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The process of mixing and heat exchange of dry dispersible substances

Olim Abdurakhmonov[1], and *Fayoz* Abdullayev[2*]

[1]Bukhara Engineering-Technological Institute, Bukhara, Uzbekistan
[2]Shahrisabz branch of Tashkent Institute of Chemical Technology, Shahrisabz, Uzbekistan

Abstract. Dry dispersible substances are used as raw materials in almost all branches of production, mainly in chemical, pharmaceutical, food, construction and other industries. Therefore, there is always a need for facilities that process this product. One of the most important of these devices is the mixer. First of all, it is an important task to create efficient and energy-efficient mixers suitable for the product type and production process. Mixers are based on the process of mixing. We used a horizontal mixer to mix the dry dispersible substances and also installed a cooling shell in the mixing zone. Based on laboratory experience, we considered the process of wet mixing of dry substances. In the process of mixing, the dependence of the degree of mixing on the design of the mixers was studied. The dependence of the power required during the mixing process on the frequency of mixing was studied. In the process of mixing the mixture, the dependence of cooling water consumption was studied. In the process of mixing, the product obtained in laboratory conditions fully meets the requirements. The created device meets the production requirements and has been determined to be economically efficient.

1 Introduction

Today, along with the increase in the production of chemical products, their use in various sectors of the national economy is also expanding. This, in turn, leads to the acceleration of the use of new technologies and the development of scientific and technical progress in all industries. The increase in the production of consumer goods requires the expansion of the base of industrial raw materials. In production, the main priority is the use of technologies with high productivity, efficient process, and low relative energy consumption. With the introduction of modern technologies in the industry, the demand for high-efficiency and energy-saving devices is increasing. This, in turn, requires the creation of improved technologies of high-efficiency and energy-efficient devices.

Production of bulk and powder products is widespread in modern industries. For example, the mixing process is widely used in chemical, pharmaceutical and food, construction and other industries. The mixing process is widely used to create a mixture of the same concentration as a result of mixing products of different phases and different concentrations. Also, during the mixing process, the process of mass and heat exchange is carried out, thereby

* Corresponding author: fayozabdullaev@mail.ru

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obtaining products within the specified requirement. By applying the mixing process in production, finished or raw products are obtained. At the same time, the requirements for the homogeneity of mixtures and the performance of mixer equipment are constantly increasing. Despite many scientific studies and design-construction work, the solution of these problems still lags behind the requirements of modern technology. When mixing dissimilar components, the main barrier to obtaining a quality mixture is based on the melting of the components at different temperatures [1].

2 Materials and methods

If we introduce the concept of degree of mixing in the process of mixing, it is the same distribution of two or more substances in the total volume of the total system. It is impossible to perfectly use the laws of the mixing process in all branches of production. Also, during the mixing process, it is possible to achieve a maximum mixing level in a short period of time. But it does not always satisfy the requirements of the technological regulation. Therefore, it is necessary to carry out scientific research on methods based on the elimination of all the negative factors affecting the mixing process and the maximization of the quality of the process [2]. The mixing process is carried out in the flow of components in different hydrodynamic structures. These flows are organized on the basis of different forms of the working body of the mixer. Basically, the process is carried out in mixers with different mixing parts. All mixers designed for high efficiency in production must be designed on the basis of accurate calculations. Determining the main optimal technological parameters of mixers is one of the main problems. Different processes and different raw materials are used in the industrial process. Depending on the type of raw materials, mixers of different structures are used. When mixing liquid products, vertical mixers are used to create suspensions and emulsions [3,4]. For dry dispersible fine dispersed substances, the horizontal type mixer in Figure 1 is more convenient. Among this type of mixers there are simple blade, anchor and ribbon types. Some devices will have an additional structural modification.

