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I. V. Lutsyuk, I. O. Iliuchok, Ya. I. Vakhula
Lviv Polytechnic National University,
Department of Chemical Technology of Silicate Materials
Iryna.V.Lutsiuk@lpnu.ua

ANALYSIS OF GLASSWARE IN PRODUCTION CONDITIONS

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The main trends of the packaging materials market were analyzed and the forecast for its further development is given. The main defects of glass and glass containers, their impact on production efficiency are considered. A comparative analysis of glass container defects is given. The causes of product defects and ways to eliminate them are considered. The quality of glass containers is evaluated according to its physical and chemical parameters. Possibilities of quality management of glass products with the use of modern methods of analysis (Quick Kaizen and RCA) have been studied.

Key words: glass containers; glass defects; defects of glass container; quality of glassware; causes of defects; ways to eliminate defects.

Introduction

In today's world, the state of the packaging materials industry is an important component of ensuring the economic development of any state. The increasing role of packaging is due to the emergence of a wide range of goods. In this regard, the packaging market is represented by a variety of packaging materials that differ in shape, texture, material composition, combination and color. Among them, the most common are: polymeric materials (41 %), glass (32 %), metal (16 %) and paper (11 %) [1, 2]. It should be noted that the requirements for packaging materials are formed depending on many factors, the main among which are their safety, environmental friendliness, reliability, compatibility, interchangeability, aesthetics and cost-effectiveness [3–5].

Glass, which has been used as a packaging material since ancient times, fully meets these requirements. This is primarily due to the fact that glass is chemically inert, hygienic, environmentally friendly.

In recent decades, glass containers have been replaced by substitute competitors: cans, plastic, tetra-packs and cardboard. Such alternative packaging has solved some of the problems of the food industry, but has not been able to replace glass completely. On the contrary, in recent years there has been a tendency to increase the use of glass as a packaging material. This is confirmed by a survey of the industry group Aktionsforum Glas and the European Union of Glass Manufacturers, according to which glass as a packaging material for food and beverages is considered the safest material by 64 and 77 % of Europeans, respectively. The transition to environmentally friendly glass containers is a global trend to reduce the use of plastic packaging and replace it with more environmentally friendly materials. Given that the UN General Assembly declared 2022 the International Year of Glass, and determined its importance in all industries, we can expect that the share of glass containers as one of the safest types of packaging in Ukraine will grow.

Equally important, in recent years, glass packaging manufacturers, thanks to modern technology, are taking a vector in the direction of changing product design to meet the demands and tastes of consumers. This gives grounds to make products of various exclusive shapes and colors. However, one of the most common and quite versatile packaging options is discolored glass containers. This is due to the fact that in such a container is clearly visible packaged product, it is easy to decorate in different ways. However, in addition to these advantages, discolored glass containers have a number of significant disadvantages that limit its use. These

limitations are mainly due to defects that are significantly noticeable on discolored glass. In this regard, discolored containers are subject to increased requirements for the presence of defects that may have different origins and causes and harm the health of the consumer. In addition, some defects can visually divert the attention of potential consumers.

It is worth noting that in production conditions to obtain a completely defect-free glass container is almost impossible. Given that there are about 300 defects today, it is very important to know the causes and ways to eliminate or prevent. Unfortunately, this issue has not been studied enough. Therefore, a comprehensive analysis of the causes of defects in glass products and ways to eliminate them in terms of specific production is an urgent and important task.

Purpose: to conduct a comprehensive analysis of defects in glassware with the establishment of possible causes of their occurrence and ways to eliminate.

Materials and methods of research

The study was conducted at an existing enterprise in Ukraine that manufactures glass containers.

The object of the study was glass containers: bottles and jars of various volumes and designs (shapes), manufactured at this enterprise in accordance with the current requirements of TUU 23.1-22555135-003:2013 and TUU 26.1-22555135-004 2011 [6, 7].

The main methods of complex analysis include: inspection of rejection by inspection equipment and analysis of rejected samples. To quickly identify the root causes of glass and glass defects and develop a corrective action plan to eliminate them and check their effectiveness was carried out using the Quick Kaizen method (abbreviated version of the root cause analysis performed for each critical defect) and RCA analysis root causes) [8, 9], which requires finding a solution to the rule “5 Why?” and testing.

Research results and their discussion

For a comprehensive analysis of glass defects and glassware, it is advisable to take into account one batch of products or at least glassware of the same range. This is due to the fact that under other conditions, the cause of the same defect and its probability will always be different. In this regard, the sample of samples taken within one batch of products for statistical observation was 500 pcs. glass jars with a capacity of 200 ml and 500 pcs. glass bottle with a capacity of 500 ml in August – September 2021.

At the initial stage of the study of defects in glass containers, it was advisable to divide them into two main groups [10–14]:

– defects indirectly glass;

– defects of the actual glass container.

