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TECHNICAL REPORT

colour inside

Flexible display devices – Part 6-21: Mechanical test methods – Foldable durability test for foldable display set

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FOREWORD

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
110/1426/DTR	110/1435A/RVDTR

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 Technical Report 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/standardsdev/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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
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FLEXIBLE DISPLAY DEVICES –

Part 6-21: Mechanical test methods – Foldable durability test for foldable display set

1 Scope

This part of IEC 62715, which is a technical report, provides information about various folding types and hinge structures of foldable products which can affect the durability of a foldable panel. This document focuses only on the issues concerning the foldable products and will not include product parts that do not affect display durability such as speakers, batteries, communication ports.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

3.1
foldable panel
flexible display panel which can be folded

3.2
foldable display set
foldable product
device to which a foldable panel is applied

3.3
in-folding
method used to fold the light emitting surface inward

3.4
out-folding
method used to fold the light emitting surface outward

3.5
multi-folding
method used to fold more than once in different positions

EXAMPLE The different folding positions can be in-out Z type or in-in G type.

3.6
in and out-folding
method used to fold in both the inward and outward direction

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

3.8
folding area
curved section of the panel due to folding

4 Foldable devices technology

4.1 General

The foldable product market has been growing steadily and the demand for foldable display panels is expected to increase in the future. The first foldable product was launched in 2019 and since then, various types of foldable products have been released during the past three years.

In 4.2, some of the techniques of the foldable product which affect the durability of the foldable panels are discussed.

4.2 Classification of folding product

4.2.1 General

The foldable product can be classified according to the folding method. The types of products released so far include in-folding and out-folding. Multi-folding (in-in folding, in-out folding) is expected in the future.

4.2.2 In-folding products

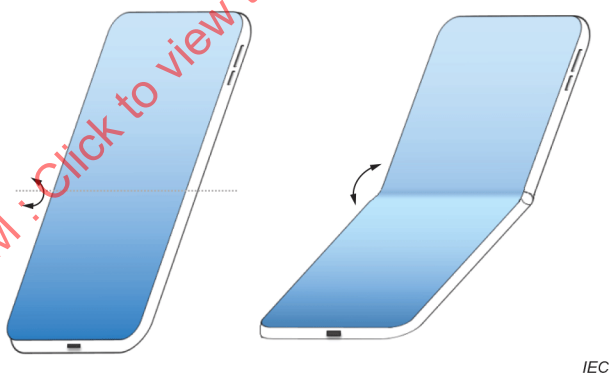

Figure 1 – Example of in-folding product

A foldable panel with the light emitting surface folded inward is called “in-folding” panel, and an “in-folding” product means a device to which the in-folding panel is applied. Figure 1 shows the most common type of the in-folding products. Such in-folding products have an advantage in that the panel surface can be protected in terms of durability because the panel is located inside the foldable product when folded.

On the other hand, since the R value for in-folding is smaller, more sophisticated technology is needed to ensure device durability.

As the R value becomes smaller, the folding stress that the panel experiences increases. To mitigate this stress, the technology of the material, stack structure and module design will be optimized so that it can buffer against the folding stress.

4.2.3 Out-folding products

The “out-folding” panel has a light emitting surface on the outside of the panel when folded, and an “out-folding” product means the device to which the out-folding panel is applied as shown in Figure 2.

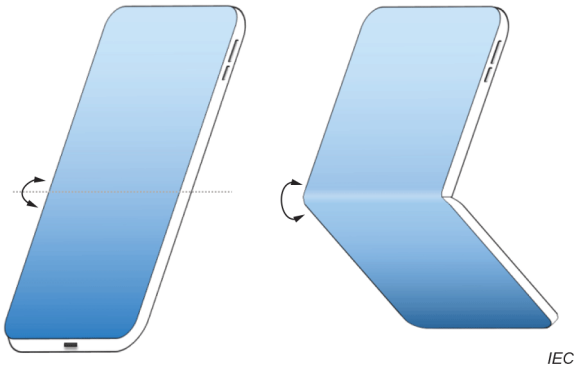

Figure 2 – Example of out-folding product

These out-folding products have a disadvantage with respect to durability because the surface of the foldable panel is exposed outward when folded so it is easily damaged. It is also more difficult to manage the flatness of the display surfaces when users configure the product in the unfolded state. This can cause distortion and bend of the display when viewed by the user. In addition, the screen can malfunction if it is unintentionally touched in the folded state.

