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Flexible display devices –
Part 6-1: Mechanical test methods – Deformation tests

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FLEXIBLE DISPLAY DEVICES –

Part 6-1: Mechanical test methods – Deformation tests

FOREWORD

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International Standard IEC 62715-6-1 has been prepared by IEC technical committee 110: Electronic display devices.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

a) changed the part title to differentiate it from other parts;
b) added new bending testing methods;
c) added detailed testing procedures.

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

FDIS	Report on voting
110/951/FDIS	110/974/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 the parts in the IEC 62715 series, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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

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

FLEXIBLE DISPLAY DEVICES –

Part 6-1: Mechanical test methods – Deformation tests

1 Scope

The object of this part of IEC 62715 is to define the standard test methods to evaluate the mechanical stability of flexible display modules, specifically mechanical stability against deformation, such as bending, rolling, twisting, and stretching. Display modules include displays such as LCD, e-paper, and OLED. This document takes into account, wherever possible, the mechanical test methods outlined under mechanical stress.

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 62341-5:2009, *Organic light emitting diode (OLED) displays – Part 5: Environmental testing methods*

3 Terms and definitions

No terms and definitions are listed in this document.

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

4 Standard atmospheric conditions

The standard atmospheric conditions in IEC 62341-5:2009, 5.3, 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

When all the different kinds of tests are carried out, the temperature and humidity condition shall be reported because the temperature and humidity are critical for the bending and rolling stability regarding image quality on the panel.

NOTE Preferably, the specimen and apparatus are kept in a controlled environment for at least 24 h prior to and after assembly, before the start of the mechanical deformation test.

5 Specimen preparation

5.1 General

The specimen shall be the display module since the final evaluation has to be made based on panel image quality such as luminance, chromaticity, uniformity, line defect, and point defect. The bending stress may cause the deterioration of image quality on a panel, [1] to [9][1].

5.2 Sample preparation

For the measurements both before and after the mechanical deformation test, the display module being tested shall be aligned on an appropriate support which has to be a flat surface. In addition, the module for the measurement shall be of the appropriate geometry for mechanical stress testing. Specify that the test apparatus should be designed to prevent added strain by stretching test specimens upon folding.

The preferred method of attachment between the display module and the test apparatus is adhesive transfer tape. The display should be bonded on both sides, and the distance between the centre of the test specimen and the point of attachment should be specified. If use scenarios require it, a clamping attachment may be used instead, in which the display is clamped on one side and allowed to slide on the other. The clamping force should be sufficient to ensure that the test specimen is firmly anchored to the test apparatus throughout the entire duration of the test cycle.

If some modules are difficult to clamp due to narrow edge width, the module should be fixed on a bendable support substrate with a suitable adhesive strip or glue. Neither the adhesive strip nor the glue should affect the measurement.

NOTE In some cases, the testing specimen can have a short length or has a very narrow edge to clamp for mechanical stress testing.

Specify that in the event of cross-instrument variability in the form of location (centre or edge)-response bias, one should investigate bend axis misalignment, bowing or uneven mounting plates.

For precise optical measurements, it is very important to define the alignment of the measurement specimen because the flexible display module can be easily deformed by external force. Measurements of the visual characteristics of a flexible module shall be made in an aligned flat state. If flexible modules are aligned in a curved state, it is difficult to make a precise visual evaluation. The measurement module shall be supported or fixed so that it is flat.

The flatness and size of the specimen shall be determined between the supplier and customer.

6 Mechanical stress test methods

6.1 General

Flexible displays have a diversity of shapes in comparison with any other non-flexible electronic displays. Therefore, a wide variety of mechanical stress test methods are available, such as a cyclic bending (folding) or dynamic bending test, a static bending test, a rolling test, a combined mechanical test and more. The selection of the appropriate test methods shall be based on the requirement of the application. For each mechanical stress test, the relevant test method specification shall be stated along with the explanation of the purpose of each unique test. The allowable critical bending radius of a panel depends on the application of the flexible display. Therefore, the required critical bending radius will be changed based on the applications.

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1 Numbers in square brackets refer to the Bibliography.

There are several factors to consider when designing a reliable and repeatable mechanical folding or deformation test method, as follows:

– Motion profiles controlled by a single hinge (or pivot axis) and which wrap around a mandrel can stretch samples, and if not precisely actuated or controlled can create a great deal of variability in the test response.
– Motion profiles controlled by more than one hinge or pivot axis can prevent added stretching on test specimens, and offer better control of the test response.
– Clamping samples can prevent shear between layers of multi-layer test specimens containing adhesive, and greatly impact test response.
– Additional considerations, such as attaching too close to the apex of the bend, and fold axis misalignment or slight distortions in the shape of the mounting plates, can also impact reliability and repeatability of the test response.
– Samples should be pre-conditioned in a controlled environment for at least 24 h prior to testing as material properties for adhesives and polymers can be affected by temperature and water uptake.

6.2 Cyclic bending test

6.2.1 General

This procedure is for conditioning the specimen under mechanical stress by repeated bending.

6.2.2 Purpose

The purpose of this test is to provide a standard procedure for evaluating the robustness of a flexible display against a cyclic bending stress which might typically happen in application. The bending properties might cover several typical parameters of the characteristics of a display panel's image quality. The typical parameters of a display panel's image quality might cover the luminance, chromaticity, uniformity, line defect, point defect, pixel shrink, and/or presence or absence of cracks.