Glass defects are the first to arise and may even be the cause of the formation of other defects in glass containers. It is impossible to get rid of these defects instantly, the response period of the furnace to corrective actions is at least 12–15 hours.

The average statistical fractions of glass defects in relation to the manufactured batch of glass containers and their impact on production efficiency are shown in Fig. 1.

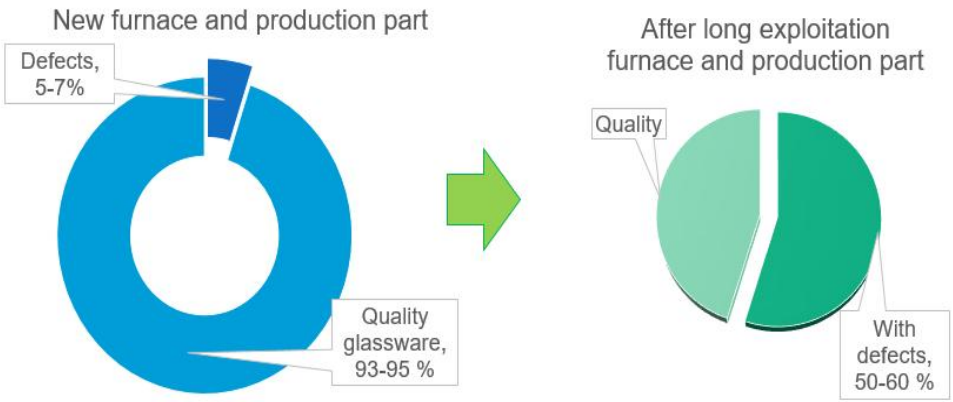

Fig. 1. Diagram of the impact of glass defects on production efficiency

Studies have shown that glass defects (including bubbles and gnats, tridymite, cristobalite, devitrite, chromium oxide inclusions, quartz inclusions, AZS, AZS drops, diopside, anortite, α-wollastonite, β-wollastonite, iron chromite, etc.) technological stages of its production due to a number of factors, the main of which are given in Table 1.

It is worth noting that the elimination of glass defects is a complex and time-consuming process. The number (or frequency) of detection of actual glass defects largely depends on the service life of the furnace. During short-term operation of the bathroom furnace, the number of defects is up to 5–7 % of all manufactured products. In the case of long-term operation of the bathroom furnace due to wear of refractories or the maximum specific removal of glass mass, the percentage of glass defects increases, and production efficiency can be reduced by half.

Glass defects can be accurately determined by SEM analysis or EDX analysis in combination with a magnifying microscope or a magnifying polarizing microscope.

Table 1

The main causes of glass defects

The causes of glass defects	Number of defects of the total, %
Heterogeneous charge	1–10
Pollution of raw materials	20–40
Destruction of refractory furnaces, ducts or feeder channels (production part)	5–50
Destruction of electrodes	3–7
Use of contaminated slag	5–20
Under-melting of the charge	2–15

The main defects of glass and their negative impact on the quality of glass containers are given in Table 2.

Table 2

Glass defects and their influence of quality of glass containers

Glass defects	Defect`s characteristic	The impact of defects on the quality of glass containers
Quartz	Accumulation of translucent grains with glass coating, grain size is equal to the size of sand used in the charge	Depending on the size, especially dangerous for pressure containers
Bubbles	Gas bubbles in the glass	Deteriorating the appearance of the product. Affects mechanical strength depending on size and location (for champagne bottles only a single fly is allowed, ie bubbles smaller than 1 mm)
Iron and its compounds	Inclusions are spherical or oblong with a metallic sheen	May be the cause of destruction if the bottle is under pressure. For other types of glass containers has a predominantly visual aspect
Nickel sulfide	Rounded ellipsoids	The defect is mostly small in the thickness of the glass, does not adversely affect the product
Molybdenum-containing compounds (MoO_3, Na_2MoO_4, $CaMoO_4$)	Ellipsoidal bubbles or long fine-grained streaks of dark flaky crystals	May be the cause of destruction if the bottle is under pressure

Containers with such defects are most often placed on control lines such as stones or bubbles, and then analyzed in a chemical laboratory under a microscope or by scanning electron microscopy or energy-dispersive X-ray analysis.

The next stage of the work was to study the quality of the glass container itself. It is known that the defects of glass containers include defects that are formed during the formation of the product or at the stage of annealing or transportation [13, 14]. The occurrence of these defects in the production environment largely depends on the range of products. The frequency of detection and occurrence of defects in glass containers compared to glass defects is slightly higher and ranges from 15 to 35–40 % (Fig. 2).

Comparative assessment of defects in glass containers gives grounds to divide them into three categories: critical, functional and visual.

