

A STUDY ON TOUGHENED GLASS USED FOR VEHICLES AND ITS TESTING METHODS

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ABSTRACT

Toughened glass for vehicles is used for most window glass, except for windshield glass, and in particular is also generally used for sunroofs installed on the roofs of vehicles. Toughened glass is known to have external impact resistance that is about four times stronger than original glass.

We would like to verify that ceramic-printed toughened glass does not meet of GTR(Global Technical Regulations) No. 6 and its strength is lower than original glass through tests.

The tests were conducted with the test piece of original glass, toughened glass, and ceramic-printed toughened glass from five glass manufacturers. In Test 1, a 227g steel ball was dropped from a height of 2 meters, and damage was checked according to the test method of GTR No. 6, and in Test 2, a steel ball was freely dropped from different heights and limited damage height was determined.

In the result of Test 1 according to the test method of GTR No. 6, while all five test pieces of toughened glass were not damaged, all the ceramic-printed toughened glass from the five manufacturers were damaged.

In the result of Test 2, none of the five test pieces of toughened glass were damaged by a 10m ball drop, the original glasses were damaged by an average of 3m ball drop, and the ceramic-printed toughened glasses were damaged by an average of 1.4m ball drop.

As the results of the tests show, ceramic-printed toughened glass does not have the features of toughened glass due to its very low strength.

Therefore, we would like to contribute to the safety of consumers by considering the GTR No.6, and by revising the toughened glass test method.

1. INTRODUCTION

Vehicle manufacturers have broadened the ceramic-printed area of toughened glass to improve the external design of vehicles and the attachment of glass to the vehicle body.

The panoramic sunroofs of vehicles are mainly made of toughened glass, and the ceramic-printed area accounts for 30~70%.

According to the details of reports from a vehicle defect reporting center of the Republic of Korea, the defect reports related to panoramic sunroof damage have been increasing in recent years. Therefore, we believe that as the ceramic-printed area has been broadened, the damage of toughened glass that is vulnerable to external impacts have also been increasing, and so have the complaints of consumers.

Hence, we would like to verify the vulnerability of ceramic-printed toughened glass through the test and consider the test method of GTR No. 6.

2. TYPE AND DEFINITION FOR VEHICLE GLASS

- a. **Laminated Glass:** Means glazing consisting of two or more layers of glass held together by one or more inter-layers of plastic material.
- b. **Toughened glass:** Means glazing consisting of a single layer of glass which has been subjected to special treatment to increase its mechanical strength and to condition its fragmentation after shattering.

- c. **Double Glazing:** Double-glazed unit means an assembly of two panes permanently assembled in manufacture and separated by a gap.
- d. **Glass-plastic Combination Glass:** Glass-plastic means glazing consisting of any glazing material which comprises one layer of glass and one or more layers of plastic in which a plastic surface of the product faces the inner side.
- e. **Original Glass:** This is the glass pane before the process to make safe glass for vehicle.
- f. **Ceramic-printed Toughened Glass:** This is the toughened glass which has been toughened after ceramic printing.

3. BALL DROP IMPACT STRENGTH TEST FOR GLASSES

a. Test Purpose

The purpose is to investigate what result comes out when ceramic-printed toughened glass is tested for GTR No. 6 and to compare the impact strength of ceramic-printed toughened glass and original glass.

b. 227 g Ball Drop Test

- **Test equipment**

- Steel ball: Hardened-steel ball with a mass of $227 \text{ g} \pm 2 \text{ g}$ and a diameter of approximately 38 mm.
- Support for ball tests: Supporting fixture, such as that shown in Figure 1, composed of steel frames, with machined borders 15 mm wide, fitting one over the other and faced with rubber gaskets 3 mm thick and 15 mm wide and of hardness 50 ± 10 International Rubber Hardness Degree (IRHD).