6.2.3 Test apparatus

The cyclic bending test equipment includes the clamp to hold a bending test specimen, the moving part to shuttle, and the control system which regulates the number of cyclic bendings, the moving distance, and the moving speed while testing. The specimen shall be securely clamped with a gripping part during the test. Several kinds of cyclic bending test equipment is available and shown in Figure 1, [4][7][10]. It is not necessary that a certain type of bending test equipment be preferred but the constant bending radius (r), equal to the radius of the rod, should be kept during the bending test.

NOTE If the bending radius of the test specimen is kept constant during the bending test, the bending rod can be removed as it would scratch the surface of the test specimen during the cyclic bending test.

For the cyclic bending test, the following apparatus is considered:

– the specimen experiences a bending stress when the specimen is shuttled back and forth (Figure 1a)) or while the specimen is folded and unfolded (Figure 1b)),
– when the specimen is repeatedly multi-bent in the inward or outward direction, a cyclic multi-inward bending equipment (Figure 1c)) or cyclic multi-outward bending equipment (Figure 1d)) can be used,
– when the specimen is repeatedly multi-bent in a Z-shape, a cyclic multi-bending equipment can be used,
– when the specimen is repeatedly bent in both the inward and outward direction, a cyclic inward and outward bending equipment can be used (Figure 1e) and/or f)).

6.2.4 Test procedure

The cyclic bending test shall be performed using a repeated motion to move regularly between two points or two states (folded state and unfolded state) as follows:

a) Prepare the required number of specimens according to 5.2.

b) Perform the initial performance, visual characteristics, test for the prepared specimens and record the result.

c) One edge of the specimen is fixed by the clamp, or fixed with an adhesive, and the other edge is supported properly as stated in 5.2.

d) Bend the specimen properly with defined conditions such as the rotation angle of the clamp roll and the bending angular velocity.

e) Bring the specimen back to the initial state before the bending.

f) If required, bend the specimen in another direction with defined conditions such as the rotation angle of the clamp roll and the bending angular velocity.

g) Bring the specimen back to the initial state before the bending with the same angular velocity and reversed direction.

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

i) After the test, the specimen is removed from the apparatus.

j) Repeat the tests with (an)other specimen(s) following c) to j).

k) The stressed performance, visual characteristics of the mechanically stressed specimen(s) with the required number of testings are measured and the results are recorded. The initial and stressed performances are compared, and the degree of change due to the bend is determined.

l) The test and performance measurement for individual specimens are conducted and recorded in the test report.

6.2.5 Testing conditions and reporting

The testing conditions are specified as follows:

NOTE 1 The numerical values of the test conditions are examples.

a) bending radius

   r (bending radius): 20 mm, 10 mm, 5 mm, 3 mm, 2 mm, 1 mm, 0,5 mm, 0,2 mm

b) bending angle and angular velocity, procedure for one cycle

   t (time for one bend and interval): 0,5 s, 1 s, 2 s, 3 s, 5 s, 10 s

c) load

d) number of repeating cycles

e) criteria for acceptance

f) number of specimens

g) the bending inner surface is the top surface (face up) or the back side surface (face down)

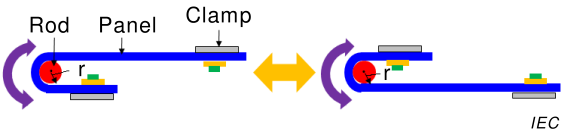
h) way of holding specimens and detailed method of holding, such as pressure

i) surface condition (such as treatment) of both specimen and apparatus

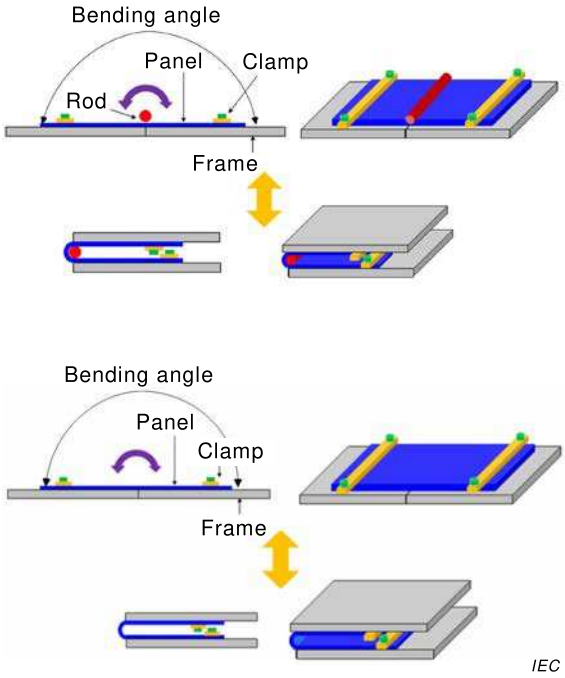
j) testing of environmental conditions, such as temperature and humidity.

NOTE 2 The criteria for acceptance include the visual performance and specimen geometry both before and after the stressing.

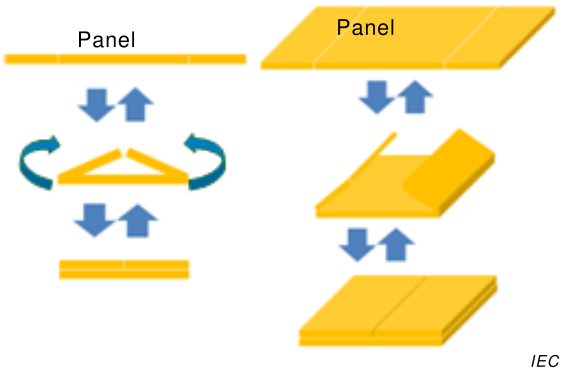
All conditions shall be reported if the test uses conditions other than those mentioned above.



