ХІМІЧНА ІНЖЕНЕРІЯ

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STUDY OF THE GLASS FURNACE TEMPERATURE FIELD EFFECT ON GLASS PRODUCT QUALITY FACTORS

Results of studying the temperature field effect on glass products quality factors are provided. Correlation functions that show relationship between furnace's characteristic temperature spots with thermocouples installed and the main quality factors of glass products are received. Temperature measurement spot which defines the quality factors of glass products is found based on the correlation functions.
Keywords: *Glass furnace, correlation function, quality factors, striae, temperature spots.*

Introduction. Glass is a material used in household, construction, transports and other fields of human activities due to its unique qualities: transparency, hardness, resistance to active chemicals and comparatively low production cost. Optical instruments, TVs, space crafts and others can't be produced without the glass. Despite the success in creating new general-purpose materials, glass is one of the most common materials used in practice.

Glass industry is one of the primary industries in the Ukrainian economy and plays an important role in forming of particular regions' and overall country's macroeconomic indicators.

Glassware is one of the most common glass products. Due to growing tendency towards using environmentally friendly materials, glassware becomes more popular, which causes the production and consumption quantities in Ukraine and all over the world to increase. In 2012, world market of glassware was estimated at $47.43 billion. It is expected that by year 2019 market will reach $59.95 billion [1].

A glass furnace is the main apparatus in the production of glass and glassware in particular, where glass melt is received by melting the glass batch. The enhancement of glass furnace efficiency due to optimization of glass melting process conditions in order to achieve desired glassware quality factors is an actual technical-scientific goal.

Analysis of previous researches. Works [2-3] describe temperature conditions effect on the occurrence of nonuniformities, bubbles and other impurities in a float glass.

Work [4] studies the effects of different glass furnace's operative conditions, in particular, fuel consumption and glass mass lift on glass quality factors. These factors, as defined by authors, are the clarification and homogenization coefficients.

Unfortunately, described researches do not review direct glass product quality factors, but the factors that, in authors' opinion, are related to them. This can lead to differences between real and desired quality factors.

Problem statement. Glassware quality factors are determined per Ukrainian state standard [5]. Most significant quality factors include: air bubbles and impurities of various origins (striae) (tabl. 1). Striae are the transparent glass-like strips, lines, etc. that consist of glass that has different composition. According to the standard, a glass bottle must not include bubbles or striae in quantities higher than listed in tabl. 1 [5]:

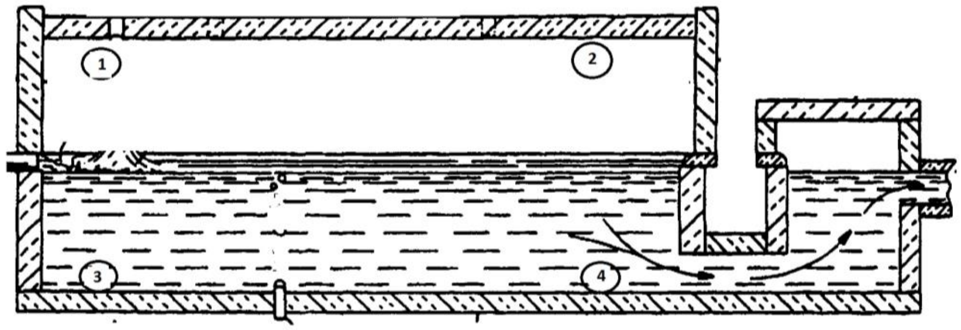
Table 1 – Glassware quality factors

Bubbles	Diameter, mm	Quantity, pcs
	1 to 1,5	8
	1,5 to 4	3
Striae (various impurities)	Size, mm	Quantity, pcs
	Up to 1	1
	1 to 1,5	1

As being stated in well-known researches [6-7], glass furnace temperature condition has the most effect on glass product quality factors. It means that it is needed to study the effect of spatially distributed temperature field of the glass furnace on these quality factors to solve the optimal control task stated above in order to achieve desired glassware quality factors.