The lower frame rests on a steel box 150 mm high. The test piece is held in place by the upper frame, the mass of which is 3 kg. The supporting frame is welded onto a sheet of steel 12 mm thick resting on the floor with an interposed sheet of rubber 3 mm thick and of hardness 50 ± 10 IRHD.

Figure 1 shows the supporting fixture used for the test and Figure 2 shows the whole device for the ball drop test.

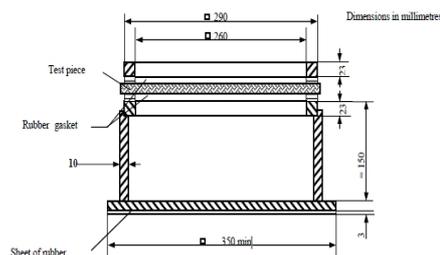


Figure 1. Drawing of Supporter



Figure 2. The test equipment for the ball drop test

- **Test piece**

- The test piece is manufactured flat, with a size of $300 \times 300 \text{ mm}$.
- The thickness of the test piece, which is used for panoramic sunroofs, is $4 \text{ mm} \pm 0.2 \text{ mm}$.
- Type of test piece: Three type of toughened glass, ceramic-printed toughened glass, and original glass from five manufactures. The test piece are marked A, B, C, D, and E.

- **Test 1**

- Test method: Test according to GTR No. 6
- Procedure
 - ① When a 227 g ball drop test is conducted at a height of $2.0 \text{ m} \pm 5_0 \text{ mm}$, the test piece shall not break.
 - ② Six test pieces shall be tested and at least five shall meet the requirements.
- Result of Test 1

Table 1. Result of Test 1(Number of Pass/Number of Tests)

Type of Glass	A	B	C	D	E
Original Glass	Pass(6/6)	Fail(4/6)	Pass(6/6)	Pass(6/6)	Pass(6/6)
Toughened Glass	Pass(6/6)	Pass(6/6)	Pass(6/6)	Pass(6/6)	Pass(6/6)
Ceramic-printed Toughened Glass	Fail(0/6)	Fail(0/6)	Fail(0/6)	Fail(0/6)	Fail(1/6)

As shown in Table 1, the original glass met of GTR No. 6 except for test piece B, and all test pieces of toughened glass met the regulation. However, none of the test pieces of ceramic-printed toughened glass met GTR No. 6.

- **Test 2**

- Test method: A 227 g ball is dropped every 20 cm from a higher position starting at 1 m till the test piece is broken. When the test piece is broken, the same test piece is tested at the same height.
- Procedure: When two sheets are damaged at the same height in a row, the height at which test pieces broken shall be taken.
- Result of Test 2.