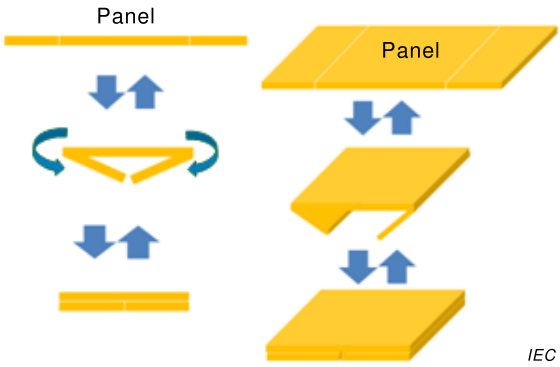
a) Cyclic bending (sliding) equipment



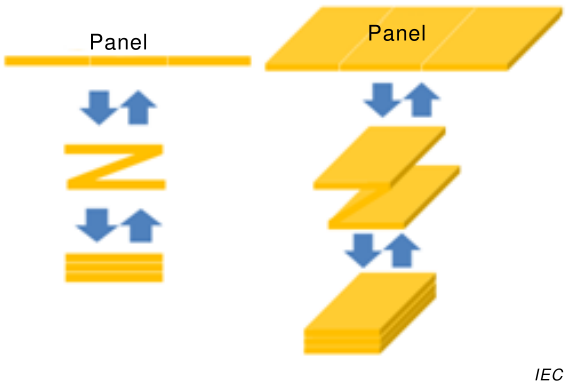
b) Cyclic bending equipment



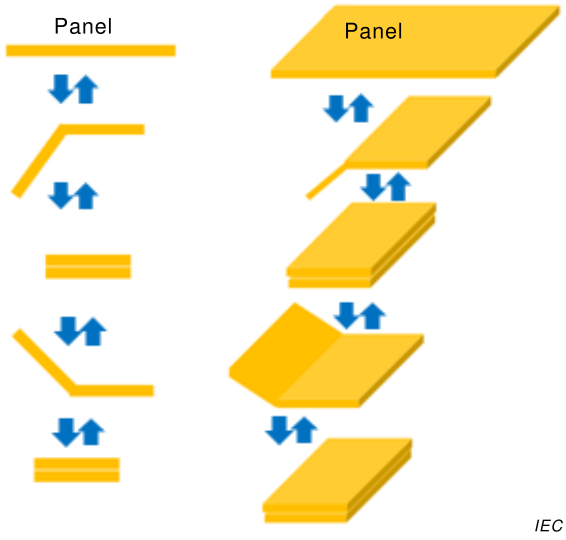
c) Cyclic multi-inward bending equipment



d) Cyclic multi-outward bending equipment



e) Cyclic multi-bending equipment



f) Cyclic inward and outward bending equipment

Figure 1 – Apparatus for diverse cyclic bending tests

6.3 Static bending test

6.3.1 General

This test is especially applicable for evaluating the static bending properties of a flexible display device by measuring its performance after it remains bent for a certain period of time. Each specimen is bent at a fixed bending radius for any length of time.

6.3.2 Purpose

This test is to provide a standard procedure for evaluating the static bending properties of a flexible display device under constant stress for a certain period of time. Each specimen is bent at a fixed bending radius for a controlled length of time.

6.3.3 Test apparatus

The body of the display panel shall firmly adhere to the surface of the test equipment during the test, where the test equipment should have a round shape with a certain radius as in Figure 2. The specimen shall be bent at a fixed bending radius for a period of time.

If the bending radius of the test specimen is kept constant during the bending test, the bending rod can be removed as it may scratch the surface of the test specimen during the static bending test. During the test, the flexible printed circuit (FPC) and the driver should be carefully handled so that they are not subject to bending damage. The chip-on-film (COF) method is preferable in order to avoid the occurrence of bending damage on the driver's integrated circuit (IC) during the bending test.

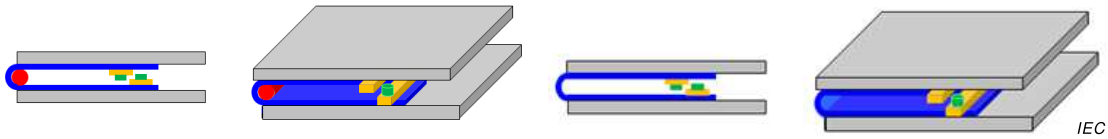


Figure 2 – Apparatus for static bending test

6.3.4 Test procedure

The static bending test shall be carried out with a fixed bending radius for a certain period of time, as follows:

a) Prepare the required number of specimens according to 5.2.

b) Perform the initial performance, visual characteristics, test for the prepared specimens and record the result.

c) One edge of the specimen is fixed by the clamp and the other edge is supported properly.

d) Bend the specimen properly with defined conditions such as the rotation angle of the clamp roll and the bending angular velocity.

e) Keep the specimen bent for certain period of time.

f) Bring the specimen back to the initial state before the bending.

g) Repeat d) to f) for a defined number of tests.

h) After the bending, the specimen is removed from the apparatus.

i) Repeat the tests with (an)other specimen(s) following c) to g).

j) The stressed performance and visual characteristics of mechanically stressed specimen(s) with the required number of testings are measured, and the results are recorded. The initial and stressed performances are compared, and the degree of change due to bending is determined.

k) The test and performance measurement for individual specimens are conducted and recorded in the test report.

