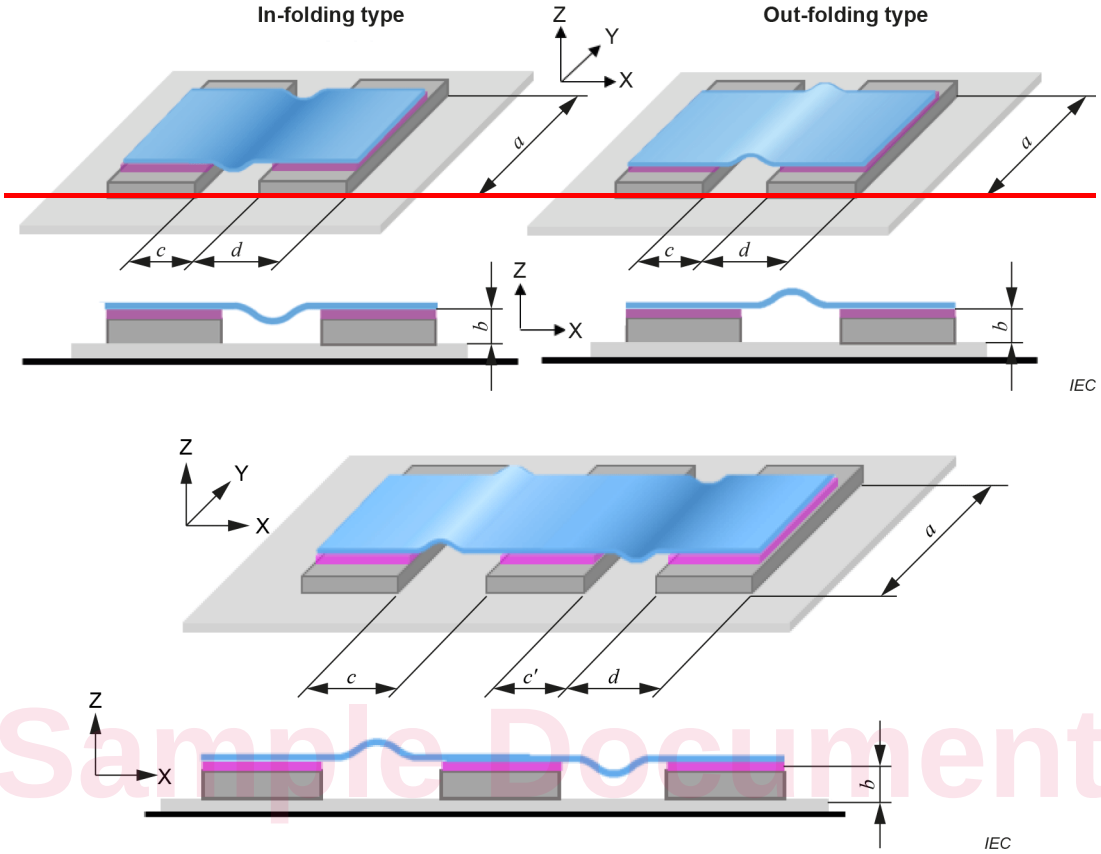


Figure 3 – Step 3: Turning over the base plate and attaching it to the back of the panel

Step 4: Turning over the base plate with the panel attached: when the base plate with the foldable panel attached is turned over, the top of the panel to be measured faces upward and the specimen preparation is complete, as shown in Figure 4.



Key

a length of jig

b height of jig

c unattached area

d width of jig

Figure 4 – Step 4: Turning over the base plate with the panel attached

The description of each element is as follows:

– *a* should be longer than the width (length of y-axis) of the foldable display panel;

– *b* should be high enough that the folding area does not touch the base plate. It can be affected by the folding radius;

– *c* should include one folding axis, so if there are *N* folding axes in the panel, *N* unattached areas are made. The minimum value of *c* should be at least 10 times the foldable panel's bending radius or higher.

NOTE 4 To measure the crease, a folding area is located in the unattached area *c* and the measurement location will include the unattached area *c*. The folding area depends on the foldable panel's bending radius. The minimum range of the folding area will be a value obtained by multiplying the bending radius by pi (π). Therefore, to prevent the effects of the fixation of the adhesive on the crease measurement, the unattached area will be at least 10 times the foldable panel's bending radius.

– *d* should not intrude the folding area, and it should support the foldable display panel to keep it flat.

The values of *c* and *d* shall be determined by the supplier and customer and reported.