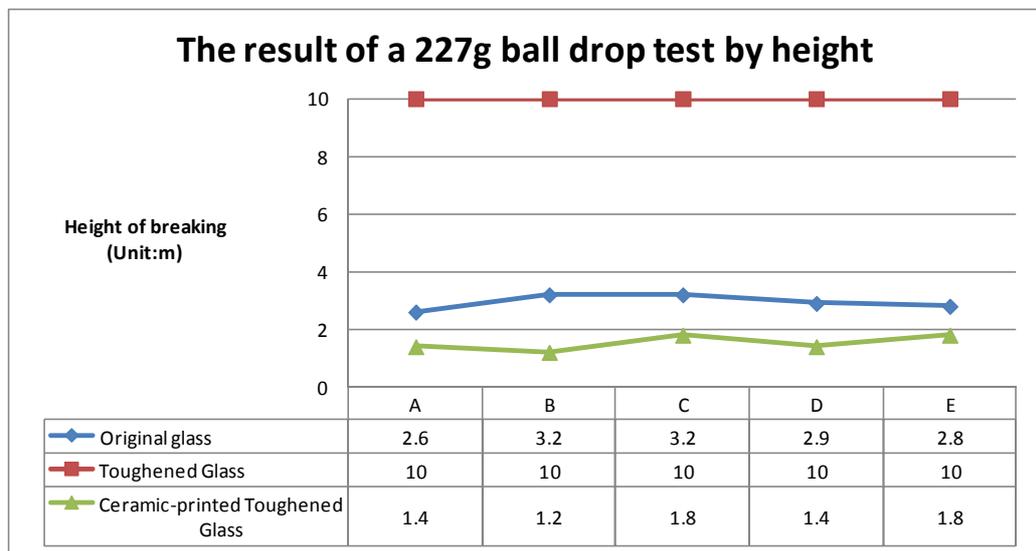


Figure 3. Result of Test 2

As shown in Figure 3, original glass was damaged at an average ball drop height of 3 m. while toughened glass was not damaged at a ball drop height of 10 m. However, ceramic-printed toughened glass was damaged at average height of 1.4 m. Also, the damage height of ceramic-printed toughened glass is lower than the damage height of original glass, showing vulnerability to external impact strength.

Ceramic-printed toughened glass does not meet the feature of toughened glass defined in GTR No. 6 in terms of strength.

4. VULNERABILITY OF CERAMIC-PRINTED TOUGHENED GLASS

a. Toughened Glass Manufacturing Process

The manufacturing process of toughened glass is divided into a pre-treatment process and a toughening process. During the pretreatment process, original glass is cut and ceramic is printed and dried. And during the toughening process, pretreated glass is put into a heating furnace and heated at 600~700°C. And then curvature is given to the glass and it is toughened through a cooling technique (rapid cooling, etc.). Figure 4 shows the manufacturing process of toughened glass by phase.

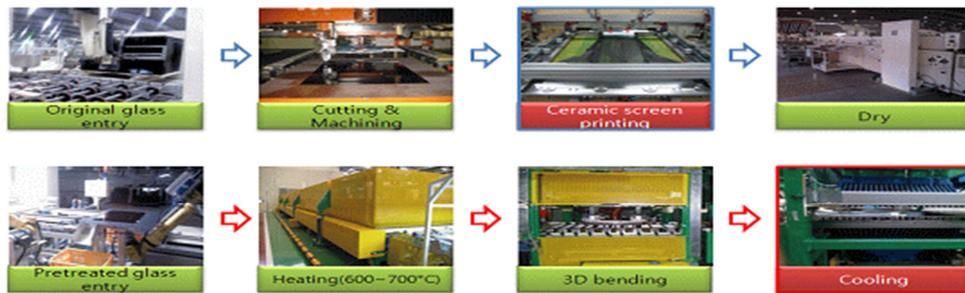


Figure 4. Manufacturing process of toughened glass

b. Stress Distribution of Toughened Glass

In toughened glass finished with a toughening treatment, both outside surfaces are very stable due to compression stress, while the inside is very unstable due to tension stress. Figure 5 shows the stress distribution of general toughened glass.

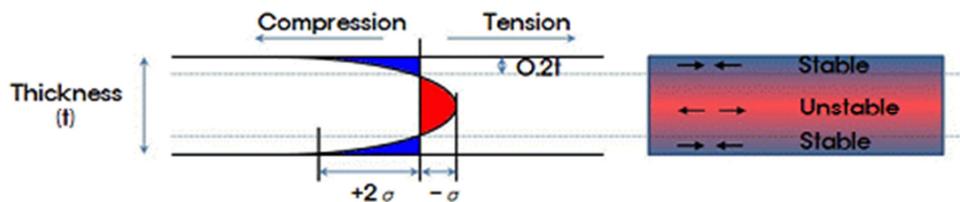


Figure 5. Stress distribution map of cross section of toughened glass

c. Ceramic Printing of Toughened Glass

During the pretreatment process, enamel paint, which is composed of frit, pigment, and medium, is printed on original glass and dried. The glass is then fused with high heat in a furnace at a high temperature. Figure 6 shows the ceramic printing and fusing process of toughened glass.

The reason for ceramic printing is the necessity of having a rough ceramic surface to maintain strong adhesive strength when glass is attached to a vehicle body. The other reasons are the concealment of interior materials and blocking of UV rays.