6.3.5 Testing conditions and reporting

The testing conditions are specified as follows:

NOTE 1 The numerical values of the test conditions are examples.

a) bending radius

   r (bending radius): 20 mm, 10 mm, 5 mm, 3 mm, 2 mm, 1 mm, 0,5 mm, 0,2 mm

b) bending angle

c) holding duration

d) load

e) criteria for acceptance

f) number of specimens

g) the bending inner surface is the top surface (face-up) or backside surface (face-down)

h) way of holding specimens and detailed method of holding, such as pressure

i) surface condition (such as treatment) of both specimen and apparatus

j) testing of environmental conditions, such as temperature and humidity

NOTE 2 The criteria for acceptance include visual performance and specimen geometry both before and after the stressing.

All conditions shall be reported if the test uses conditions other than those mentioned above.

6.4 Combined bending test

6.4.1 General

This test is especially applicable for evaluating two kinds of bending properties (cyclic bending properties and static bending properties (see Figure 3)) of the flexible display device, after the flexible display remains in the curved shape for a certain period of time and goes through the cyclic bending condition for a certain period of time in real use environment.

6.4.2 Purpose

The objective of this test is to provide a standard procedure for evaluating the combined bending properties of cyclic bending and duration time bending. This test aims to take the real product use environment into consideration, where the real product keeps the panel in a curved, folded, or rolled shape for a long time when it is used or before it is rolled out.

6.4.3 Test apparatus

The combined bending test utilizes the same apparatus as the cyclic bending test as shown in Figure 3. The instrument controller shall be capable of stopping the mechanism while the specimen is in a bent state during each iteration of the cycle.

6.4.4 Test procedure

The cyclic bending test procedure is modified to include a ‘hold’ of adjustable duration between each iteration of the cycle where the specimen remains in a fully bent state [4] as follows:

a) Prepare the required number of specimens according to 5.2.

b) Perform the initial performance, visual characteristics, test for the prepared specimens and record the result.

c) One edge of the specimen is fixed by the clamp and the other edge is supported properly.

d) Bend the specimen properly with defined conditions such as the rotation angle of the clamp roll and the bending angular velocity.

e) Bring the specimen back to the initial state before the bending.

f) After performing a certain number of times the bending test in d) and e), bring the specimen in a fully bent state, then hold.

g) After certain a period of time on hold, bring the specimen back to the initial state.

h) If required, bend the specimen in another direction with defined conditions such as the rotation angle of the clamp roll and the bending angular velocity.

NOTE If required, the specimen and apparatus are set in a proper setting, such as rotation of the rod, etc.

i) The bent module is returned to the initial state before the bending with the same angular velocity and reversed direction.

j) After performing a certain number of times the bending test in h) and i), bring the specimen in the fully bent state, and then hold.

k) After the test, bring the specimen back to the initial state.

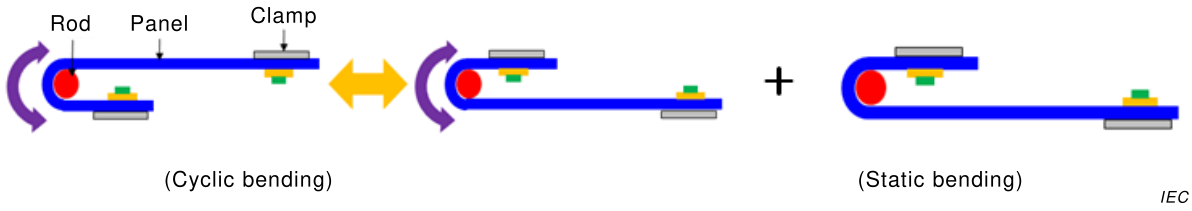
l) Repeat d) to k) for a defined number of cycles.

m) Bring the specimen back to the initial state.

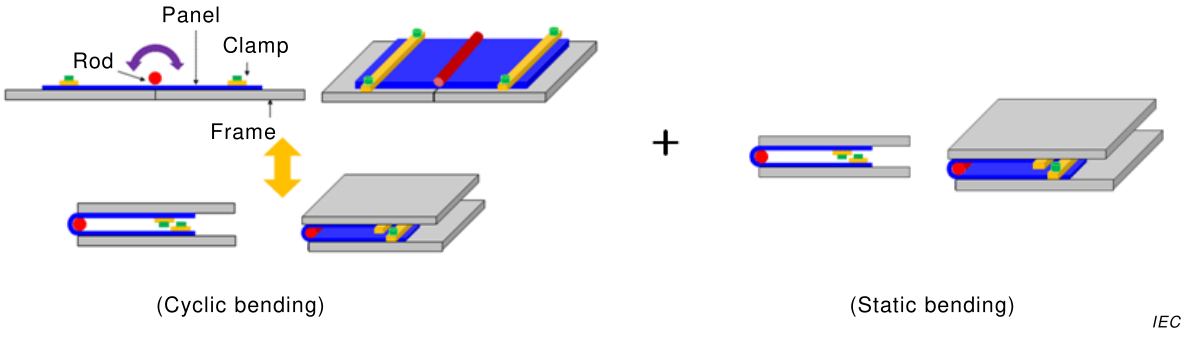
n) Repeat the test with (an)other specimen(s) following c) to m).

