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INTERNATIONAL STANDARD

colour inside

Flexible displays devices –
Part 6-23: Mechanical test methods – Mechanical misaligned folding test method

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CONTENTS

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FLEXIBLE DISPLAY DEVICES –

Part 6-23: Mechanical test methods – Mechanical misaligned folding test method

FOREWORD

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

Draft	Report on voting
110/1702/FDIS	110/1717/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 display devices*, 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- withdrawn, or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 market for foldable panels has been growing steadily. The first foldable product which has foldable panel was launched in 2019 as a smartphone. Since then, many other manufacturers have released a variety of foldable smartphones. In the future, it is expected that various types of foldable products such as smartphones, tablets or laptop computers, etc. will be released continuously.

These foldable products would be folded and unfolded repeatedly by users. This means that as the period of use increases, the number of times for folding and unfolding the foldable product increases. For this reason, the mechanical robustness of the foldable panel is expected to vary depending on the duration of use and the user style (e.g. heavy users). [1][1] This document will introduce the mechanical durability test to reflect the actual usage environment. This test method can also be an important evaluation item as much as the mechanical durability test for the initial foldable panel state.

The example of an actual usage environment can be demonstrated in the below situation. As mentioned earlier, when the usage time increases, the number of folding and unfolding of the foldable product also increases. Taking smartphones as an example, users unfold the foldable product in order to use it, then fold it again to easily hold or carry it. Users repeat this action several times in a day: they unfold and fold foldable products repeatedly to receive calls, to send text messages or to search the Internet. Users often drop foldable products or bump their foldable products somewhere because they hold their smartphone almost every day.

If the users repeatedly fold and unfold the device, or if the device is subjected to shocks (such as dropping or pressing in local area), it can cause the misaligned state of the foldable product. In this document, the situation that can cause misalignment of the foldable product is limited to the state of being shocked by dropping or being pressed after repeated folding and unfolding. The test simulates all of these processes and is defined as the mechanical misaligned folding test. Therefore, this mechanical misaligned folding test consists of a cyclic folding test and a drop test.

This document introduces the measurement conditions and measurement methods of the mechanical misaligned folding test method, which is an objective mechanical durability test method that takes into consideration the actual usage environment of the foldable panel.

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

FLEXIBLE DISPLAY DEVICES –

Part 6-23: Mechanical test methods – Mechanical misaligned folding test method

1 Scope

This part of IEC 62715 specifies the standard measuring methods to evaluate the mechanical durability of foldable display modules, especially mechanical durability under the condition reflecting the actual usage environment.

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

IEC 62715-6-1:2018, *Flexible display devices – Part 6-1: Mechanical test methods – Deformation tests*

IEC 62715-6-3, *Flexible display devices – Part 6-3: Mechanical test methods – Impact and hardness tests*

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
foldable panel
flexible display panel which can be folded

3.2
misaligned state
situation in which the folding alignment of the foldable panel becomes abnormal as being shocked by dropping or being pressed after repeated folding and unfolding

3.3
point defect
all or part of a single subpixel, the minimum colour element, which is visibly brighter or darker than surrounding subpixels of the same colour

3.4
line defect
defect in a vertical or horizontal, bright or dark line, parallel to a row or column observed against a dark or bright background, respectively

3.5
in-folding
method used to fold the display surface inward

3.6
out-folding
method used to fold the display surface outward

3.7
***R* value**
radius of curvature of the folding area

3.8
folding area
curved section of the panel due to folding

4 Standard atmospheric conditions

The standard atmospheric conditions in IEC 62715-6-1:2018, Clause 4, shall apply as follows, unless otherwise specifically agreed between the manufacturer and the customer.

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 in the test reports.

5 Test sample preparation

5.1 General

The test sample shall be the foldable display module, since the final evaluation shall be made based on the panel image quality such as luminance, chromaticity, uniformity, line defect and point defect.

5.2 Visual inspection

The test sample shall be visually inspected to check the image quality (e.g. line defect, point defect) and surface damage. The purpose of this visual inspection is to confirm that the test sample is operating properly and has no surface damage before performing the measurement.

Visual inspection shall be performed under the conditions and methods specified in IEC 62341-6-2:2015, 5.2.2.1, unless otherwise specified.

5.3 Sample preparation

Since the foldable panel is easily deformed by external force, the test sample shall be aligned with the test apparatus. The test sample can be aligned using adhesive tape or clamp, and these parts shall not affect the mechanical misaligned folding test. In addition, the test sample shall remain flat during the visual inspection.