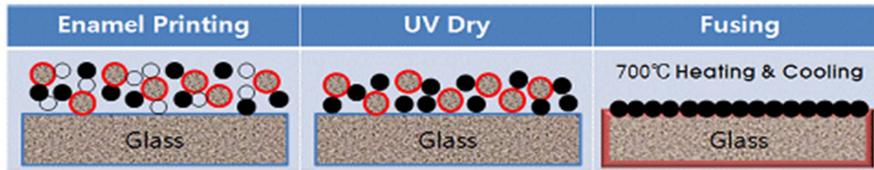


Figure 6. Ceramic melting process of toughened glass

※ Enamel materials: ● Frit, ● Pigment(Ceramic), ○ Medium

d. Reason why Ceramic-printed Toughened Glass is Vulnerable

Ceramic fusion of toughened glass makes the glass surface very unstable because it hampers the formation of compression stress on the surface. Figure 7 shows the stress distribution of ceramic-printed toughened glass. The ceramic-printed layer hampers the toughening of glass on the outside surface and marks unstable tension stress work.

Therefore, it can be damaged by a small impact more easily than original glass.

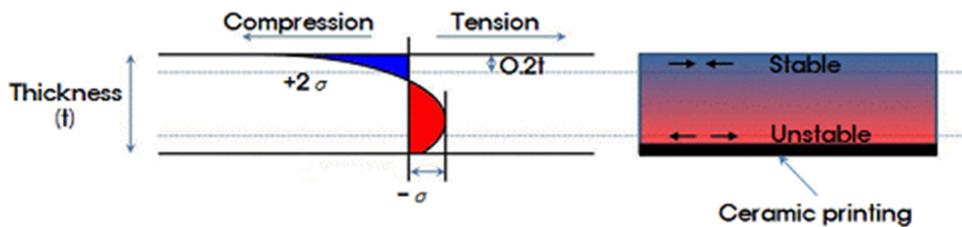


Figure 7. Stress distribution of ceramic-printed toughened glass

e. Case of Ceramic-printed Toughened Glass

Ceramic-printed toughened glass is used for most vehicles. As shown in Figure 8, it is used for sunroofs, side window glass, and rear window glass.



Figure 8. Use case of ceramic-printed toughened glass

f. Damage Cases of Ceramic-printed Toughened Glass

Figure 9 shows cases of damage to ceramic-printed toughened glass by external impacts. In all cases, the ceramic-printed area is damaged.



Figure 9. Damage case of ceramic-printed toughened glass

5. CONSIDERATION OF SAFETY REGULATION FOR TOUGHENED GLASS FOR VEHICLES

a. The Global Technical Regulation of Toughened Glass for Vehicles(GTR No. 6)

<p>Global technical regulation No. 6</p> <p><A. STATEMENT OF TECHNICAL RATIONALE AND JUSTIFICATION></p> <p>30. The purpose of the 227 g steel ball test is to assess the resistance of the glazing to impacts from stones or other flying objects that might be encountered in everyday use.</p> <p><B. TEXT OF REGULATION></p> <p>3.3.7. Uniformly toughened -glass : means glazing consisting of a single layer of glass which has been subjected to special treatment to increase its mechanical strength and to condition its fragmentation after shattering.</p> <p>6.3.4.1. The test pieces shall be flat samples measuring 300 x 300 mm, specially made or cut from the flattest part of a windscreen or pane.</p> <p>6.3.4.2. Test pieces can alternatively be finished products that may be supported over the apparatus described in paragraph 6.3.1.</p> <p>6.3.4.3. If the test pieces are curved, care should be taken to ensure adequate contact with the support.</p> <p>6.3.2.3. The point of impact shall be within 25 mm of the centre of the supported area for a drop height less than or equal to 6 m, and within 50 mm of the centre of the supported area for a drop height greater than 6 m.</p>
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b. Analysis of GTR No. 6

The features of toughened glass for vehicles can be divided into two things. First, the external impact strength is three to four stronger than original glass. Second, when it is damaged it breaks into small pieces without sharp points.