o) The stressed performance and visual characteristics of the mechanically stressed specimen(s) with the required number of testings are measured, and the results are recorded. The initial and stressed performances are compared, and the degree of change due to the bend is determined.

p) The test and performance measurement for individual specimens are conducted and recorded in the test report.



a) Combined bending test A



b) Combined bending test B

Figure 3 – Apparatus for combined bending tests consisting of the cyclic bending test and static bending test

6.4.5 Testing conditions and reporting

The testing conditions are specified as follows:

NOTE 1 The numerical values of the test conditions are examples.

a) bending radius

r (bending radius): 20 mm, 10 mm, 5 mm, 3 mm, 2 mm, 1 mm, 0,5 mm, 0,2 mm

b) bending angle and angular velocity, procedure for one cycle
   t (time for one bend and interval): 0,5 s, 1 s, 2 s, 3 s, 5 s, 10 s
c) duration of ‘hold’ state
d) load
e) number of repeating cycles
f) criteria for acceptance
g) number of specimens
h) the bending inner surface is the top surface (face up) or backside surface (face down)
i) way of holding specimens and detailed method of holding, such as pressure
j) surface condition (such as treatment) of both specimen and apparatus
k) testing of environmental conditions, such as temperature and humidity

NOTE 2 The criteria for acceptance include the visual performance and specimen geometry both before and after the stressing.

All conditions shall be reported if the test uses conditions other than those mentioned above.

6.5 Rolling test

6.5.1 General

This test is especially applicable for evaluating the rolling properties of a flexible display module after a flexible display is rolled out, rolled in, or remains in the shape of a roll.

6.5.2 Purpose

The objective of this test is to provide a standard procedure for evaluating the robustness of the rolling properties of the flexible display panel.

6.5.3 Test apparatus

The specimen shall be firmly clamped with a gripping part on the roller side and on the stationary side. The roller shall be moved forward and backward alternately at a fixed distance, speed, and rolling number as in Figure 4. The roller side has a slot where the edge of the specimen is inserted and clamped. The roller repeatedly shuttles along the roller shaft and the specimen does not touch the plate of the equipment during the rolling test as shown in Figure 4.

During the test, the FPC and the driver should be carefully handled so that they are not subjected to twist damage. The COF method is preferable in order to prevent the occurrence of twist damage on the driver's IC during the bending test.