It is impossible to achieve a fuller picture of glass furnace in real conditions due to limited quantity of measurement instruments. Therefore, it is required to determine how and how much the measureable glass furnace temperatures affect selected quality factors (bubbles and striae per bottle) in order build an effective glassware quality control system. This defines the object of the article.

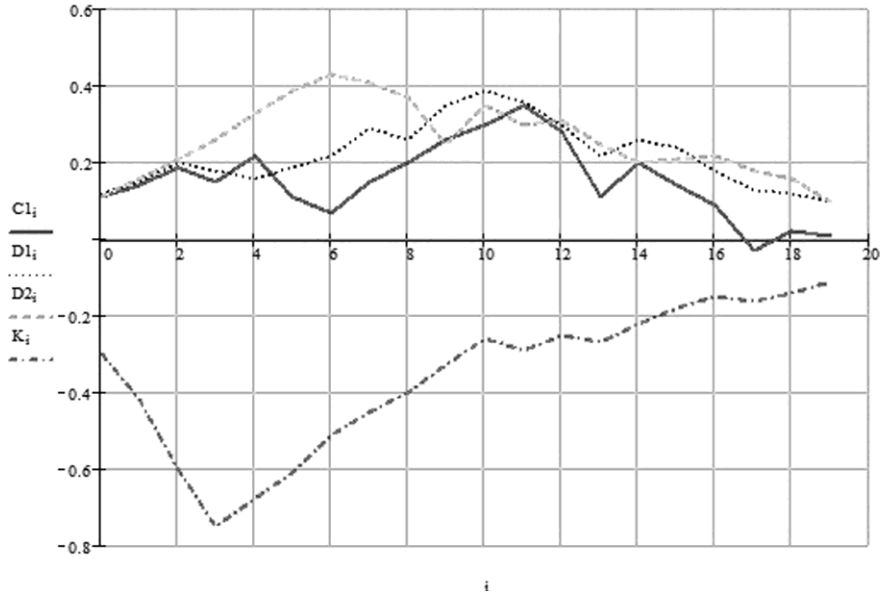
Results. Object of study was a glass furnace in glass bottle production at Vetropack Gostomel Glass Factory JSC. The temperatures were measured at spots shown on fig. 1.



1 – thermocouple in furnace arch above glass batch loading zone; 2 – thermocouple in furnace arch at the exit; 3 – thermocouple at the bottom of the furnace in glass batch loading zone; 4 – thermocouple at the bottom of the furnace at the exit

Fig. 1 – Studied temperature measurement spots

Correlation analysis was used for the research. Normalized correlation functions (fig. 2-5) were computed using Mathcad software package and show relationships between measured temperature and bubble quantity (1 to 1.5 mm diameter), measured temperature and bubble quantity (1,5 to 4 mm diameter), measured temperature and striae quantity (up to 1mm size), measured temperature and striae quantity (1 to 1.5mm size).



C1 – between temperature in furnace arch above glass batch loading zone and bubble quantity (1 to 1.5 mm diameter); D1 – between temperature at the bottom of the furnace in glass batch loading zone and bubble quantity (1 to 1.5 mm diameter); D2 – between temperature at the bottom of the furnace at the exit and bubble quantity (1 to 1.5 mm diameter); K –between temperature in furnace arch at the exit and bubble quantity (1 to 1.5 mm diameter)

