UDC 621.039.56

***Tarakhtii O.S.***
Odessa National Polytechnic University

***Nesterovich S.A.***
Odessa National Polytechnic University

# COMPARATIVE ANALYSIS OF MODERN SYSTEMS FOR AUTOMATION OF THE MIXING AREA OF THE COMPONENTS OF THE ELCTROPHORAPHORE

*The comparative analysis of modern systems for automation of the mixing area of the components of electrical porcelain is carried out in the article. Possible constructions of aggregates and methods of work for implementation of this process are represented. Also management methods are reviewed and a new structure of management system is proposed. The aim is to study modern methods for assessing the quality of mixing bulk materials in the production of electrical porcelain, as well as alternative approaches to designing of automated control systems for the mixing process in a drum mixer.*

***Key words:*** *automatic control system, electrotechnical porcelain, quality criterion, optical method, concentrate of key components, mixing of bulk materials.*

**Introduction.** Different wares made of electrical porcelain are needed in manufacturing as well as for providing electricity to enterprises and people. Electrical porcelain is a silicate material based on natural raw materials. Since Ukraine has substantial reserves of raw materials, the production of electrical porcelain is beneficial and in-demand. The basic components of electrical porcelain are: kaolin, clay, quartz, feldspar, gypsum, pegmatite, zircon. High requirements for electrical porcelain cause using for its production only pure and stable in the composition ceramic raw materials. Threaded conductors for textile machines from dense glazed porcelain reliably work with carbon fiber, kevlar and aramid fibers. The chemical resistance of porcelain makes it an indispensable material for chemical engineering. Another scope of application of porcelain is furniture and sanitary industry, door handles, water fittings and buttons. In addition: cartridges and sockets for the lighting industry, cartridges for high-voltage insulators, tubes TRF from special high-strength porcelain, insulators for power and electrical engineering, as well as for electrothermia, terminal blocks and more. Since the electrical porcelain production technology is insufficiently automated, multi-stage and energy-intensive, that causes the problem of determining the processes, which should be automated in order to reduce electricity costs.

In the process of electrical porcelain production, the manufacturing process is carried out in several areas: dosing, mixing and quality control. Significantly, the quality of products depends on the mixing site. Therefore, the site of mixing of components is chosen as an object of the research. Since the purpose of any production is to obtain a product of good quality with minimal costs, the realization of this condition is possible with maximum automation of this process, that is why a system of regulation of the continuous action mixer is chosen as the subject of automation [5].

**The aim** of the paper is to determine the most prevalent types of mixers at Ukrainian enterprises, it is necessary to analyze the most common methods of mixing as well as to determine the types of aggregates, which are used to mix the components of the electrical porcelain.

According to its organizational and technical structure, the mixing process can be divided into periodic and continuous groups, thereafter, mixers are also divided into intermittent and continuous mixers.

While using periodical mixers, portions of the mixture components are periodically poured into the mixer, which makes it possible to set up an exact ratio, as well as to ensure stable operation with a large number of components. However, continuous mixers make their task faster due to the fact that the components are simultaneously mixed and transported to the discharge nozzle, achieving homogeneity.

The choice between continuous and periodic mixing depends on the properties of the components (particle size, shape, specific gravity, humidity and other properties) [1].

The mixing process consists of the following elementary processes:

1) moving the layers of the material while increasing the inclination of its free surface to a score exceeding the angle of natural slope; with the layers of the material slipping one by one, scattering on separate particles, which penetrate the adjacent layers (convective mixing);

2) the gradual penetration of particles of various components through the newly formed boundaries of the section (diffusion mixing);

3) accumulation and agglomeration of particles of the same mass and composition in separate parts of the mixer chamber (the process of aggregation).

While mixing loose materials in a drum mixer, all of these elementary processes proceed simultaneously. However, the degree of their influence is not the same in different periods of mixing.