On the other hand, compared to in-folding products, the R value for out-folding products is larger and results in a reduction of the folding stress. Figure 3 shows the R comparison between in-folding and out-folding products.

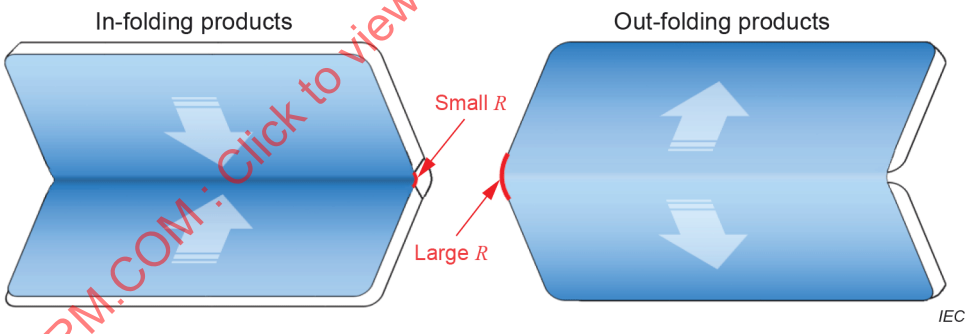

Figure 3 – R comparison of in-folding versus out-folding

4.2.4 Multi-folding products

Although they have not been released yet, it is expected that the multi-folding products that have a panel that can be folded several times will be launched in the near future.

Multi-folding products can fold the panel more than once. In terms of the types of product that can be folded twice, there is, for example, the in-out folding product of a Z-type that folds inward and outward once like a Z shape, as shown in Figure 4. Figure 5 shows the in-in folding product of a G-type which is folded inward twice.

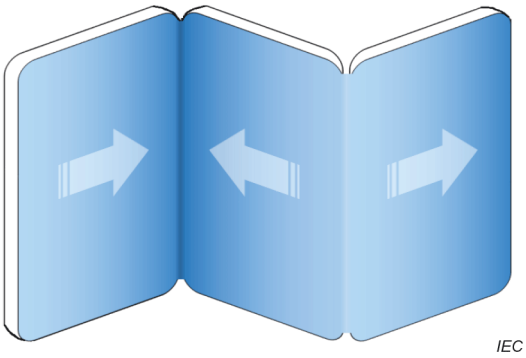

Figure 4 – Example of multi-folding Z-type product

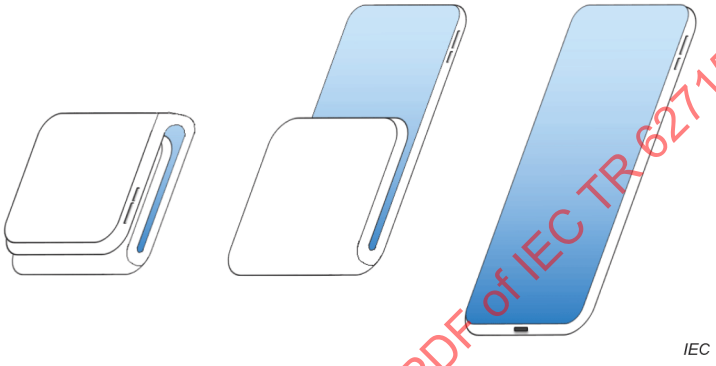

Figure 5 – Example of multi-folding G-type product

4.2.5 In- and out-folding products

The foldable products released so far can be folded only in one fixed direction determined by the manufacturer, as described in 4.2.2 and 4.2.3. But it will also be possible to launch products in the future which can be folded not only inward but also outward so that a user can fold freely in both directions. Figure 6 shows the expected form of in and out-folding products.