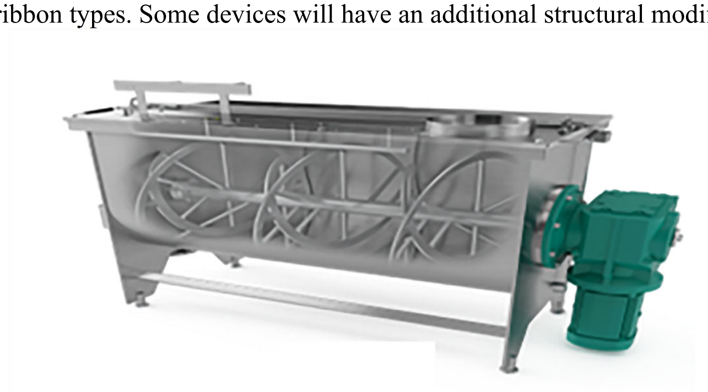

Fig. 1. Horizontal ribbon mixer.

Some products need to be cooled or heated during the mixing process, and it is advisable to install cooling or heating shells on the equipment. It is possible by installing a shell on the horizontal and vertical mixers, which helps to efficiently carry out the process taking place in them. The problem of mixing different phase environments, especially in non-isothermal systems, to prevent temperature rise, is also waiting for its solution. It is an important task for industries that require increasing chemical reactions, mass and heat exchange coefficient [5,6]. Some of the processes and chemical reactions carried out in mixing plants are by cooling, thereby obtaining the desired product. In mixer devices, the mixing part serves for intensive mixing of the mixture of various structures. The choice of mixing methods and equipment is determined by the purpose of the mixing process and the type and condition of the materials to be mixed. Therefore, in any mixers created, the first thing is to speed up the processes carried out in it and ensure that the product mixed in it is of high quality. It also reduces energy and time spent on it. By reducing the cost and metal consumption of the device, it is possible to increase the efficiency of the device and speed up the process [7,8].

3 Results and discussion

When mixing dry dispersable materials and obtaining a homogeneous mixture by wetting dry dispersable materials, it is desirable to use horizontal mixers mainly with blades. A bladed horizontal mixer design was created to prepare the mixture by mixing the dry dispersible compounds (Figure 2). The housing of the mixing device also has a cooling shell. Heat is released as a result of a chemical reaction when some dry dispersable substances are wetted and mixed to obtain a mixed product, and this heat needs to be cooled. If this heat is not removed, it will damage the quality of the product. A cooling shell is also placed in the mixing device developed for this reason. The structure of the mixing part and its speed are considered to be the most important factors in increasing the efficiency of mixing devices.

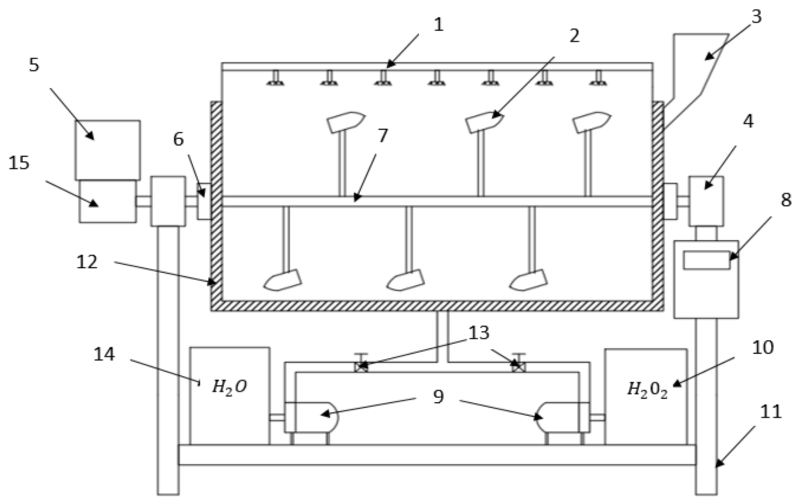

Fig. 2. A mixer laboratory device.

