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SURFACE PROPERTIES OF FLOAT GLASS AFTER VARIOUS TYPES OF HEAT TREATMENT

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The surface properties of float glass tempered by air and by contact method have been studied. Air tempering was performed by traditional method, contact one was realized by a new method when a glass sample was fixed between the heat conductive plates and then heated to the temperature of tempering. Further, the glass cooling was carried out by water spraying. The changes in thickness, density, and contact angle were examined before and after tempering. It has been found that after tempering the thickness of samples increases, and the density and the hydrophilicity decreases. After further heat treatment at the temperature of tempering followed by slow cooling it has been found that due to stress relaxation the density, thickness and contact angle decrease.

***Keywords**: glass tempering, stress, contact angle*

INTRODUCTION

Nowadays, the toughened sheet glass is widely used in building for glazing of various types of construction. One of the most common methods of glass strengthening is thermal tempering, which consists in the intensive air cooling of glass at the tempering temperature. One of disadvantages of the modern technology is a significant energy uptake because in the process of hardening it is necessary to use high-performance ventilators for efficient cooling and transporting sheets along the furnace. Among the actual issues, there is also thermal tempering of glass of different thicknesses and small sizes. Today, there are restrictions on the thickness, which should not be less than 2.5 mm and larger than 19 mm, and the smallest size of a sheet of glass is 300×400 mm.

One of the perspective new energy efficient methods of thermal tempering is the contact method when that a glass sample is fixed between the heat conductive plates and in such form are heated to the temperature of tempering and cooled by water [1, 2]. This method eliminates the need of use high-power ventilators for cooling and transporting glass. In addition, there is a possibility of tempering the glass of different sizes without a significant restructuring of the parameters of the technological cycle.

Tempered glass differs from the initial glass by a number of properties, including density and wettability. Since the properties of the glass depend on the structure and surface quality, there is a necessity of more detailed research these properties for the initial glass and glass tempered by air and by contact method.

EXPERIMENTAL METHOD

For studying the properties of tempered 6 mm float glass sheet the samples of 50×25 mm were used. Glass tempering was carried out by air and by contact methods.

Air tempering was performed by heating a glass sample in a muffle furnace. The temperature was 680 °C, thermostating was 3 min, duration of cooling was 1.5 min, ventilator power was 300 W. The value of residual stresses of the tempered sample was 770 nm/cm.

Tempering of a glass sample by contact method was performed at the device consisting of a moving electric oven, devices of temperature control in the oven, water sprayers and a water tank. Before lowering the furnace, the glass sample was fixed between heat conductive plates. For tempering non-metal plates were used (there is a possibility of using metal ones). After reaching the temperature of 680 °C, the thermostating was performed for 3 min. Cooling of plates was carried out by water. Water consumption was 0.04 l/s, duration of spraying was 20 s. The value of residual stresses of tempered sample was 880 nm/cm.

Glass density was determined by the Galushkin method. Samples were dipped in a glass

flask with a mixture of heavy liquids. This flask was placed in a thermostat. The temperature was gradually increased with rate of 25 degree/min. The density of glass was determined by the difference of temperatures at which the sample lowered and crossed the certain marks.

Contact angle was determined by measuring the size of a drop of distilled water on a glass surface using a digital camera. The volume of a drop was 0.01 ml. This value was determined as the average of 5 measurements.

RESULTS

The results have shown (Table 1) that after tempering, the thickness of glass samples increases and, respectively, the density decreases (Table 2). The growth of the thickness for glass stresses in the vicinity of 800 nm/cm is 0.01 mm. In this case, the density decreases from 2506 to 2503 kg/m^3. Thus an increasing of glass thickness to 0.01 mm leads to a decrease in density to 3 kg/m^3.

The phenomenon of reducing the density of tempered glass has been described in [3–5], it is considered that the cause is the formation of tensile stresses in the middle layers of glass.