Fig. 2 – Correlation functions

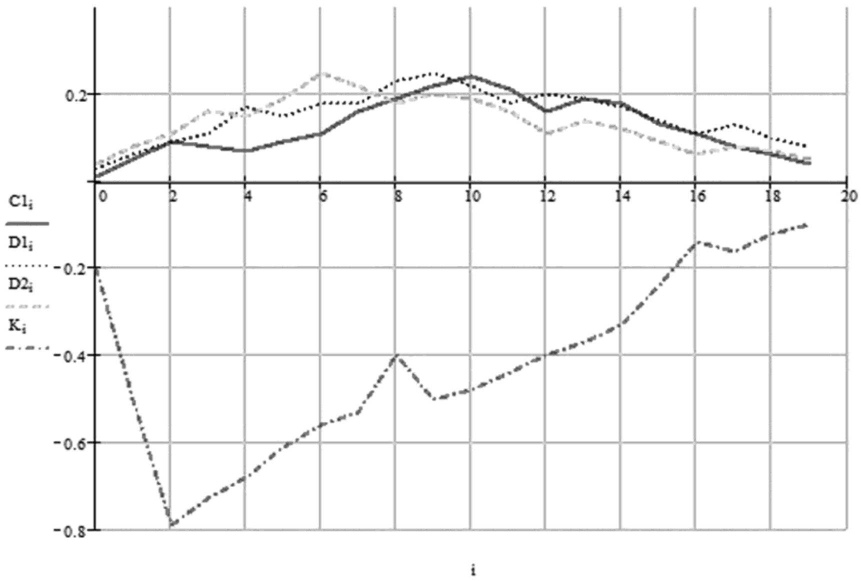


Fig. 3 – Correlation functions C1, D1, D2 and K (notation see Fig. 2) between measured temperature and bubble quantity (1.5 to 4 mm diameter)

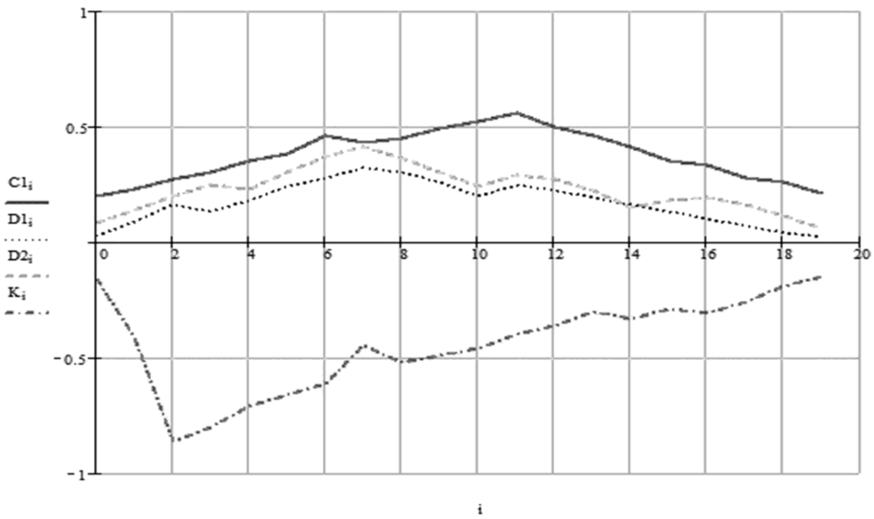


Fig. 4 – Correlation functions C1, D1, D2 and K (notation see Fig. 2) between measured temperature and striae quantity (up to 1 mm size)

As seen in the results, maximum correlation between studied values is observed at different moments of time, which is explained by substantial lag of a controlled object.

Temperature in furnace arch at the exit has the biggest impact on tableware quality factors. Increasing temperature in this zone leads to decrease in bubble quantity explained by the accelerating glass clarification processes [8]. An increase in gas flow to the furnace and glass mass temperature leads to an increased intensity in convective movement of the glass mass under the glass batch. This also increases homogenization capability of the granular cycle [8]. A more homogenized glass mass will be arriving to the production, which will improve optical properties of the glass and decrease the number of striae. Also, the temperature in furnace arch at exit has the biggest correlation with quality factors over shortest period of time, what means that this temperature can be used as a control action in glass melting process control.