The entire mixing cycle can be divided into three stages (Fig. 1). At the first stage (section I), convective mixing is intensively developed. The initial heterogeneity of the substance decreases very swiftly. At this stage, the process speed is almost independent of the physical and chemical properties of the components, since the mixing proceeds at the level of the macros.

Substantive impact on the speed of the mixing process at the first stage has the trajectory of movement of the material inside the mixer.

The second stage (section II) occurs after the mixing components are generally distributed over the volume of the drum mixer. At this stage, the impact of convective and diffusion processes becomes proportional, as the process of redistribution of particles occurs at the level of individual particles (the motion of particles relative to each other).

Finally, at the third stage, when the minimum degree of heterogeneity is reached, the segregation process begins to affect (section III, curves 1 and 2). If, after partial segregation, the formed agglomerates are dispersed again, then the degree of homogeneity of the substance, estimated by the coefficient of variation, fluctuates near some score (curve 1). It is also possible (curve 2), when two opposite processes at an exact moment are balanced.

**Materials and Methods.** As we have mentioned, the mixing process is divided into periodic and continuous. Basing on the analysis of technological processes and equipment at the enterprises which produce electrical porcelain, we determined that the mixing process with use of a drum mixer is hold without grinding [2]. There are also installations for mixing electrical porcelain, which are shredded during the mixing process. The working speed of the rotation provides the optimum quality of the substance and mostly depends on the physical and chemical properties [2].

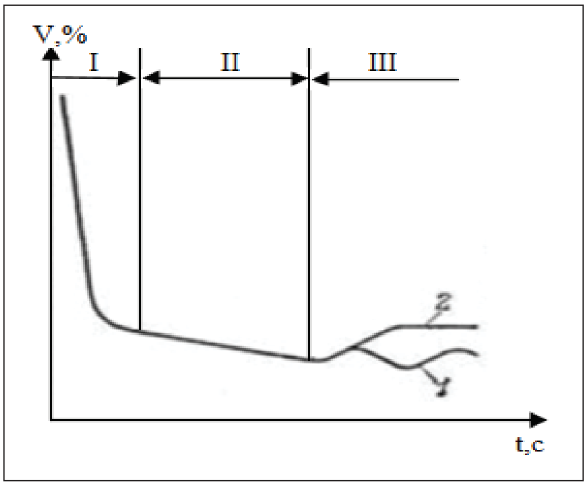


**Fig. 1. The diagram of the variation coefficient change (V) for the substance obtained in the drum type mixer (t is mixing time)**

The method of simultaneous mixing and grinding is considered below. Such a method can be used when the materials, which should be mixed, are close in their physical and mechanical characteristics, so that they have the same density, dimensions.

Consider the continuous process of mixing materials that we produce in a continuous drum mixer . It consists of a tubular body – 1, several bands – 2 and 4, supporting rollers 6 and 10, an electric motor – 7, a gear unit – 8, and a gear pair 9 and 3. The substance in the drum enters through the dispensing point 11, the end-product comes out from the opposite end. The substance in a mixer can be supplied continuously or dosed.

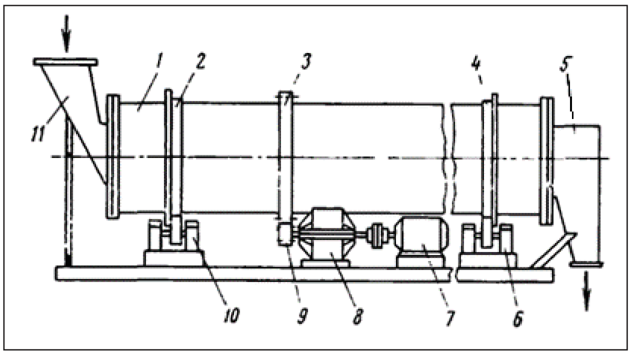


**Fig. 2. Scheme of a drum mixer of continuous action**

There are mixers of the following types for mixing loose materials: drum mixer with a belt stirrer, continuous operating mixer, operating mixer of periodic action, mixers with rotary blades, mixers, equipped with progressive blades.