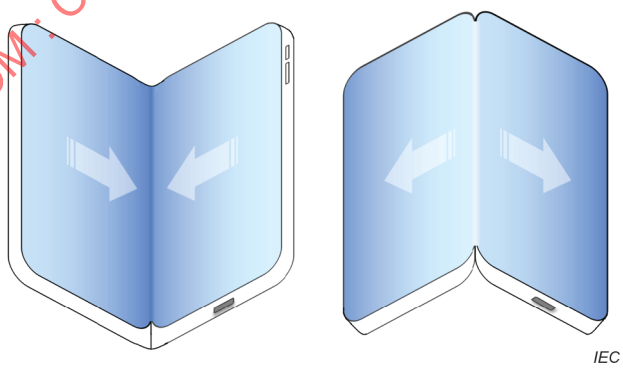

Figure 6 – In- and out-folding products

4.3 Hinge structure

4.3.1 General

Subclause 4.3 describes the structure of the hinge that can affect the durability of the foldable display, especially the folding area.

The flexible display developed today can be folded to a minimum curvature within the display screen's undistorted range but not as flat as paper. Since the resilience force increases with a decrease in the radius of the curvature, a robust configuration would be designed to maintain the device in its folded state. The hinge structure maintains the stable curvature and the consistency of the minimum R value. A hinge structure example is shown in Figure 7.

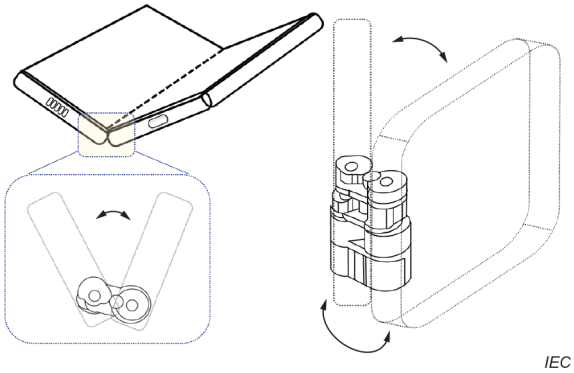

Figure 7 – General hinge structure

The hinge structure was used at the module-level for the flip phone, which had its heyday in the early 2000s before the launch of smartphones. Figure 8 shows an example form of flip phone.

Figure 8 – Flip phone

The physical button of the cell phone keyboard was gradually replaced by a touch screen panel, and after the release of the smartphone, the shape of the bar type became the most common, and the hinge structure was no longer used.

However, as the flexible display is developed, a smartphone product which adopts the foldable display with a hinge structure has begun to be released. The structure and shape of such hinges can directly affect the durability of the foldable display panel.

4.3.2 Role of the hinge structure

4.3.2.1 Design of the product

The overall design of the foldable product can be determined by the hinge structure. Depending on how the hinge is designed, the thickness and weight of the foldable product will be different, and the folding type introduced in 4.2 is also affected as one of the mechanical designs. In addition, the maximum folding angle, minimum force required for unfolding, and folding sequence are all included in the foldable product design category.

The folding angle of a foldable product means the angle formed by the two light emitting regions that face each other when the panel is folded, and is shown in Figure 9. For example, when the

in-folding product is completely folded, the folding angle is 0°, and when it is totally unfolded, the folding angle is 180°. The range of this angle is determined by the hinge structure of the set. In the case of an in-folding product, the hinge is designed so that the user cannot open the product by more than 180° of the folding angle, and if excessive force is applied, the product and the panel can be damaged. This folding angle can also be adjusted by the design of the hinge structure. The design that can be fixed at a specific certain folding angle by the frictional force between internal parts is also possible through the hinge structure design when folding and unfolding the product.

