

THE STRUCTURE AND MECHANICAL PROPERTIES OF INDUSTRIAL GLASSES AFTER ACTION OF THE CONSTANT MAGNETIC FIELD

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ABSTRACT:

The influence of constant magnetic field on the structure and mechanical properties of industrial glasses has been investigated. The subjects of investigation were bottles and jars of colorless glass, bottles of green glass, flat glass samples, illuminating glassware made from transparent colorless and milk glasses. The analyses of glass structure were done with the help of section etching by solution HF and infra red reflection spectroscopy. Parameters of treatment of glass samples and glassware: vector's magnitude of the magnetic induction being up to 0.25 T, temperature - between 300 and 600 °C, duration - between 1 and 300 s. Thermomagnetic treatment increases mechanical strength of glassware by 20–40 %, microhardness of industrial glasses - by 10–20 %.

KEYWORDS: constant magnetic field, industrial glass, mechanical strength, microhardness

1. INTRODUCTION

Industrial glassware is characterized by low mechanical strength and bad thermal stability and as a result losses of production on the stage of manufacturing, transportation and exploitation reach 5 %. To increase mechanical properties and thermal resistance of glassware various types of coating, ion exchange, etching in hydrofluoric acid, tempering and dealkalization by acid gases are used [1, 2]. For modification of glass surface reliable equipment is needed for coating reagents on glassware, besides it leads to environment pollution in this case. It induces search for new methods of glass strengthening. Interaction of inorganic glasses with electromagnetic fields has been studied since the second half of the past

century. Particular attention in the published works has been paid to the mechanism of action of magnetic fields on glasses and change of their mechanical strength and thermostability. The aim of this work was to investigate influence of constant magnetic field on mechanical characteristics and thermal resistance of industrial glassware.

2. EXPERIMENTAL

The subjects of investigation were flat glass samples, bottles and jars of colorless glass, bottles of green glass, ampoules made from medicinal glass, illuminating glassware made from transparent colorless and milk glasses. The chemical compositions of industrial glasses are given in Table 1.

Table 1 Chemical compositions of industrial glasses

Glass type	Weight content of oxides, %								
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	SO ₃	Other
Flat	72.65	1.55	0.11	7.60	3.71	13.62	0.35	0.31	-
Container	71.85	2.51	0.07	6.60	4.54	13.89	-	0.45	-
Medicinal	72.81	4.52	0.05	6.05	0.82	8.15	1.64	-	6.11 B ₂ O ₃
Transparent	73.31	1.80	0.04	6.95	-	16.46	1.15	0.24	-
Milk	66.91	7.05	0.04	3.67	-	13.60	4.19	0.27	4.3 F ⁻

Glass containers are made using sectional glass-forming machines (IS-8-2, AL106-2). Experiments on the thermomagnetic treatment of glassware were held in laboratory and industrial conditions.

Samples of industrial glasses and glass containers were exposed to the effect of constant magnetic field. Parameters of treatment of glass samples in laboratory conditions: vector's magnitude of the magnetic induction - up to 0.15 T, temperature – between 300 and 600 °C, duration – between 1 and 300 s. Procedure of glass treatment by magnetic field in laboratory conditions is the following. After the annealing glassware was broken and some flat pieces were picked up.

The samples obtained were washed by water and wiped by spirit. Constant magnetic fields have been created with the help of electromagnet. In clearance of the core at room temperature the kiln was introduced with samples of glass. Then the temperature was raised to the designed, heating was stopped and treatment by constant magnetic field was held. After treatment, samples were cooled in a closed kiln up to room temperature. For laboratory samples there were measuring of microhardness.

The value of microhardness was measured by microhardnessmeter PMT-3M. The procedure of microhardness measuring was the following. A diamond pyramid pricked each sample about 20 times. In order to obtain reproducible results the duration of loading on the pyramid was 10 s and duration of exposition to glass surface – 5 s for every measurement. The indentation length was measured twice. The load on the indenter of the diamond pyramid Vickers made 0.5 N. The relative error of determination of microhardness did not exceed ± 4 %.

The main regimes of the thermomagnetic treatment of glass containers in industrial conditions were the following: temperature – between 500 and 550 °C, vector's magnitude of the magnetic induction – up to 0.25 T, duration – between 1 and 4 s. Jars and bottles were subjected to the effect of

electromagnetic field just after molding at transportation them into lehrs.

Equipment was installed on the conveyer for transportation of glassware to the lehr. Special precautionary measures with the glass containers treated had not been used. Mechanical properties of glassware were characterized by resistance to internal hydrostatic pressure, resistance to the compression in the direction perpendicular to the body walls and microhardness.

Mechanical strength of jars and bottles were characterized by value of internal hydrostatic pressure resistance. The pressure had risen until the glassware was broken. Absolute error of measuring of pressure did not exceed ± 0.01 MPa. Not less than 10 glassware were used for each treatment regime.

Additionally, the jars were tested on the resistance of the compression in the directions both along and perpendicular to the body walls. Loading speed was 20 mm/min using the press UMM-5. The jars were located between support plates of press, the joint line being aligned always at the same position. The absolute error of measuring was ± 10 N.

The number of jars used for testing in one experiment was not less than 20. To obtain comparable results the jars were taken up from the same form of glass-forming machine.

Thermostability of bottles and jars were determined by the following means. The glassware was heated in reservoir with hot water and then was carried into bath with cold water. The temperature drop was grown till the destruction of the glassware. The temperature deviation in reservoir was not higher than ± 0.5 °C. Twelve glassware from each lot were tested in the experiments.