Electrical porcelain is a multi-component substance which consists of: kaolin, clay, quartz, feldspar, gypsum, pegmatites, zircon. High requirements for electrical porcelain cause using for its production only pure and stable in the composition of ceramic raw materials [2].

As an object of automation, a drum mixer of continuous action was chosen, since the mixers of this type the most precisely mix the fractions of the same products as well as ones which differ in their sizes and gravity, hardness, fluffiness.

A mixer of the selected type meets the requirements for mixing components of electrical porcelain.

Results. Existing automation systems are operator-oriented and, as a rule, they are implemented locally, what means that the individual control of each subsystem of the process is executed. It would be optimal to manage the entire process at once.

On the basis of the analysis, we will consider the system of an electric porcelain of “Inmaks” in accordance with GOST U 51330.20–99. The mixing section control system consists of a subsystem of loading, dispensing, controlling the speed of the mixer, controlling the rotation time of the drum. The loading subsystem includes a hopper with components I ... III and capacitive level sensors for the Camlogic batches of the PFG06 series. The subsystem of dosing consists of valves for supplying components IV ... VI, dispensers D1 ... D3. And also the flowmeters C-LEVER.

The subsystem of speed control and rotation time of the drum consists of a drum mixer VII with an electric drive. Considering the site of dosing as an object of management, the main parameters that affect the quality of mixing of components is the consumption of components, the speed of the drum rotation and the time of mixing [3]. To control the filling of the drum mixer, we choose an acoustic method that has sufficient accuracy [3]. Accordingly, choose an acoustic sensor ECHO-AS-0. The block scheme of the process is shown in figure 3.

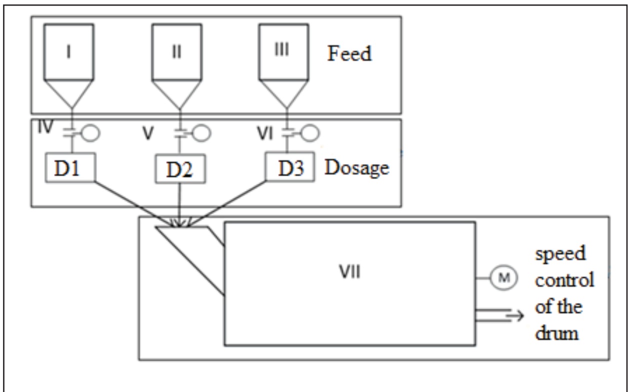


**Fig. 3. The block scheme of the mixing section with subsystems**

An analysis of existing control systems shows that the most common approach is to implement a mixing control system as separate local subsystems – the level of stabilization in bunkers, the subsystem of dispensing, the level of components in the mixer, and the stabilization of the number of turnovers of the drum mixer. As a rule, quality control of mixing is hold periodically by laboratory.

This approach does not provide optimal control of the entire site in the presence of perturbations that affect each subsystem, and most importantly, there may be significant deviations in the quality of mixing [4].

For this agregate was developed a system of regulation, which makes it possible to control not only loading, but also shredding.

As the most commonly used electrical porcelain contains about 70% $SiO_2$, 25% $Al_2O_3$ and 5% other oxides, we choose these components and as the third $Na_2O$.

Considering a site of dosing as an object of management, the main parameters that affect the quality of mixing the components are the consumption of components, the speed of the drum, and the time of mixing. To control the filling of a drum mixer, an acoustic method with sufficient accuracy is chosen. Considering the grinding area as an object of control, the main parameters affecting the quality of grinding components are the consumption of components and the loading rate.