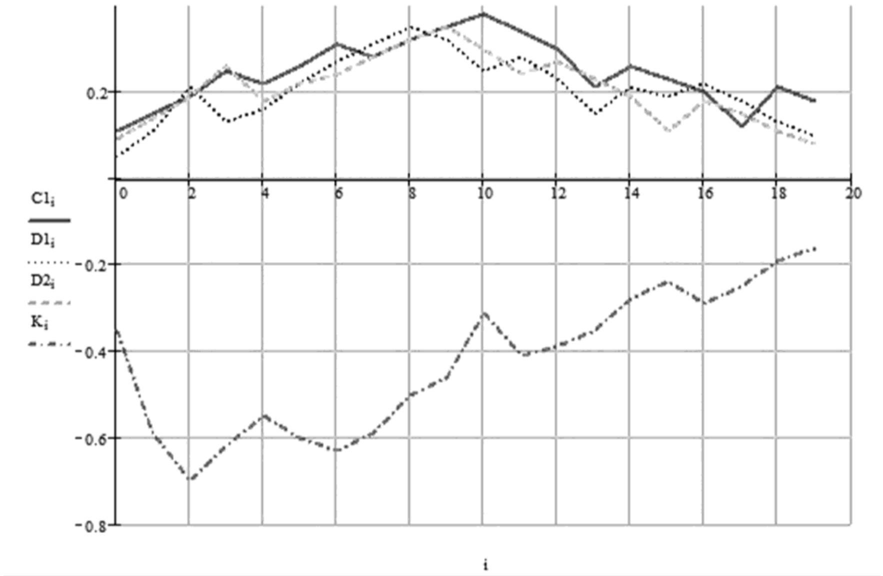


Fig. 5 – Correlation functions C1, D1, D2 and К (notation see Fig. 2) between measured temperature and striae quantity (1 to 1.5 mm size)

Conclusion. This work includes results of studying the correlation relationships between temperature at different spots in glass furnace and quality factors of the produced glass bottles. It can be stated, based on research, that the temperature in furnace arch on exit can be used as a control action in order provide an effective control of glass bottle quality factors. Achieved results give the opportunity to develop the glass bottle quality factor control system at Vetropack Gostomel Glass Factory JSC and to study its performance.

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ВПЛИВ ТЕМПЕРАТУРНОГО ПОЛЯ СКЛОВАРНОЇ ПЕЧІ НА ПОКАЗНИКИ ЯКОСТІ СКЛОВИРОБІВ

Наведено результати досліджень впливу температурного поля скловарної печі на показники якості скловиробів. Одержані кореляційні функції, котрі показують зв'язок між характерними температурними точками у печі, в котрих розташовані термопари, та основними показниками якості скловиробів. На основі даних кореляційних функцій визначено точку вимірювання температури котра є визначальною для основних показників якості.

Ключові слова: *скловарна піч, кореляційна функція, показники якості, свилі, температурні точки.*

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ЗАЛЕЖНІСТЬ ПИТОМОЇ ЕЛЕКТРОПРОВІДНОСТІ ВУГІЛЬНОЇ ШИХТИ ВІД ТЕМПЕРАТУРИ, СТУПЕНЮ ГРАФІТИЗАЦІЇ ТА ГРАНУЛОМЕТРИЧНОГО СКЛАДУ

Використовуючи експериментальні дані про електропровідність сипкого коксу та графітованих сумішей, одержано залежності, що дозволяють визначати питомий електричний опір залежно від вмісту сирого й графітованого коксу в суміші в діапазоні температур від 20 до 1000 °С, а також питомого електричного опору для сирого коксу й графітованої суміші залежно від її гранулометричного складу.
Ключові слова: *питома електропровідність, кокс, графіт, температура, гранулометричний склад.*

Постановка проблеми. Дослідження питомого електроопору (ПЕО) вуглецевих матеріалів належить до галузі енергозбереження в графітувальних печах. Вугільні матеріали є не лише сировиною для виготовлення