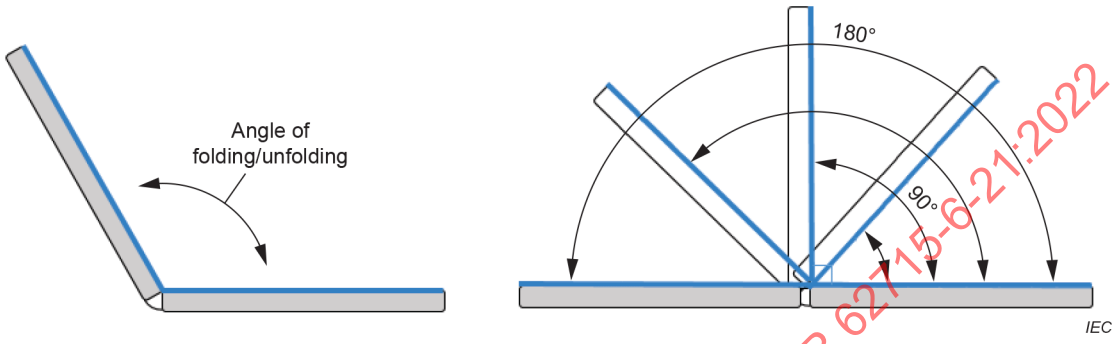

Figure 9 – Angle of folding and unfolding

The hinge structure can guide the user as to the order and the method of folding the panel. For example, in the case of a multi-folding G type product, there is an area to be folded first, and the different R values of each side of the panel can determine the folding order. If the users attempt to fold the product in the opposite order, the hinge structure would operate so that it cannot be folded.

The minimum force required when the user unfolds the product, which means the opposite force to overcome the force to keep the product closed, is determined by the hinge structure. If this force is too strong, the user will feel uncomfortable because it requires a lot of force to unfold and fold, and if this force is too small, the users will feel that the folded state is unstable.

These design elements can be decided entirely by the manufacturer and are a completely different issue from the foldable panel. As described above, the hinge structure can greatly affect the design of foldable products, and it can also be linked to the durability of the entire products.

4.3.2.2 Durability of the product

The durability of foldable products can be affected by the durability of each component of the product and the completeness of the mechanism that connects the interactions between them. There are two main sorts of components of the foldable products, the foldable panel and the hinge structure. The hinge structure is a frame component of the foldable product and at the same time has a role of mechanism that makes the display panel foldable. Therefore, if even one of the inner parts of the hinge deviates from its connection structure, a problem can arise in the process of folding the product, which will affect the durability of the panel and product.

In order to satisfy the design elements of various foldable products introduced in 4.3.2.1 and be supplied to consumers as mass-produced products, the durability of the hinge structure itself will be supported when performing such a folding function. Basically, in order for the foldable panel to maintain a constant R and to be able to fold well, connection between each component of the product is designed to prevent defects caused by foreign matter inflow in the gap, and the hinge part will also be aligned.

In an actual environment where consumers use foldable products, foldable panels are exposed to external forces and shocks. In the process of folding and unfolding the foldable product in a set state containing a hinge, the foldable panel can be damaged if the hinge structure is not

strong enough. For example, if the consumers twist the product in the wrong folding direction, the foldable panel will be affected because the R value in the folding area is not maintained constant, or another area which is not the designated folding area is folded forcibly. This is why the robustness of the hinge structure affects the durability of the entire product.

In addition, the impact on the foldable panel can be changed depending on the characteristics of the consumer's usage. In particular, the manner for folding and unfolding the foldable product is different from person to person. For example, there might be a person who unfolds the product by holding the edge of the panel with both hands, and some other person who wants to unfold the product by putting a finger between the panels using only one hand. As a result, there will be a difference in stress applied to both sides of the foldable panel, and this causes the situation of folding misalignment.

Many manufacturers have been making efforts to develop more robust hinge structures in order to improve the durability of the entire products. For example, in order to complement the durability of the hinge structure itself, parts that are both waterproof and flexible, such as silicon material, can be added inside to supplement the dustproof and waterproof functions. Also, a bar-type rail can be added between the panel and the support layer to mitigate external shocks on the corners.

In addition, there is an example of development for complementing the completeness of the folding mechanism, in which a storage space is provided inside the hinge and structure that can be folded without an empty space while being folded with a large curvature that gives less stress to the panel when folded.

4.3.2.3 Experience of the product

For "good" foldable products, the screen will be well folded and at the same time well unfolded. This is because when a user unfolds the product to see the large screen, which is one of the advantages of a foldable product, distortion or curvature in the folding area in the middle of the screen adversely affects the user's experience.