To assess the potential of using LQR regulators for loading and shredding in a drum mixer, a structure of a multidimensional model of the system of regulation of the level and quality of grinding in the mixer has been developed. In [5] time regulation was performed. Since not the time of material processing, but the quality of the end-product determines the result, the model is represented by three channels of regulation: the quality of mixing, the level of loading and the consumption of the materials. Each of them represents a separate sub-system of regulation for deviation. Since simultaneously managing the quality of the substance on all of three channels is quite complicated, the model proposes to implement stabilization through the channels of the level of loading in the mixer and through the dosing channel. Then the mixing quality will be determined at constant level of consumption and loading, and quality management will be performed by changing the mixing and grinding time taking into account the required dispersion composition. To implement this system, it is necessary to apply sensors at mixer output in order to determine the mixing quality and dispersion composition of the components, based on these considerations, the structure of the mixing quality management system will have the following form (Figure 4).

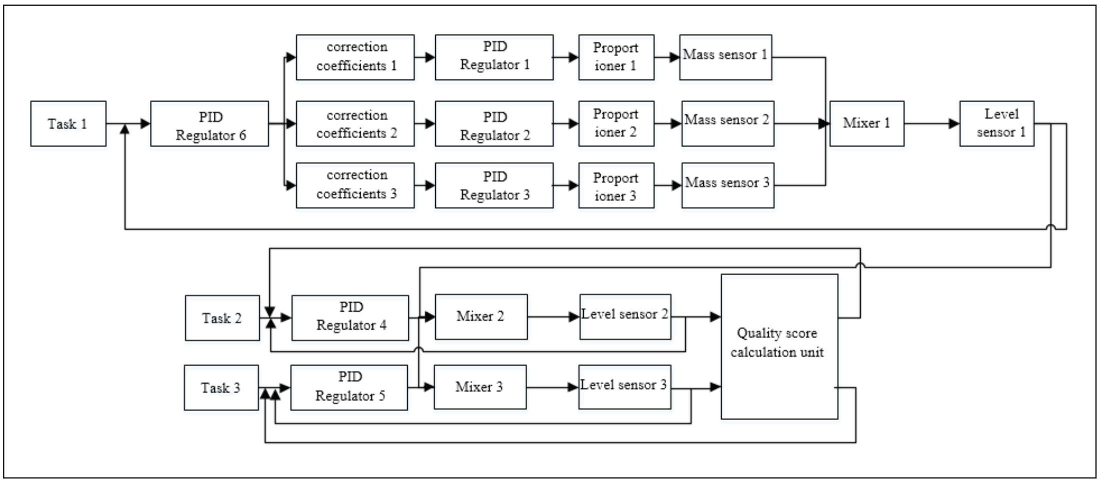


**Fig. 4. The block scheme of the management system of the quality control**

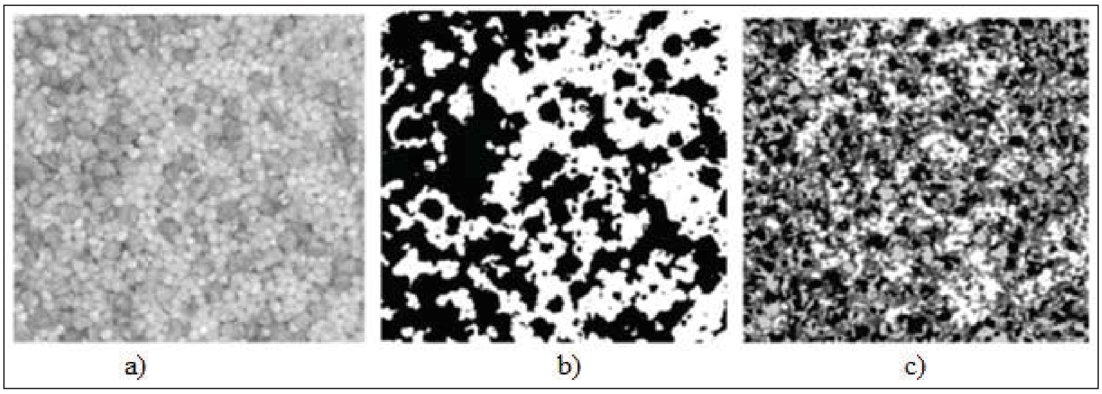


**Fig. 5. An example of segmentation:**
**a) the original image; b) segmentation into two clusters; c) segmentation into five clusters**