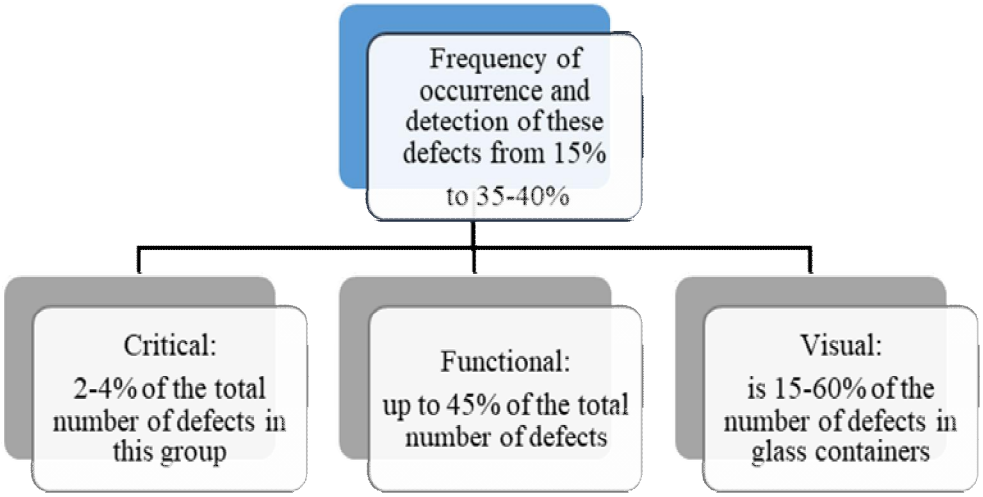

Fig. 2. Assessment of the impact and frequency of defects in glass containers

Critical defects are defects that threaten or may endanger the life and health of consumers. The number of their formation is on average up to 2–4 % of the total number of defects in glass containers. These include: swing, spike on the product, adhesion of glass outside or inside, loose glass inside, double bottom, internal contamination, pressed corolla or its sharp protrusion ("burr"), open bubbles on the inner or outer surface, sugar corolla, sharp seams ("wings"), etc. In production conditions, their appearance is controlled by screens and inspection machines. To date, this category officially includes 19 defects. AQL of these defects (permissible quality level) is 0 pcs. This means that it is forbidden to supply consumers with such defects [15].

Functional defects are defects that can adversely affect the process of filling glass containers, but do not cause any harm to the consumer. The number of defects is up to 45 % of the total number of defects in glass containers. This category of defects includes about 100 defects, the main of which are devitrification, uneven distribution of glass, mismatch of geometric dimensions and capacity of the product, internal pressure, rough and offset seams, horizontally offset crown, fold at the end of the crown, non-parallel crown, rough throat, cuts different locations, etc. The number of defects largely depends on the range and resource of forms, the process of formation and other factors. This category of defects allows a certain amount of defective products that can be sent to the consumer, provided that these defects are minimally pronounced [14, 15].

Visual defects are defects that are completely safe for the health of the consumer, they only slightly impair the appearance of glass containers, as they are mostly inconspicuous. The number of such defects is 15–60 % of the total number of defects, 0 glass containers. These include stress-free stones, drops of cold spray, rough rough seam, fuzzy engraving, midges, traces of shape and more.

The reason for rejecting these defects can only be the appearance of the container. It should be noted that at the request of the consumer, these defects can sometimes fall into the category of critical or functional [14, 15].

In addition to these defects, their physical and chemical parameters play an important role in assessing the quality of glass containers.

Based on the results of research, it is established that the glass containers manufactured at the enterprise fully meet the requirements for capacity and weight. No violations were found in any of the samples.

Studies of samples for physical and mechanical parameters (thermal shock, internal hydrostatic pressure, impact strength, the amount of hot and cold spraying) showed compliance with current standards.

One of the important characteristics of glass containers that determines the efficiency of its operation is water resistance. The results of research show that the main factors influencing water resistance are the volume (Fig. 3) and shape of the product (Table 3). The values of the water resistance index for the tested samples are high and are at the level of the requirements of European standards.