The size of the test sample shall be determined by the manufacturer and the customers.

6 Mechanical test method

6.1 General

The mechanical misaligned folding test consists of a cyclic folding test and a ball or pen drop test to evaluate the mechanical durability against external shocks and user's environment.

These two tests are performed sequentially. The cyclic folding test, which refers to IEC 62715-6-1, shall be performed before the drop test, which refers to IEC 62715-6-3.

6.2 Purpose

This document introduces test methods to evaluate the mechanical robustness properties of foldable panel under the actual use environment.

The cyclic folding test is performed to simulate the user's repeated folding and unfolding behaviour while actually using the foldable display device. The drop test is performed to evaluate the mechanical robustness properties of the foldable panel against a dropping or shock that can occur when actually using the foldable display device. The ball drop test simulates an impact in a relatively large area (as this would be the case when dropping the device), and the pen drop test simulates an impact in a relatively small area (as this would be the case when pressing or breaking the panel with a sharp object).

6.3 Test apparatus

6.3.1 Cyclic folding test

The cyclic folding test apparatus includes the clamps to hold the test sample, the moving part to fold and unfold the test sample, and the system that controls the number of cyclic folding and mechanical moving speed while testing. These parts of the cyclic folding test apparatus shall not interfere with the test sample, and the method of holding test sample shall be reported.

The test sample undergoes a folding stress when the test sample is folded and unfolded with the constant folding radius. The cyclic folding apparatus depends on the folding type (in-folding or out-folding) of the test sample. Figure 1 and Figure 2 show examples of test apparatus.

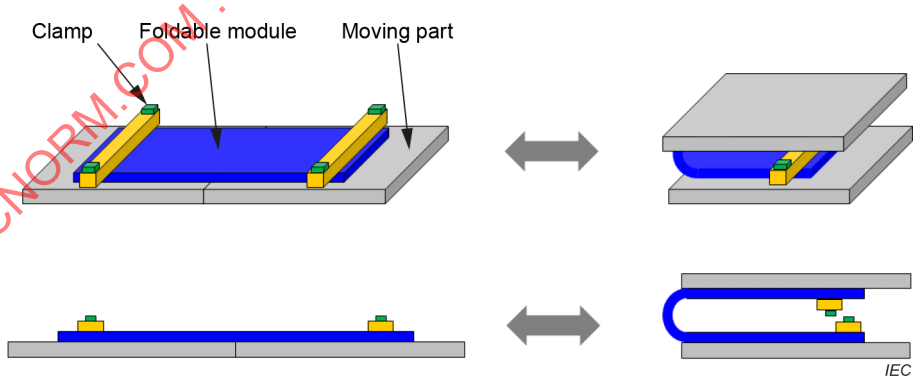

Figure 1 – Example of test apparatus for in-folding type sample

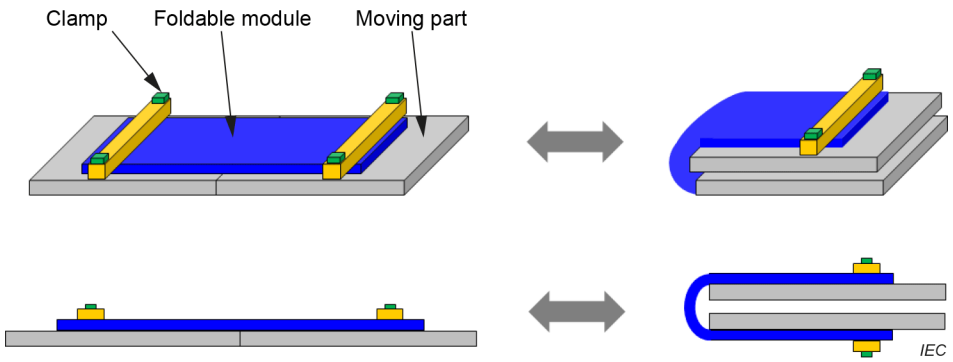

Figure 2 – Example of test apparatus for out-folding type sample

The detailed conditions of each component cited above regarding the cyclic folding test apparatus shall be determined between the manufacturer and the customer. If other requirements are needed, other test conditions can be used on agreement between the manufacturer and the customer, and it shall be reported. Since the test results can vary depending on the test conditions, consistent conditions shall be used for accurate and reproducible evaluation.