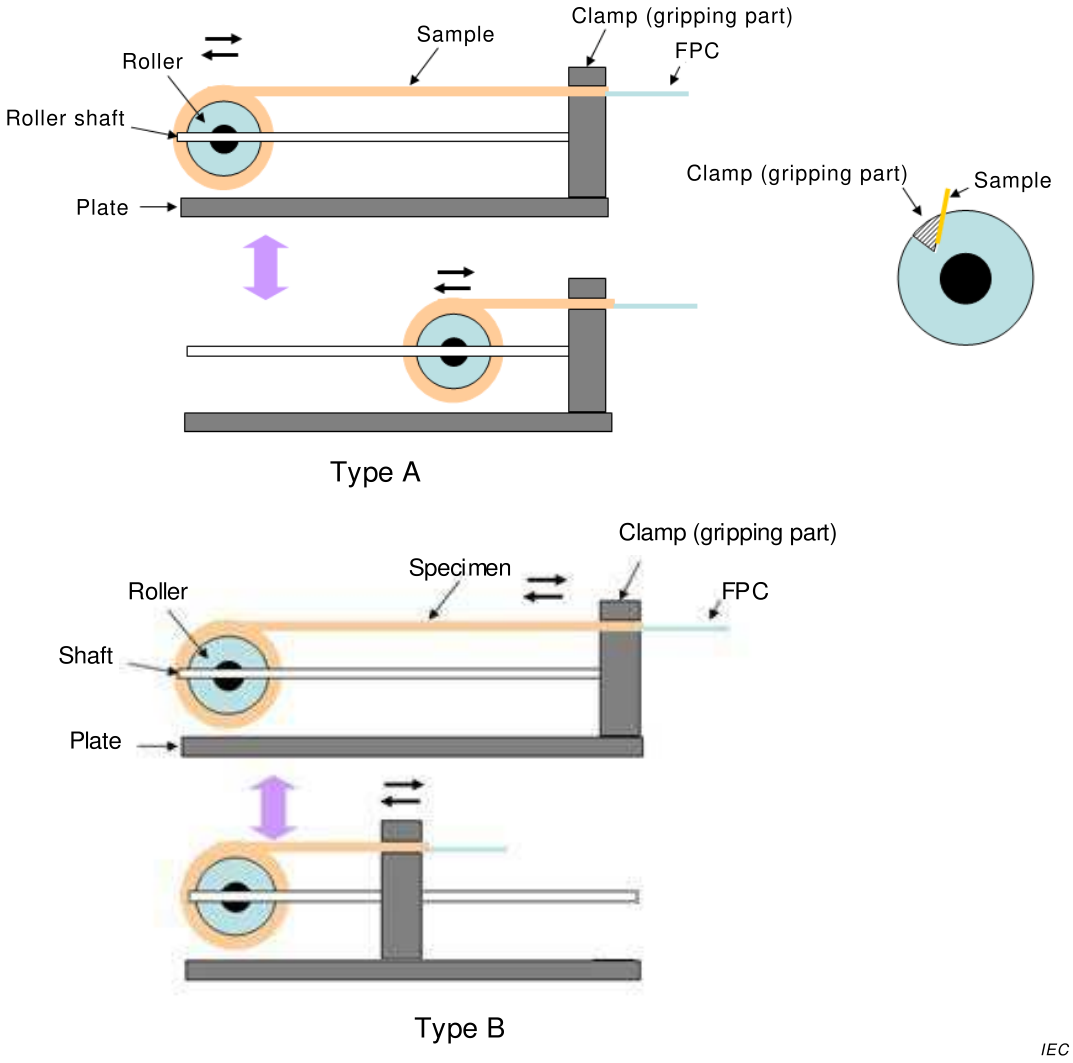


Figure 4 – Apparatus for rolling test

6.5.4 Test procedure

The rolling test shall be performed as follows:

a) Prepare the required number of specimens according to 5.2.

b) Perform the initial performance, visual characteristics, and test for the prepared specimens and record result.

c) Each specimen size is measured and recorded.

d) One edge of the specimen is fixed on the roll as shown in Figure 4 and the other edge clamp is supported with an individually defined load. Align the specimen with the top surface on the inner or the outer side of the roller.

e) Roll the specimen with defined conditions such as rolling radius, rolling distance, rolling angular velocity and load.

f) Bring the specimen back to the initial state before the rolling, with the same angular velocity and reversed rotation direction.

g) Repeat d) to e) for a defined number of cycles. It is optional to test the other surface side at the same conditions, this being done by agreement between supplier and customer. In this case, follow d) to g) with the reversed surface side.

h) After the test, remove the specimen from the apparatus.

i) Repeat the test with (an)other specimen(s) following c) to h).

j) The stressed performance, electrical and optical characteristics of the mechanically stressed module(s) with the required number of testings are measured, and the results are recorded. The initial and stressed performances are compared, and the degree of change due to the rolling test is determined.

k) The test and performance measurement for individual specimens are conducted and recorded in the test report.

6.5.5 Testing conditions and reporting

The testing conditions are specified as follows:

a) roll radius

b) angular velocity, procedure for one cycle

c) holding duration

d) load

e) number of repeating cycles

f) criteria for acceptance

g) number of specimens

h) rolling inner surface (top surface or back surface)

i) way of holding specimens and detailed method of holding, such as pressure

j) surface condition (such as treatment) of both specimen and apparatus

k) testing of environmental conditions, such as temperature and humidity.

NOTE The criteria for acceptance include the visual performance and specimen geometry both before and after the stressing.

All conditions shall be reported if the test uses conditions other than those mentioned above.

6.6 Static rolling test

6.6.1 General

This test is especially applicable for evaluating the static rolling properties of a flexible display module after a flexible display is rolled out, rolled in, or remains in the shape of a roll.

6.6.2 Purpose

The objective of this test is to provide a standard procedure for evaluating the robustness of the static rolling properties of the flexible display panel.

6.6.3 Test apparatus

The specimen shall be firmly clamped with a gripping part on the roller side and on the stationary side. The roller shall be moved forward and backward alternately at a fixed distance, speed, and rolling number as in Figure 4. The roller side has a slot where the edge of the specimen is inserted and clamped. The roller repeatedly shuttles along the roller shaft and the specimen does not touch the plate of the equipment during the rolling test as shown in Figure 4.

During the test, the FPC and the driver should be carefully handled so that they are not subjected to twist damage. The COF method is preferable in order to prevent the occurrence of twist damage on the driver IC during the bending test.

6.6.4 Test procedure

The rolling test shall be performed as follows:

a) Prepare the required number of specimens according to 5.2.

b) Perform the initial performance, visual characteristics, test for the prepared specimens and record the result.

c) Each specimen size is measured and recorded.

d) One edge of the specimen is fixed on the roll as shown in Figure 4 and the other edge clamp is supported with an individually defined load. Align the specimen with the top surface on the inner or the outer side of the roller.

e) Roll the specimen with defined conditions such as rolling radius, rolling distance, rolling angular velocity and load.

f) Hold the specimen in a rolled shape for a certain period.

g) Bring the specimen back to the initial state before the rolling with the same angular velocity and reversed rotation direction.

h) Hold the specimen in a rolled shape for a certain period, if required.

i) Repeat e) to h) for a defined number of cycles.

j) It is optional to test the other surface side at the same conditions, this being done by agreement between supplier and customer. In this case, follow d) to i) with the reversed surface side.

k) After the test, remove the specimen from the apparatus.

l) Repeat the test with (an)other specimen(s) following c) to k).

m) The stressed performance, electrical and optical characteristics of mechanically stressed module(s) with the required number of testing are measured, and the results are recorded. The initial and stressed performances are compared, and the degree of change due to the rolling test is determined.

n) The test and performance measurement for individual specimens are conducted and recorded in the test report.

6.6.5 Testing conditions and reporting

Testing conditions are specified as follows:

a) roll radius

b) angular velocity, procedure for one cycle

c) hold duration

d) load

e) number of repeating cycles

f) criteria for acceptance

g) number of specimens

h) rolling inner surface (top surface or back surface)

i) way of holding specimens and detailed method of holding, such as pressure

j) surface condition (such as treatment) of both specimen and apparatus

k) testing of environmental conditions, such as temperature and humidity

NOTE The criteria for acceptance include the visual performance and specimen geometry both before and after the stressing.