The ability both to fold and unfold well comes from the hinge structure. In particular, the completeness of the foldable product is determined by how to design the inner structure of the hinge, which is invisible. As explained in 4.3.1, the hinge in the foldable product is a structure that stably maintains the folded state and the R value, and at the same time, it inevitably affects the folded and unfolded state while in contact with the folding area. This will determine the quality in which users experience the foldable product.

For example, when a foldable product unfolds, consumers can perceive the mark on the folding area and a slightly bumpy surface of the display. This is a phenomenon that started to arise when the display panel is folded as a new form factor rather than when using the flat panel as it is. It is possible that it will worsen over time due to the deterioration of the hinge structure or the adverse conditions of usage. These factors greatly affect the user's product experience, and IEC 62715-6-22 [1][1] specifies the definition and measurement method for “crease” and “waviness” of the foldable panel.

When the foldable product is unfolded, the hinge can be concealed in the internal storage space so that the user can fold or unfold the screen smoothly. This is an example of a hinge structure that has enhanced the user's product experience. This is considered as an example of a technology that affects user experience innovation by keeping the screen flat and thin without being affected by structural influences as the hinge at the back of the panel is hidden inward when the entire folded product screen is unfolded.

As a result, the hinge structure first determines the design of the foldable product as a structure or frame, and then determines the durability of the entire product. It is an important part that

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

finally determines the experience of users based on design and durability of the foldable products.

4.3.3 Types of hinge structure

The hinge structure of the foldable product can generally be classified according to the R value of the foldable panel. There is a hinge that makes the products fold while the R is kept more or less constant, and there is a hinge that makes the products fold with R values that change more substantially as a function of position along the device.

The case where R is more or less constant is referred to here as the constant R type and is shown in Figure 9. Note that while referred to as constant R, the panel in fact takes on an elliptical rather than perfectly semi-circular shape in the region of bending.

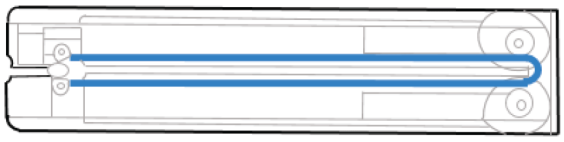

Figure 10 – Constant R type hinge

The type in which R is more significantly varying has the characteristic that the cross-sectional shape at which the panel is folded is in the shape of a water drop or vial, and the R can change more substantially according to the position along the device as shown in Figure 11.

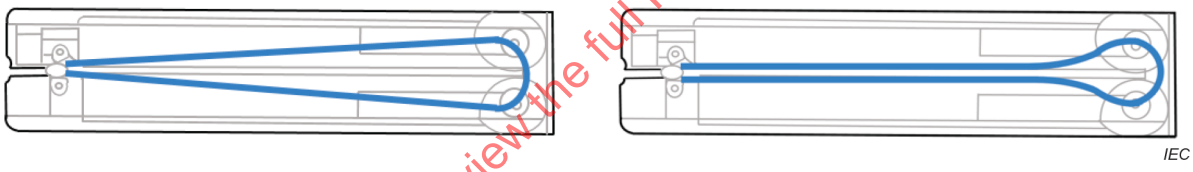

Figure 11 – Varying R type hinge

Unlike constant R type hinge, the varying R hinge structure generally has a larger R in the folding area so that the folding stress and the crease can be reduced when folded; the farther away from the folding area, the smaller R value is.

The varying R hinge type can also be applicable to the case that makes the hinged part invisible from the exterior of the product. In this case, some part of the folding area is embedded, so that it can minimize the gap between the two light emitting regions that face each other when the panel is folded. It can also decrease the thickness of the foldable product.

5 Durability items of folding products

5.1 General

In Clause 5, the items that can be considered in the durability test of foldable products are considered.

Over the last few years, various foldable products that have adopted foldable display panels have been released. Accordingly, many reviewers have conducted durability tests for foldable products that have been shared publicly. However, these test results can be misleading and give the wrong conclusions about the devices.