As we can see, the control object is multiparameter, so it is advisable to use modern LQR regulators for its management. Therefore, it is proposed to manage the quality of mixing according to the model and the research of the control system is proposed to carry out at different levels of the forecast. The choice of the forecast level will be made basing on the information about priori data of the mixing time and the desired disperse composition.

Since there is no complete quality criteria, so it is proposed to select it considering expert assessments. Due to [5] a two-point standardized evaluation system is proposed – in the quality of mixing – 0,7; and in the dispersed composition – 0,3. Basing on the proposed block scheme of the management system of the quality control, its development in the software package MATLAB SIMULINK will be performed as a further work.

There are such methods for assessing the quality of mixing materials: weight, sowing on screens, optical, acoustic. The first and the second methods allow determining the heterogeneity of the mixture, the components of which vary either in weight or size. The third method of determining the concentrations of the main component is based on a comparative analysis of the ability of the components of the mixture to absorb, reflect and refract light. The disadvantages of these methods include their complexity and considerable time necessary to spent on quality analysis.

Recently, new ways of assessing the quality of the mixture have been proposed. Thus, [6] describes a method for determining the coefficient of heterogeneity of a substance of heavily separated bulk materials that differ in color, which includes determining the number of samples, the minimum permissible weight of the sample, sampling the mixture, finding the concentration of the main component in the sample, calculating the ratio of heterogeneity of the mixture. Finding the concentration of a key component, the content of the sample is first distributed uniformly on a flat surface, photographed or scanned. Then they carry out computer processing of the image, representing it as an array of numbers, each element of which is expressed by a pixel, whose number corresponds to the color of the component. Then, select a range of numbers and assign all the pixels in that range to the key component and the other pixels are assigned to another range, then calculate the pixels corresponding to each component and determine the concentration of the key component, which determines the mixture heterogeneity coefficient.

$$\sum_{K=1}^{K} \sum_{S_{i,j} \in X_k}^{K} (S_{i.j} - \mu_k)^2 \to \min, \qquad (1)$$

where K – is a number of criteria; Xк – is an array of pixels; μк – is centre of mass of vectors.

The main idea of this operation is that the image is segmented according to the number of clusters (Fig. 5a). If the number of clusters is equal to two, then the mask will have a black-and-white appearance after the clustering (Fig. 5b), if there are more than two clusters, then the mask will have in its composition K gradations of gray (Fig. 5c).

In the third step, the coefficient of uniformity of the mixing R for each color component is calculated using the formula:

$$R = (100\% - \sqrt{\frac{1}{m*n} * \sum_{P=1}^{P} (Yp - \bar{Y}p)) * 100\%)}, \qquad (2)$$

where $\frac{1}{m*n} = L$ – current range of calculation of the coefficient of uniformity for given n and m; K – number of pixels in the L site; Yp – is the number of pixels in the L region belonging to the nth cluster; Yp – is an average pixel number calculated for all ranges of L.

The proposed algorithm is implemented in the MATLAB application package using the graphical GUI interface. The resulting coefficient of uniformity confirms the visual assessment and its value is 7%. Analysis of the processing results shows that the uniformity coefficient for the first mixture is 63%, and for the second one it is 73%. Thus, the possibility of determining the coefficient of uniformity of the mixing of materials containing n components in its composition was proved theoretically and experimentally. Also, the proposed method allows to use color information, which provides a more accurate estimation of the uniformity coefficient.