All conditions shall be reported if the test uses conditions other than those mentioned above.

6.7 Torsion test

6.7.1 General

This test is applicable for evaluating the torsion properties of a flexible display module after being subjected to torsion during a certain period of time. For flexible displays, torsion is likely to happen easily during use.

6.7.2 Purpose

The objective of this test is to provide a standard procedure for evaluating the robustness of a flexible display device against cyclic torsion stress which might typically happen in the application.

6.7.3 Test apparatus

The specimen shall be firmly clamped and twisted at a certain degree of torsion angle, as shown in Figure 5, during the test. The specimen shall be securely clamped with an appropriate gripping part. During the test, the FPC and the driver shall be carefully handled so that they are not subjected to twist damage. The edge of the specimen with the FPC and the driver's IC in the stationary side shall be fixed in order to prevent the occurrence of twist damage during the bending test. When the specimen is twisted, the extra tension is applied on the side of the specimen in addition to the twist tension. Therefore, the moving part on the stationary side shall move forward and backward during the test because the extra and unnecessary tension applied on the specimen should be removed as shown in Figure 5a) and b).

6.7.4 Test procedure

The torsion test shall be performed as follows:

a) Prepare the required number of the display modules according to 5.2.

b) Preform the initial performance, visual characteristics, test for the prepared modules and record result.

c) Each specimen size is measured, visually inspected and recorded.

d) Both edges of the testing module(s) are fixed on the gripping parts as shown in Figure 5.

e) Apply torsion with defined conditions such as clockwise angle and oscillation velocity.

f) Bring the specimen back to the initial state before the testing with the same angular velocity and reversed rotation direction.

g) Apply torsion with defined conditions such as counter clockwise angle and oscillation velocity.

h) Bring the specimen back to the initial state before the testing with the same angular velocity and reversed rotation direction.

i) Repeat e) to h) for a defined number of cycles.

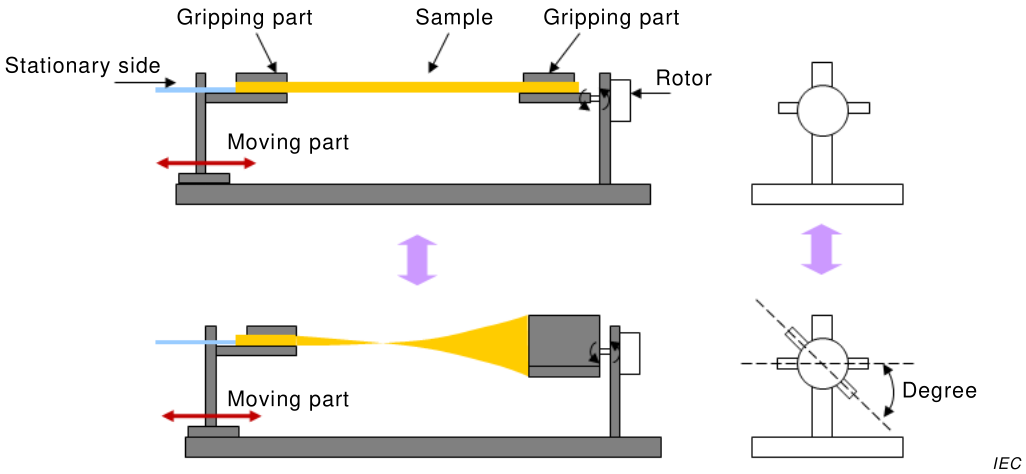
j) It is optional to test the other surface side at the same conditions, this being done by agreement between supplier and customer. In this case, follow d) to i) with the reversed surface side.

k) After the test, remove the specimen from the apparatus.

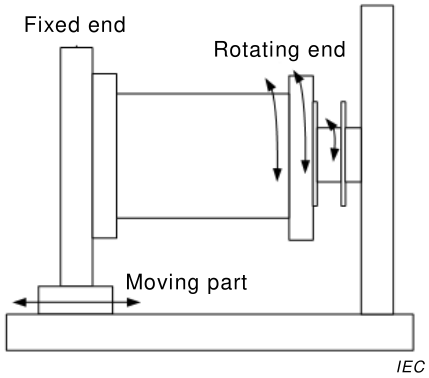
l) Repeat the test with (an)other specimen(s) following c) to k).

m) The stressed performance, electrical and optical characteristics of the mechanically stressed module(s) with the required number of testings are measured and the results are recorded. The initial and stressed performances are compared, and the degree of change due to the torsion test is determined.

n) The test and performance measurement for individual specimens are conducted and recorded in the test report.



a) Torsion test equipment



b) Torsion test equipment

Figure 5 – Apparatus for diverse torsion tests

6.7.5 Testing conditions and reporting

The testing conditions are specified as follows:

a) number of specimens
b) performance range for initial and stressed electrical and optical performance
c) torsion angle and rotation angular velocity
d) applied tensile stress
e) number of cycles
f) criteria for acceptance
g) way of holding specimens and detailed method of holding, such as pressure
h) surface condition (such as treatment) of both specimen and apparatus
i) testing of environmental conditions, such as temperature and humidity

NOTE The criteria for acceptance include the visual performance and specimen geometry both before and after the stressing.

All conditions shall be reported if the test uses conditions other than those mentioned above.