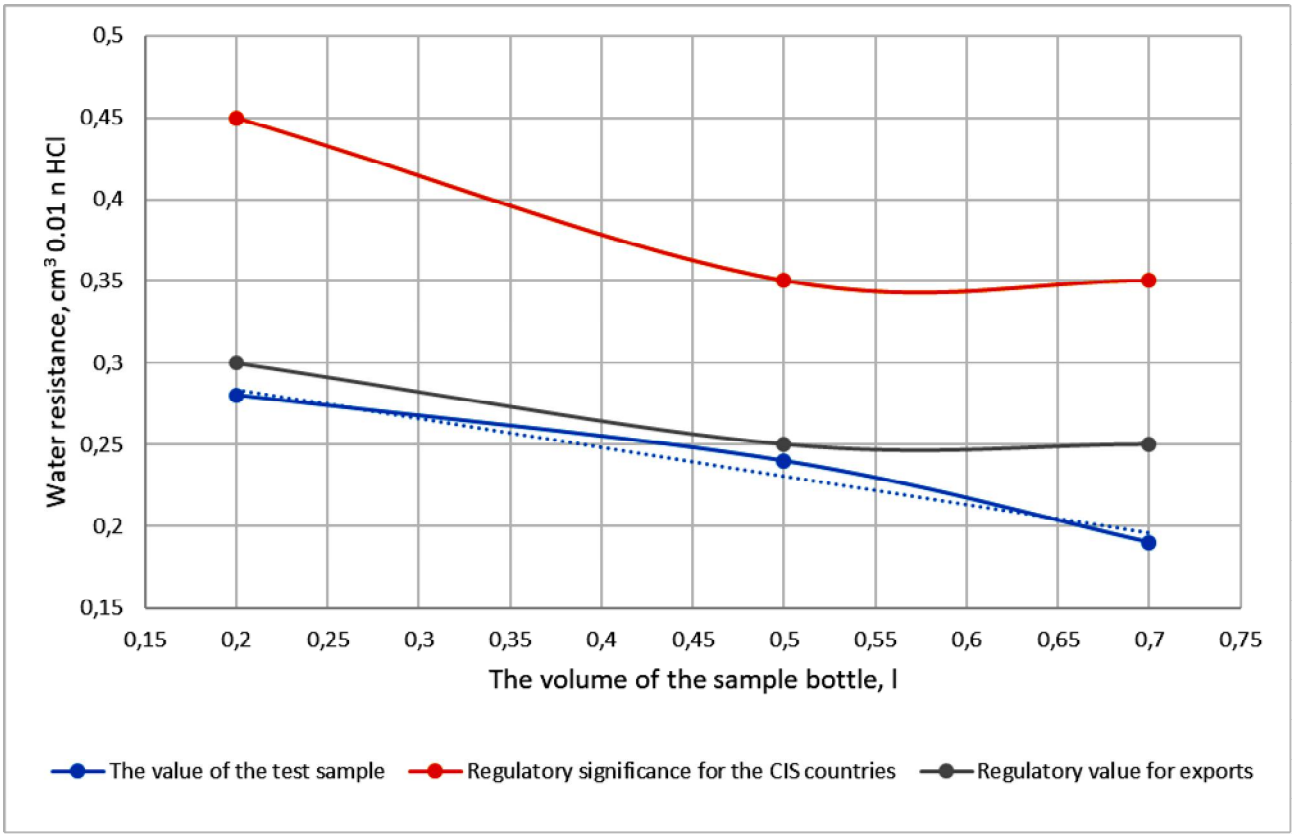

Fig. 3. Graph of water resistance depend on the volume of the sample

Table 3

Influence of bottle shape on water resistance of glass container

Bottle shape	Volume of the sample bottle, l	Water resistance, cm^3 0.01 n HCl		
		defined	normative value for CIS countries	regulatory value for exports
Rectangular	0.2	0.28	0.45	0.3
Round	0.2	0.14	0.45	0.3

Conclusions

Therefore, based on the analysis, it can be argued that quality control of glass packaging materials and the study of defects in both glass and glass products is an extremely responsible process and requires special attention.

When defects are detected, only a comprehensive, competent, consistent and logical approach will allow to effectively identify the causes of their occurrence. Based on this approach, you can make effective decisions about corrections and corrective actions to eliminate these shortcomings. It is advisable to find out the root causes of glass and glass defects using Quick Kaizen and RCA analysis.

The research results show that the physical and chemical characteristics of glass containers meet the requirements of current standards.

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І. В. Луцюк, І. О. Ілючок, Я. І. Вахула
Національний університет “Львівська політехніка”,
кафедра хімічної технології силікатів
Iryna.V.Lutsiuk@lpnu.ua

АНАЛІЗ ВАД СКЛЯНОЇ ТАРИ У ВИРОБНИЧИХ УМОВАХ

Проаналізовано основні тенденції ринку пакувальних матеріалів та наведено прогноз щодо його подальшого розвитку. Розглянуто основні вади скла та скляної тари, їхній вплив на ефективність виробництва. Наведено порівняльний аналіз вад скляної тари. Розглянуто причини виникнення вад виробів та способи їхнього усунення. Оцінено якість скляної тари за її фізико-хімічними показниками. Вивчено можливості управління якістю скляних виробів із використанням сучасних методів аналізу (Quick Kaizen і RCA).

Ключові слова: скляна тара; вади скла; вади скляної тари; якість скловиробів; причини виникнення вад; способи усунення вад.