The measurement object should be a specimen which consists of the foldable panel fixed on the jig and base plate for reproducibility of the measurement. It is also a similar condition to the foldable panel inserted in the foldable device. However, the attachment method which consists of adhesive fixing while preparing specimen should not affect the measurement. In the process of attaching, it is necessary to attach the panel to the jig with the panel turned over to prevent the forcible pulling of the panel. This is described in step 2 and step 3, and the attachment method shall be reported. In the process of measuring the completed specimen after attachment, care should be taken to measure the original waviness of the panel, not the waviness of the adhesive or jig. It should also be noted that only the data of the specimens obtained under the same conditions be compared so that the various factors such as thickness, type, size and location of adhesive and jig used in the specimen preparation do not affect the data.

An example of reporting the items for specimen preparation described in 5.3 is shown in Table 1.

Table 1 – Example of specimen preparation condition

Specimen no.	Base plate		Folded storage condition					Foldable panel
	Attachment method	Unattached area (c) (≥ 10 times the bending radius)	1. Before folding	2. Folded state storage condition			3. Unfolded	Bending radius
			Mechanical test (type/ number)	Temp.	Humidity	Storage time	Delayed time	
1	Adhesive tape	20 mm	Cyclic folding/100	25 °C ± 3 °C	85 %	24 h	15 min	2 R

If a specimen is ready, particles should be removed from the surface before the measurement, using an appropriate cleaning method for the specimens, for example compressed air, wiping with isopropyl alcohol, using an anti-static gun, etc.

5.4 Measurement location

5.4.1 General

Crease and waviness measurements can be taken at several specified locations on the surface of the foldable display panel. If there are multiple measuring areas in one specimen, the location and the size of each measuring area shall be reported. The height and width of the measuring area shall be determined by the supplier and customer. Figure 5 is an example of crease and waviness measuring area in the foldable display panel with two folding axes.

5.4.2 Crease

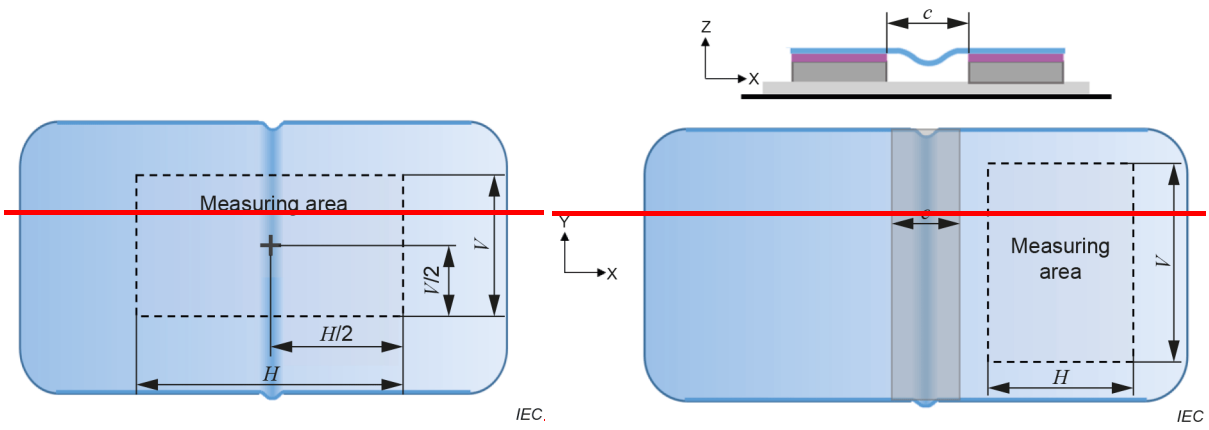
~~A folding area which is the curved section of the foldable display panel due to folding shall be located in the measuring area. This folding area should be located at the centre of the crease measuring area. Figure 5a) is an example of the crease measuring area in the foldable display panel.~~

A folding area shall be located at the centre of the crease measuring area, and only one folding area shall be included in one measuring area.

5.4.3 Waviness

The measuring area of waviness shall not include an unattached area (c, having a value of 10 times the foldable panel's bending radius or higher, as described in 5.3). In other words, the measuring area shall be designated from the point at which it is at least 5 times the foldable panel's bending radius away from the folding axis so that unattached area and waviness

measuring area do not overlap. ~~Figure 5b) is an example of the waviness measuring area in the foldable display panel.~~



~~(a) Example of crease measuring area location~~ ~~(b) Example of waviness measuring area location~~