6.8 Tension test

6.8.1 General

This test is applicable for the evaluation of the tension properties of a flexible display module after being subjected to a constant tension at the moment of change between folding and unfolding and between roll-in and roll-out (see Figure 6).

6.8.2 Purpose

The objective of this test is to provide a standard procedure for evaluating the robustness of a flexible display device against cyclic tension stress which might typically happen in the application.

6.8.3 Test apparatus

The apparatus consists of a fixed and movable clamp in which the specimen will be secured for the test. The movable clamp shuttles forward and backward linearly at a set rate as shown in Figure 6. The instrument repeatedly applies and relieves the tension in the specimen for a set number of cycles. During the test, the FPC and the driver shall be carefully handled so that they are not subjected to tension damage. The edge of the specimen with the FPC and driver's IC in the stationary side shall be fixed in order to avoid the occurrence of twist damage during the bending test.

6.8.4 Test procedure

The tension test shall be performed as follows:

a) Prepare the required number of display modules according to 5.2.

b) Each specimen size is measured, visually inspected and recorded.

c) Perform the initial performance, visual characteristics, test for the prepared modules and record the result.

d) Both edges of the testing module(s) are fixed by the gripping part as shown in Figure 6.

e) Apply tension with defined conditions such as tension force or strain distance.

f) Bring the specimen back to the initial state before applying tension.

g) Apply tension with the same force losing speed and in the reversed direction.

h) Repeat e) to g) for a defined number of cycle.

i) After the test, the testing module(s) is(are) removed from the apparatus.

j) The stressed performance, electrical and optical characteristics of the mechanically stressed module(s) with the required number of testing are measured and the results are recorded. The initial and stressed performances are compared, and the degree of change due to the tension test is determined.

k) The test and performance measurement for individual specimens are conducted and recorded in the test report.

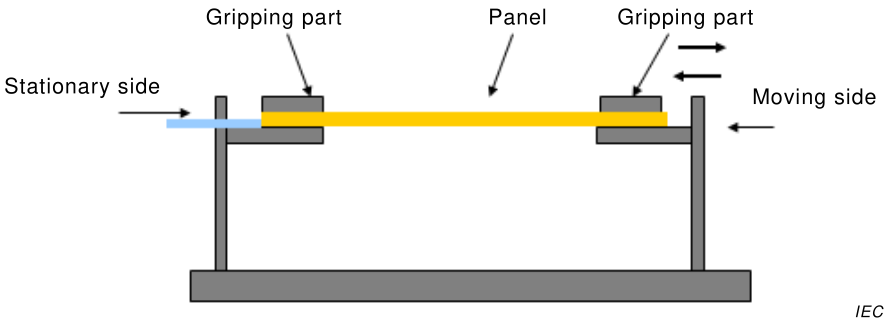


Figure 6 – Apparatus for tension test

6.8.5 Testing conditions and reporting

The testing conditions are specified as follows:

a) maximum tension force or maximum deformation distance applied to the specimen
b) tension application procedure such as time-dependent tension force, duration time between tension application
c) number of cycles
d) criteria for acceptance
e) number of specimens
f) way of holding specimens and detailed method of holding, such as pressure
g) surface condition (such as treatment) of both specimen and apparatus
h) testing of environmental conditions, such as temperature and humidity

NOTE The criteria for acceptance include visual performance and specimen geometry both before and after the stressing

All conditions shall be reported if the test uses conditions other than those mentioned above.

Bibliography

[1] Suo, Z. et al. Mechanics of rollable and foldable film-on-foil electronics. *Appl. Phys. Lett*. 1999, **74**(8), 1177-1179

[2] Gleskova, H., Wagner. S. and Suo. Z. Failure resistance of amorphous silicon transistors under extreme in-plane strain. *Appl. Phys. Lett*. 1999, **75**(19), 3011-3013

[3] Gleskova, H. et al. Electrical response of amorphous silicon thin-film transistors under mechanical strain. *J. Appl. Phys*. 2002, **92**, 6224-6229

[4] Grego, S. et al. A method to evaluate mechanical performance of thin transparent films for flexible displays. *Thin Solid Films*. 2007, **515**, 4745–4752

[5] Menard, E., Nuzzo. R. G. AND Rogers. J. A. Bendable single crystal silicon thin film transistors formed by printing on plastic substrates. *Appl. Phys. Lett*. 2005, **86**(9), 093507

[6] Chen. Z. et al. A Mechanical Assessment of Flexible Opto-electronic Devices. *Thin Solid Films.* 2001, **394**, 202-206

[7] Servati, P. and Nathan. A. Functional Pixel Circuits for Elastic AMOLED Displays. *Proceedings of the IEEE.* 2005, **93**(7), 1257-1264

[8] Rolland, A. et al. Electrical Properties of Amorphous Silicon Transistors and MIS-Devices: Comparative Study of Top Nitride and Bottom Nitride Configurations. *J. Electrochem. Soc*. 1993, **140**(2), 3679-3683

[9] Shur, M. S. et al. SPICE Models for Amorphous Silicon and Polysilicon Thin Film Transistors. *J. Electrochem. Soc*. 1997, **144**(8), 2833-2839

[10] Cairns. D.R. and Crawford. G.P. Electromechanical Properties of Transparent Conducting Substrates for Flexible Electronic Displays. *Proceedings of the IEEE*. 2005, **93**(8), 1451-1458

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