6.3.2 Drop test

The ball or pen drop test apparatus includes a hard plate, an object used for dropping (ball or pen), and a height indicator to which is affixed an object holder, as shown in Figure 3.

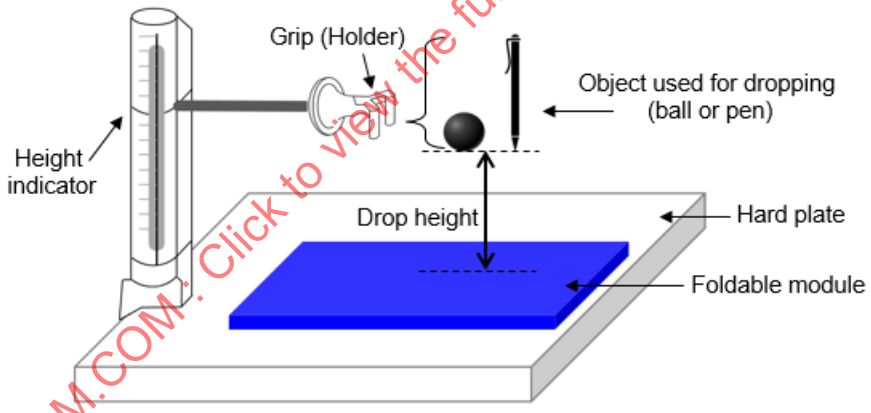

Figure 3 – Example of drop test apparatus

The test sample which has been tested for cyclic folding shall be placed on the hard plate. The hard plate shall be flat and larger than the test sample. In addition, it shall be thick and hard enough not to affect the test results, because the test results will differ significantly depending on the designs and materials of the hard plate. The material (e.g. granite, steel) and thickness (e.g. 10, 50, 100 mm) of the hard plate shall be determined between the manufacturer and the customer.

The object used for dropping – either a ball or a pen – shall be selected. The factors to consider in the specification of the object used for dropping include the weight, the material type, and the size, such as the diameter for the ball or the tip size for the pen, which are the parts that directly touch the test sample. The test conditions of the drop test, such as the material of the ball (e.g. steel, rubber, plastic), the weight of the ball or pen (e.g. 3 g, 5 g, 7 g), the diameter of the ball (e.g. 5 mm, 10 mm, 15 mm) and the tip size of the pen (e.g. 0,3 mm, 0,5 mm, 0,7 mm, 1,0 mm), shall be determined between the manufacturer and the customer.

The equipment that drops the object perpendicularly to the surface of the test sample from the desired height is shown in Figure 3 as an example. In order to obtain a consistent drop height during the test, special equipment that drop the object at a reproducible height, such as mechanical grips or electromagnetic holders that can hold the ball or the pen, as well as magnetic plates, are available. A height indicator can also be used to check the precise drop height. The drop height is the distance from the surface of the test sample to the end point of the ball or pen. The end point means the edge of the ball or pen that meets the surface of the test sample.

The detailed conditions of each component cited above regarding the ball or pen drop test apparatus shall be determined between the manufacturer and the customer. If other requirements are needed, other test conditions can be used based on agreement between the manufacturer and the customer. Since the test results can vary depending on the test conditions, consistent conditions shall be used for accurate and reproducible evaluation.

6.4 Test procedure

6.4.1 Cyclic folding test

The cyclic folding test which refers to the contents of the cyclic bending test in IEC 62715-6-1 shall be performed before the ball or pen drop test described in 6.4.2. The cyclic folding test shall be performed using a repeated motion regularly between two points or two states (folded state and unfolded state) as follows.

a) Prepare the required number of test samples according to 5.3.

b) Check the prepared test samples for initial performance against the required visual characteristics defined in 5.2.

c) One edge of the test sample is fixed by the clamp, or fixed with an adhesive tape, and the other edge is supported properly.

d) Fold the test sample with defined conditions such as the folding angle and the folding angular speed.

e) Bring the test sample back to the initial state before folding again.

f) If necessary, fold the test sample in another direction with defined conditions such as the folding angle and the folding angular speed.

g) Bring the test sample back to the initial state before folding with the same angular speed and reversed direction.

h) Repeat d) to g) for a defined number of cycles.

i) After the test, the test sample shall be removed from the apparatus.

j) Repeat the test with other test samples following d) to i).

k) Report the test conditions and results.

