Features of Stressed State and Properties of Glass Tempered by Contact Method

Zheplynskyy Taras[1], Serkiz Oksana[2]

Chemical Technology of Silicates, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery street 12,

[1] E-mail: zheplynskyi@ukr.net

[2] E-mail: kseniaserkiz@gmail.com

***Abstract* – The main advantages of the new energy-saving method of glass tempering are described. It was found that the thickness of the strengthened layer and the ratio of tensile to compressive stresses is greater than in a traditional method. The influence of tempering on the value of microhardness and contact angle of glass surface was investigated.**

Key words – float glass, methods of tempering, residual stresses, microhardnes, contact angle.

I. Introduction

Nowadays, besides the traditional applications, float glass is widely used as a construction material (stairs, ceilings, floors, etc.), therefore the need of studying and improvement of various methods of glass strengthening is constantly increasing [1, 9].

One of the most widespread methods of glass strengthening is tempering. But this method requires significant consumption of energy. Therefore, it is important to develop more energy- saving methods of glass strengthening. One of them is the contact tempering [2, 3]. The advantage of this method is using water as a cooling agent and the compactness of device, because the process of heating and cooling is carried out at the same place without moving the glass.

Research the properties and structure of tempered glass are dedicated a number of works [1, 4, 6-9]. In the new method the cooling process is different from the traditional tempering, therefore there is a need of studying the properties and structure of the stressed state of that glass.

Among the various properties of glass the especial attention should be paid to studying the surface state of glass from which mainly depends the strength of glass.

In this paper the microhardness and contact angle of the glass surface were investigated.

II. Experimental technique

To investigate the influence of tempering regimes on the formation of residual stresses 6 mm float glass samples by size 50×25 mm were used (Table 1).

Tempering was conducted by the contact method, which based on the fact that glass sample is fixed between the heat conductive plates and then in that form is heated to the tempering temperature. Then, after holding at a certain temperature, it is cooled by spraying the outer surface of heat-conductive plates. The temperature of tempering varied in the range from 670 to 685 ^{0}C, the holding time was180 secs. Water consumption was 0,035-0,045 l/sec, the duration of spraying was 30-35 secs.

TABLE 1

COMPOSITION OF FLOAT GLASS, (WT. % OXIDES)

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	Others
72.8	1.00	0.10	3.4	8.9	13.5	0.3

Microhardness was determined by measuring the length of diagonals of pattern obtained on the surface of the sample by the pyramidal diamond indenter after penetration under load. The load on the indentor was 100 g, holding time was 15 secs. The length of the indentation diagonals was measured by using Axio programme. The results are the average of 20 shots done in different parts of the surface of the glass. Diagrams of the distribution of residual stresses in the glass were obtained by SCALP-04 [5].

Contact angle was determined by measuring the size of a drop of distilled water by using the digital photography. The volume of a drop was 0.01 ml.

III. Experimental results and disscusion

To investigate the properties of tempered float glass the samples with different values of residual stresses were used.

The value of stresses depends on the tempering temperature, the duration of cooling and water consumption. Details of the influence of these parameters is described in [6].

The thickness of strengthened layer plays important role in exploitation of glass constructions. In the glass tempered by traditional method its value is 1/6 of the total thickness [7]. For 6 mm glass it is 1 mm. The research results of glass samples tempered by contact method showed (Table 2), that the thickness of the compressed layer is in the range from 1,31 to 1,41 mm (Fig. 1). This significantly increases the exploitation reliability of glass products.

TABLE 2

CHARACTERISTICS OF STRESS DISTRIBUTION IN GLASS TEMPERED BY CONTACT METHOD

Compre-sion, MPa	Tensile stress, MPa	The ratio of compression/ tension	Thickness of compressed layer, mm
120	44	2,7	1,36
109	38	2,9	1,38
102	42	2,4	1,41
95	35	2,7	1,40

In addition to increasing the thickness of the compressed layer an increase of the value of parameter χ (the ratio of compressive to tensile stresses) is observed. For the traditional tempered glass with compressive stresses of 110 MPa that parameter is 2.1 [5]. For the contact method its value can reach 2.9 (Table 2).

In the traditional method of tempering the value of tensile stresses in the middle layer exceeds the maximum strength limit of 50 MPa. Therefore that glass is not subjected to any mechanical treatment. In glass tempered by contact method the tensile stresses do not exceed 44 MPa. This allows to do drilling and cutting of tempered glass samples.