Conclusions. Different wares made of electrical porcelain are needed in manufacturing as well as for providing electricity to enterprises and people. Electrical porcelain is a silicate material based on natural raw materials. Since Ukraine has substantial reserves of raw materials, the production of electrical porcelain is beneficial and in-demand. In the process of electrical porcelain production, the manufacturing process is carried out in several areas: dosing, mixing and quality control. Significantly, the quality of products depends on the mixing site. Therefore, the site of mixing of components is chosen as an object of the research. The drum mixer of continuous action was selected for the mixing process. For which a parametric scheme was developed. On the basis of the parametric scheme two models with PID, PI and regulators, and with LQR-regulator, on two channels were developed: the level in the drum – output quality, number of turnovers – output quality. To control the quality of mixing, an optical method was selected which is performed by the method of comparison of the frames received from the optical sensor. Our own criterion of the production efficiency is proposed.

**References:**


1. Makarov Yu.I. Apparatus for blending loose materials. M.: Mechanical Engineering, 1973. 215 p.
2. Ostapova Yu.A., Tigar A.M. Modeling of the control system for the loading level of components in a drum mixer: materials. M.: Economics and management in the conditions of the structure of the information society, 2017. 60 p.
3. Uteush E.V., Uteush Z.V. Basics of automation of grinding materials in ball mills. M.: Glavpoligafmash, 1975. 156 p.
4. Evaluation of mixing quality of bulk materials with different size of fractions: Journal / R.I. Cherkasov, K.A. Adigamov, V.V. Voronin, N.V. Gapon, R.A. Sizyakin. M.: Modern problems of science and education.
5. Patent of the Russian Federation 2371698 MPK G01N1 / 28. Method of determining the coefficient of heterogeneity of bulk materials / A.E. Lebedev, A.I. Zaitsev, A.B. Kapranova, A.A. Pavlov, A.V. Sugak. 2009.

**ПОРІВНЯЛЬНИЙ АНАЛІЗ СУЧАСНИХ СИСТЕМ АВТОМАТИЗАЦІЇ НА ДІЛЯНЦІ ЗМІШУВАННЯ ПІД ЧАС ВИГОТОВЛЕННЯ ЕЛЕКТРОТЕХНІЧНОГО ФАРФОРУ**

*У статті проведено порівняльний аналіз сучасних систем автоматизації ділянки змішування компонентів електротехнічного фарфору. Представлені можливі конструкції агрегатів та методи роботи для реалізації цього процесу. Також розглядаються методи управління, запропоновано нову структуру системи управління. Метою є дослідження сучасних методів оцінки якості змішування сипучих матеріалів у виробництві електротехнічного фарфору, а також альтернативних підходів до проектування автоматизованих систем керування процесом змішування в барабанному змішувачі.*

***Ключові слова:*** *автоматична система управління, електротехнічний фарфор, критерій якості, оптичний метод, частка ключових компонентів, змішування сипучих матеріалів.*

**СРАВНИТЕЛЬНЫЙ АНАЛИЗ СОВРЕМЕННЫХ СИСТЕМ АВТОМАТИЗАЦИИ НА УЧАСТКЕ СМЕШИВАНИЯ ПРИ ИЗГОТОВЛЕНИИ ЭЛЕКТРОТЕХНИЧЕСКОГО ФАРФОРА**

*В статье проведен сравнительный анализ современных систем автоматизации участка смешивания компонентов электротехнического фарфора. Представлены возможные конструкции агрегатов и методы работы для реализации этого процесса. Также рассматриваются методы управления, предлагается новая структура системы управления. Целью является изучение современных методов оценки качества смешивания сыпучих материалов при производстве электротехнического фарфора, а также альтернативных подходов к проектированию автоматизированных систем управления процессом смешивания в барабанном смесителе.*

***Ключевые слова:*** *система автоматического управления, электротехнический фарфор, критерий качества, оптический метод, доля ключевых компонентов, смешивание сыпучих материалов.*