GTR No. 6 provides a 227 g ball drop test to evaluate external impact strength, the feature of toughened glass, and fracture test to evaluate if it is broken into small pieces without sharp points.

The height of the ball drop test provided in GTR No. 6 is 2 m. This is lower than the height of damage of original glass in our test. Therefore, to evaluate the mechanical strength of toughened glass, setting the 227 g ball drop height as more than or equal to 3 m should be considered.

Also, if toughened glass has a ceramic-printed area, it cannot be regarded as equal to toughened glass. Therefore, the test method for ceramic-printed toughened glass needs to be provided separately.

For your reference, there is the item that heated wire installed in window glass is excluded from tests in UN Regulation No. 43, "Uniform provisions concerning the approval of safety glazing materials and their

installation on vehicles.” It is considered that the device needed to secure a view rather than the strength of glass is allowable regardless of strength.

Regulations No. 43			
<ANNEX 5>			
3.1. 227g ball test			
3.1.1. Indices of difficulty of the secondary characteristics.			
Material	Index of difficulty	Colouring	Index of difficulty
Polished glass	2	Colourless tinted	1
Float glass	1		2
Sheet glass	1		
The other secondary characteristic (namely, incorporation or otherwise of conductors)is not involved.			

6. CONCLUSION

Ceramic printing technology, the surface process technology of toughened glass, was evaluated as an innovative technology when it was developed. It is said the development of this technology has reduced the production process for the attachment of window glass to vehicle bodies and improved durability. Also, the design of a vehicle body has freely gone luxe, and UV rays can be blocked. In this way, ceramic printing has a lot of benefits.

Because of these many benefits, the ceramic-printed area in the toughened glass has been broadened. In particular, as panoramic sunroof-equipped vehicles became popular, the ceramic area went bigger in design, and vehicles with ceramic-printed toughened glass account for as much as over 70% of vehicles.

However, it was confirmed that the ceramic-printed area of toughened glass has the drawback that its strength was lower than original glass, as shown in table 1 and Figure 3.

Therefore, as it is vulnerable to small external impacts or vibration, it leads to the damage of the whole toughened glass. In particular, in the case of a sunroof, which is installed above the head of a driver, if the glass is damaged, the glass fragments fall onto the head of the driver and threaten safe driving.

Hence, it is considered that if ceramic printing is necessary for toughened glass for a vehicle, it should be applied in the minimum area needed for the attachment of glass to the vehicle body.

The low strength of the ceramic printed area of toughened glass, which was determined in this study, is expected to be overcome through technology development for ceramic painting or various kinds of surface treatment technology. If it cannot be overcome with current technology, the safety regulation for window glass should be revised to minimize the risk. Therefore, it is believed that regulation of the ceramic-printed area of glass through the revision of the current regulation can contribute to safe driving.

RERERENCE

[1] Motor Vehicle Safety Standard of Korea, Article 34 “Window Glass”, Article 105 “Stability of Window Glass”

[2] UN ECE Regulation No. 43 “UNIFORM PROVISIONS CONCERNING THE APPROVAL OF SAFETY GLAZING MATERIALS” Revision 1, Revision2 and Revision 3.

[3] FMVSS 571.205 Standard No. 205 “Glazing materials”.

[4] SAE Standard ANSI / SAE Z26.1-1996.

[5] UN Global Technical Regulation No. 6 “SAFETY GLAZING MATERIALS FOR MOTOR VEHICLE AND MOTOR VEHICLE EQUIPMENT” 12 March 2008.

[6] KAC Homepage ‘<http://kac.kccworld.co.kr>’

[7] HANGLAS Homepage '<http://www.hanglas.co.kr/auto/>'

[8] NSG Group Homepage '<http://www.nsg.com/en/our-businesses/automotive>'