A diagram of the stress distribution is different from the traditional by the fact that in this case the ratio of the area of compressive to tensile stresses is not equal to 1, it is 1.7. This retio is also observed in glass, strengthened by ion exchange [1]. However, the reason for this phenomenon is not fully studied and requires further investigation.

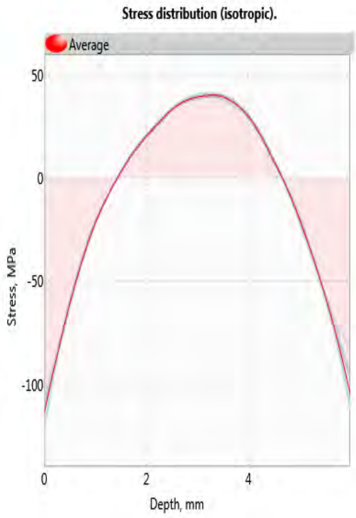

Fig. 1. Diagram of distribution of stresses in glass tempered by contact method

And as in traditional tempering, microhardness of glass tempered by contact method is lower than in the initial glass. This decrease of microhardness some researchers associated with a decrease of the glass density [7] the others with the presence of tension layer in the glass [8]. It also requires additional research. However, analyzing the microhardness of glass tempered by contact method (Table 3) its value is bigger than in the glass tempered by traditional method (5.3 GPa and 5.1 GPa).

TABLE 3

MICROHARDNESS AND CONTACT ANGLE OF DIFFERENT TYPES OF GLASS SAMPLES

Microhardness, GPa		Contact angle, degree
Initial sample	5,6	26
Air method	5,1	32
Contact method	5,3	36

As seen from Tab. 3, the surface wettability depends on the presence of surface stresses. Contact angle of glass, tempered by air is bigger than in the initial sample by 25%. The same tendency is observed in the glass tempered by contact method. But in this case, the contact angle increases to a greater degree (35%). This phenomenon also requires thorough research.

Conclusion

A new method of glass tempering is more energy-saving than the traditional air one. The advantages of this method are the use of water as a cooling agent and compactness of a device, because the process of heating and cooling is carried out at the same position without moving glass.

The method of contact tempering gives the possibility to obtain glass with greater thickness of compressed hardened layer and with the increased ratio of compressive to tensile stresses.

Tempering causes a decrease of microhardness, but its value is bigger than in glass, tempered by the traditional method.

Wettability of the surface depends on the presence of stresses in the glass. Contact angle of glass tempered by contact method is larger than in the initial by about 35%.

References

[1] S. Karlsson, B. Jonson, C. Stalhandske, "The technology of chemical glass strengthening – a review", Glass Technol. Eur. J. Glass Sci. Technol. A, vol. 51 (2), pp. 41–54, Apr. 2010.

[2] T. B. Zheplynskyi, Z. I. Borovets, M. Y. Holovchuk, "Sposib hartuvannia skla," ["Method of glass tempering"] Patent Ukrainy na vynakhid №96886, 12.12.2011.

[3] T. B. Zheplynskyi, Z. I. Borovets, R. M. Sheremeta, O. K. Serkiz, "Ustanovka dlia hartuvannia skla," ["Device of glass tempering"] Patent Ukrainy na vynakhid №96886, 12.12.2011.

[4] P. Castellini, L. Stroppa, N. Paone, "Laser sheet scattered light method for industrial measurement of thickness residual stress distribution in flat tempered glass", Optics and Lasers in Engineering, vol. 50, pp. 787–795, May 2012.

[5] H. Aben, J. Anton, A. Errapart, "Modern photo-elasticity for residual stress measurement in glass", Strain, vol. 44, pp. 40-48, Jan. 2008.

[6] T. Zheplynskyy, O. Serkiz, "Contact method of glass toughening", Glass International, vol. 36, pp. 42-44, Jun. 2013.

[7] A. Koikea, S. Akibaa, T. Sakagamia, K. Hayashia, S. Itoa, "Difference of cracking behavior due to Vickers indentation between physically and chemically tempered glasses", vol. 358, Issue 24, pp. 3438–3444, Dec. 2012.

[8] K. Kese, Z. Li, B. Bergman, "Influence of residual stress on elastic modulus and hardness of soda-lime glass measured by nanoindentation", J. Mater. Res. vol. 19, pp. 3109-3119, Nov. 2004.

[9] J. Schneidera, S. Schulaa, W. Weinhold, "Characterisation of the scratch resistance of annealed and tempered architectural glass", Thin Solid Films, vol. 520, pp. 4190–4198, Apr. 2012.