The analyses of glass surface layers were done with the help of section etching by solution HF and infra red reflection spectroscopy. At the first stage of investigation, plates of flat glass were used to work out the experimental procedure. Three

glass samples were fixed in fluorocarbon polymer cassettes and then were joined to the fluorocarbon polymer wheel and put into a weak solution HF (0.1-1.0 % by weight).

The samples in the solution HF rotated with speed 100 rotations/min. After etching, the samples were washed with distilled water, dried and weighed. Duration of etching changed within 5 to 30 minutes. The temperature of the solution HF made (30±0.1) °C. Thickness of the dissolved layer and rate of etching were calculated on mass losses of the sample before and after etching. During one etching a layer of glass with thickness from 0.05 up to 1.0 µm dissolved.

A relative error of the experiment did not exceed 4 %. By the method of flame

photometry concentration of Na⁺, K⁺ and Ca²⁺ were measured in extracts after etching. In the following experiments not only glass plates were subjected to etching, but samples of a complex form as well. In this case samples were kept in solution in stationary position, i. e. without rotation.

3. RESULTS AND DISCUSSION

Microhardness of sheet glass after thermomagnetic treatment in laboratory conditions grows up. Results are given in table 2 (vector's magnitude of the magnetic induction – 0.15 T, duration – 30 s, magnetic lines of force perpendicular to the plane of samples). Microhardness of untreated glass was 4.48 GPa.

Table 2 Influence of temperature on microhardness of sheet glass treated by constant magnetic field

Temperature, °C	Microhardness of glass, GPa	
	Magnetic treatment	Heat treatment
20	4.48	4.48
100	4.46	4.45
200	4.47	4.49
300	4.49	4.48
400	4.63	4.52
500	4.72	4.55
550	4.84	4.61
600	5.03	4.67

The data of table 2 demonstrates that with raising of temperature of magnetic treatment microhardness of glass grows. Increment of microhardness was registered at temperature of treatment 400 °C and higher. The position of magnetic lines of force relatively to the plane of samples is also reflected on the results of the experiment. Microhardness grows higher when magnetic lines of force are found perpendicular to the plane of samples.

It is known that additional heat treatment changes properties of glass [2]. In our experiments parallel with thermomagnetic treatment of samples additional heat treatment of glass was held in the same conditions (without effect of magnetic field). Investigations showed that repeated heat treatment of glass practically does not

change its microhardness. Consequently raise of microhardness of glass after thermomagnetic treatment is connected only with the effect of magnetic field. The increment of green glass after treatment by electromagnetic fields is higher than for containers of colorless glass. Increment of microhardness of container glass after the effect of electromagnetic fields is compared to the effect which is achieved by application of protection coats and dealcalization by acid gases [1, 2].

Important results have been obtained at treatment of glass containers by electromagnetic fields in industrial conditions. Mechanical resistance of jars under the effect of constant magnetic field grows. Results of testing of jars with 0.65 l capacity are shown in table 3.

Table 3 Influence of constant magnetic field on mechanical strength of jars (temperature – between 500 °C and 550 °C, duration – between 1 and 2 s)

Vector's magnitude of the magnetic induction, T	Resistance on the compression F, kN					
	F _{min}	ΔF _{min} , %	F _{max}	ΔF _{max} , %	F _{aver}	ΔF _{aver.} , %
0	1.50	-	3.43	-	2.38	-
0.05	1.63	8.7	3.88	13.1	2.49	4.6
0.10	1.84	22.7	4.12	20.1	2.75	15.5
0.19	1.90	26.7	4.48	30.6	2.90	21.8
0.25	2.21	47.3	4.37	27.4	3.16	32.8

Table 3 demonstrates that with raising of value of vector's magnitude of the magnetic induction mechanical strength of glassware grows.

The obtained level of strengthening of jars in constant magnetic field is compared to the effect of improving the strength of glass containers by means of making protection coats and thermochemical treatment by gases [2]. It is important that the minimum mechanical strength of jars on the account of magnetic treatment increases to a higher extent than the average mechanical strength. The effect of strengthening depends on duration of treatment. The experiment demonstrates that with raising the duration of treatment mechanical strength of glassware grows.

Thermomagnetic treatment of jars and bottles increases their resistance to internal hydrostatic pressure by 40 %, thermal stability by 10 % and microhardness by 15 %. So, treatment of electromagnetic fields increases mechanical properties and thermal stability of glass containers. The main merits of the method of electromagnetic treatment of glass are - the possibility of strengthening of glassware of any form at the stage of their manufacturing. Technology of manufacturing glassware does not change and sanitary conditions of work do not impair.

Compactness of structure of flat glass changes after thermomagnetic treatment. Decrease of dissolution rate of glass surface layer by 5-15 % witnesses it. Analysis of changes of glass structure compactness is held depending on the parameters of magnetic field, temperature and duration of treatment. Infrared spectroscopy data witness changes of silicon-oxygen tetrahedrons' polymerization degree.

4. CONCLUSION

Primarily influence of constant magnetic field on microhardness of industrial glasses has been investigated.

It has been established that with elevation of temperature, of value of vector's magnitude of the magnetic induction and duration of thermomagnetic treatment in laboratory conditions microhardness of all types of glass grows up.

Increment of microhardness of industrial glasses after the effect of constant magnetic field makes from 10 to 20 %. Thermomagnetic treatment of jars and bottles in industrial conditions increases their mechanical strength by 40 %, thermal stability by 10 % and microhardness by 15 %. Analysis of changes of glass structure compactness is held depending on the parameters of magnetic field, temperature and duration of treatment.

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