Measurement results of contact angle showed (Table 2) its value in tempered glass to be larger than that in initial one. Thus, the formation of surface compression stresses after tempering leads to the increased hydrophobicity of glass.

Later an additional heat treatment according to the tempering regime followed by slow cooling to the room temperature was conducted.

Table 1. Change of glass thickness after heat treatment

Glass samples	Residual stresses, nm/cm	Change of thickness, mm	
		after tempering	after additional treatment
initial	–	–	–0.01
tempered by air	770	0.01	–0.02
tempered by contact method	880	0.01	–0.02

Table 2. The properties of glass before and after additional heat treatment

Glass samples	Density, kg/m^3		Contact angle, degree	
	before	after	before	after
initial	2506	2510	35	26
tempered by air	2503	2510	38	30
tempered by contact method	2503	2510	39	31

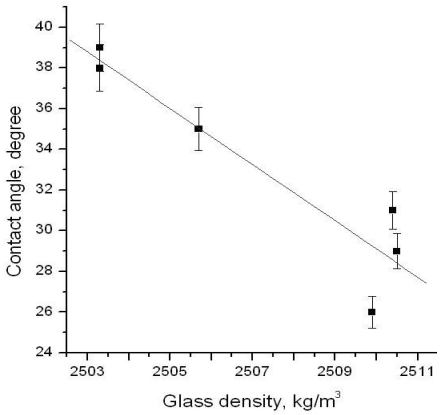

Fig. Contact angle as a function of density

The results showed that due to the additional thermal treatment, the relaxation of residual stresses was occurred and the glass structure became more dense. This led to an increase in density of glass and reduced its thickness. The density increased both in initial and tempered samples and reached the same value of 2510 kg/m^3.

The value of contact angle decreased after the additional treatment. In general, we can assume that the contact angle of glass increases with the decreasing of density (Fig.).

CONCLUSION

The new method of contact tempering is more energy saving than traditional one due to using water cooling instead of air. Glass tempering leads to an increase in thickness, which results in a decrease in the density. The formation of the compressed surface layer leads to an increase in hydrophobicity.

Additional heat treatment of glass leads to the compaction of the structure that increases the density of glass both in initial and tempered samples. With increasing of density, contact angle decreases.

Властивості поверхні флоат-скла після різного виду термічного оброблення

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Досліджено властивості поверхні флоат-скла, гартованого повітряним і контактним методами. Повітряне гартування проводили традиційним методом, а контактне новим методом, коли зразок скла фіксують між теплопровідними пластинами і нагрівають до температури гартування. В подальшому охолодження скла відбувається шляхом поливання водою. Досліджено зміну густини, товщини і крайового кута змочування до і після різних методів гартування. Встановлено, що після гартування товщина зразків зростає, а густина і гідрофільність зменшуються. Після проведення додаткового термічного оброблення при температурі гартування з подальшим повільним охолодженням було виявлено, що у зв'язку з релаксацією напружень спостерігаємо зменшення густини, товщини і крайового кута змочування.

***Ключові слова**: гартування скла, напруження, крайовий кут змочування*

Свойства поверхности флоат-стекла после термической обработки различного типа

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Были исследованы свойства поверхности флоат-стекла, закаленного воздушным и контактным методами. Воздушное закаливание проводили традиционным методом, а контактное новым методом, когда образец стекла фиксируют между теплопроводными пластинами и в таком виде нагревают до температуры закалки. В дальнейшем охлаждение стекла происходит путем полива пластин водой. Было исследовано изменение толщины, плотности и краевого угла смачивания до и после различных методов закаливания. Установлено, что после закалки толщина образцов возрастает, а плотность и гидрофильность уменьшаются. После проведения дополнительной термической обработки при температуре закалки с последующим медленным охлаждением было обнаружено, что в связи с релаксацией напряжений наблюдается уменьшение плотности, толщины и краевого угла смачивания.

***Ключевые слова**: закалка стекла, напряжение, краевой угол смачивания*

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