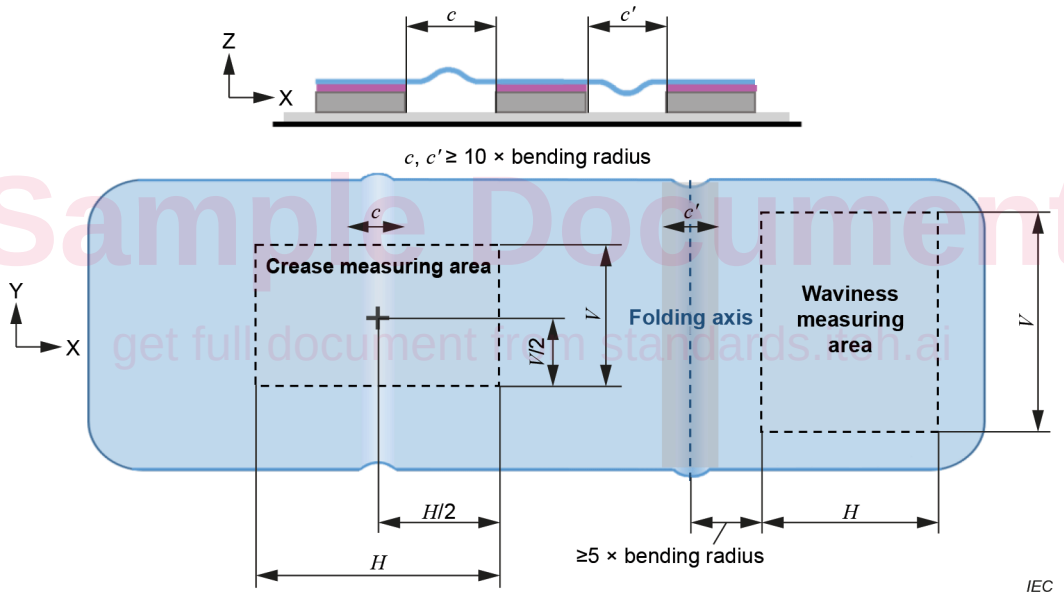


Figure 5 – Example of crease and waviness measuring area

6 Measurement methods

6.1 General

In this document, three types of methods are described for implementation:

a) a non-contact method in which a screen is used to measure the surface without contact;

b) a non-contact method using a laser;

c) a contact method in which a stylus contacts the surface for measurement.

The contact method can be used when the non-contact method cannot be performed (e.g. the display surface becomes matte after applying an anti-glare film and the image is not reflected). However, the contact method is not recommended since this method can damage the foldable display surface.

The non-contact topography (see 6.3) can be adopted to measure both crease and waviness. The non-contact profilometry (see 6.4) and contact profilometry (see 6.5) methods can be adopted to measure crease. These three methods are one of many ways to analyse the surface as described in the Introduction. It does not mean that other methods are excluded; these can be selected by decision between the supplier and the customer. 6.3.4, 6.4.4 and 6.5.4 focus on how to analyse the measured surface data and express it as crease and waviness of the foldable display. Data comparisons shall be made between the data measured and analysed under the same measurement method, environment, and conditions.

6.2 Purpose

The purpose is to measure the crease and waviness of the specimen which would appear in actual usage. Due to the morphological and geometric changes of crease and waviness, several issues can appear, such as luminance uniformity, viewing angle, and image distortion.

6.3 Non-contact topography

6.3.1 General

To measure crease and waviness the phase measuring deflectometry (PMD) method is used in this document ~~since PMD is the proper method to measure large sizes~~, as it is suitable for measuring large areas and can yield highly accurate data [10]. The principle of PMD is to display fringe patterns on a screen which is located far from the DUT, and to observe the fringe patterns reflected via the surface of the DUT. Any slope variation of the surface of the DUT leads to distortions of the pattern, so the PMD can measure the slope of the surface with high accuracy (see [11], [12], [13]). From this measured slope data, the altitude and curvature can be derived by integration and differentiation, respectively (see [14] and [15]). Altitude and curvature are used to represent the crease and waviness, and the principle and data analysis are given in detail in 6.3.2 and 6.3.4.

6.3.2 Test apparatus

Figure 6 shows an example of a measurement system based on PMD. The main devices for PMD include an imaging device (e.g. charge-coupled device (CCD), digital camera), a screen (e.g. TFT-LCD monitor) and a computer. Computer-generated fringe patterns are sequentially displayed on the screen, and the screen shall be flat and sufficiently large so that it can project on the surface of the DUT without distortion. The patterns displayed on the screen in the PMD are typically sinusoidal fringes which are smooth intensity curves, and the phase calculation is not very sensitive to a small amount of out-of-focus effect. The camera captures the reflection of the patterns displayed on a screen through the surface of the DUT (see [10], [14], [15]). Since PMD is a method of analysing changes between the reference pattern displayed on the screen and the reflected image captured by the CCD, it is important to clearly detect the difference between those two patterns.