The display state of the foldable module during the measurement, as well as the cyclic folding test conditions, such as the folding angle, the folding speed, the time for one fold and the interval between each fold, and the number of repeated cycles, shall be determined between the manufacturer and the customer. An example of cyclic folding test conditions is described in Table 1.

Table 1 – Example of cyclic folding test conditions

Sample No.	Foldable module			Cyclic folding test conditions			
	Type	Bending radius (R)	Display state	Folding angle	Folding speed	Interval time	Repeated cycles
1	In-folding	5 mm	Off	0°	1 s^{-1}	2 s	100

6.4.2 Drop test

After performing the cyclic folding test described in 6.4.1, the ball or pen drop test shall be performed using the same sample that has been used for the cyclic folding test.

The ball or pen drop test shall be performed as follows.

a) Prepare the required number of test samples that have been tested according to 6.4.1.
b) Unfold the test sample and place it on the hard plate.
c) Fix the test sample so that it does not move during the test.
d) Hang and fix the selected object used for dropping on the grip (holder).
e) Adjust the drop height by using the height indicator and object holder.
f) Drop the object at a consistent drop height so that it can hit the specified position of the test sample perpendicularly.
g) Change the hit position in the test sample several times and repeat the process described in f).
h) Repeat e) to g) while increasing the drop height step by step until a damage on the test sample is observed.
i) Report the test conditions and results. The test result can be the maximum drop height at which damage does not occur within the determined number of hits.

The hit position can be one or several points (e.g. the centre point of the test sample, a total of nine points per test sample, three points for each of the left, centre and right areas). The hit position shall include at least one point in the folding area of the test sample.

The damage that occurs after the drop test can include the line defect, the point defect and the surface damage (e.g. scratch, breakage). The damage degree and criteria (if applicable) shall be determined between the manufacturer and the customer. The process of evaluating the image quality of the test sample can be added after the drop test to observe the damage phenomenon. In this case, all the conditions and methods to evaluate the quality of the image and the time interval between the drop test and the image quality evaluation shall be determined between the manufacturer and the customer and reported.

After the first hit, the ball shall not successively collide with the panel in order to prevent additional damage caused by the second hit of the ball. This can cause inconsistent results.

The display state of the foldable module during the measurement, as well as the drop test conditions, such as the hit position, the number of hitting of the test sample, the starting height selected for the drop, and the drop height interval, shall be determined between the manufacturer and customer. An example of drop test conditions is described in Table 2.

Table 2 – Example of drop test conditions

Sample No.	Foldable module			Drop test conditions						
	Type	Bending radius (R)	Display state	Object	Object size	Object weight	Hit position	Number of hitting	Starting height	Interval height
1	In-folding	5 mm	Off	Rubber ball	5 mm	5 g	One point - Centre of folding area	5	5 cm	5 cm

6.5 Reporting

Report the test conditions and test results as follows. If there are multiple samples, all of the following items shall be reported for each sample.

The test condition items to be reported are as follows.

a) Environmental conditions, such as temperature and humidity.
b) Test sample condition:
   – type of folding;
   – R value;
   – number of test samples.
c) Visual inspection (5.2) results of initial state.
d) Cyclic folding test conditions:
   – folding angle, angular speed for one cyclic folding;
   – time for one fold and interval between the folds;
   – number of repeated cycles (e.g. 0, 100, 1 000, 10 000, 100 000);
   – method used to hold the test samples.
e) Time interval between the cyclic folding test and the drop test.
f) Ball or pen drop test conditions:
   – material of the hard plate (e.g. granite, steel);
   – thickness of the hard plate (e.g. 10, 50, 100 mm);
   – size of the hard plate;
   – type of the dropping object (ball or pen);
   – material of the dropping object (e.g. steel, rubber, plastic);
   – diameter (of the ball or the pen tip) or size of the dropping object (e.g. 0,3 mm, 0,5 mm, 0,7 mm, 1.0mm, 5 mm, 10 mm, 15 mm);
   – weight of the dropping object (e.g. 3 g, 5 g, 7 g);
   – hit position on the test sample;
   – number of hits;
   – interval of the drop height during the test.

The test result items to be reported are as follows.

a) Maximum drop height at which damage does not occur within the defined number of hits.
b) Time interval between the drop test and the evaluation of the panel image quality (if performed).
c) Damage type on the sample (if applicable).

Data comparisons shall be made between the data tested under the same test conditions. If additional items that do not have specified conditions are necessary to report, it shall be determined by agreement between the manufacturer and the customer.