The bottom of the horizontal mixer is in the form of an arc, and the blades (2) are arranged in the form of a triangle on the horizontal rotating axis (7). From the top of the device, there is a spout (1) for spraying liquid and a slot (3) for loading the product. At the bottom of the device there is a slot for pouring the finished product. In the main body of the device, cold water enters the cooling shell (12) from one side and flows out from the other side. Electromotor driving the device (5), bevel gear (15), tightening ring (6), rotating bearing (4). Frequency control inventor (8), support legs (11). It consists of pumps (9), opening and closing valves (13), which drive liquids. In the device, an experiment was carried out to obtain a bleaching agent by reacting a dry product - sodium percarbonate as a liquid with a water tank (14) and a hydrogen peroxide tank (10). During the experiment, various data were obtained and the data were analyzed in a graphical form by calculating based on the calculation formulas. A variety of method and design changes have been made to the mixer device to increase its efficiency. We conducted experiments on mixers with three different designs (Figure 3). Mixers consist of blades and ribbons arranged in three different ways on the axis of rotation. They are shown from above. The blades is placed in the form of a triangle

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on the axis of rotation (Figure 3-a), the blades are placed in the form of a plus on the axis of rotation (Figure 3-b), and the tapes are connected in the form of a spiral (Figure 3-c). This is how the mixer was created in three different ways. It is designed for dry dispersion mixtures. The mixing part of the device is called "mixer".

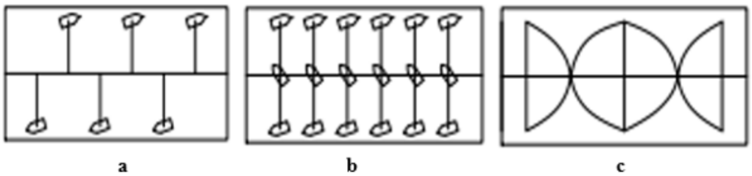

Fig. 3. Mixers.

The tasks performed by this device are as follows:

- mixing of dispersible powdery products;
- preparing a uniform mixture by moistening dispersible powdery products with liquid;
- cooling the mixture during mixing;
- physical or chemical reactions can be carried out.

In the process of mixing, the mixing efficiency is determined by the degree of homogeneity. The degree of homogeneity is generally understood as the mutual distribution of two or more substances after perfect mixing of the whole system. Thus, the degree of homogeneity is a type of excitation efficiency, and the degree of homogeneity is used to evaluate the intensity of excitation. The higher the degree of mixing (I), the smaller the difference in the concentration of the mixed substance in different areas of the reactor volume.

The degree of mixing is determined by the following formula:

$$I = (x_1 + x_2 + x_3 + \cdots + x_k)/k$$

here, k – number of samples, x_1, - x_k is the relative concentration of the substance in the samples determined by the following formulas.

$$x_i = \varepsilon_i/\varepsilon_0 \qquad (\varepsilon_i < \varepsilon_0 \text{ when })$$

$$x_i = (1-\varepsilon_i)/(1-\varepsilon_0) \qquad (\varepsilon_i > \varepsilon_0 \text{ when })$$

here, ε_i, $\varepsilon_0 -$ is the volume fraction of the ith component under analysis and in the sample and in the whole device [9,10].

Calculations were made to determine the degree of mixing of the mixing device using these formulas. When determining the degree of mixing, samples are taken from different points of the mixture and poured into the calculation formula. In the mixing device, the mixing frequency is controlled by 8 and the mixing is adjusted to the appropriate rotation frequency at different times of the process. During the experiment, dry product is first poured into the device and mixing is started. The wetting liquid is sprinkled in and the mixing is continued, the specified amount of liquid is added and thoroughly mixed. The mixing process is carried out according to the three different constructions shown in Figure 3. The effectiveness of the mixture device is dependent on time on the basis of three different mixtures to determine the effectiveness of the mixture. Which structure is considered possible to have the same content in how long. The schedule of dependence on time on the basis of three different structures of the level of mixing levels is drawn. Different results are achieved on the basis of structures on the device of the product.

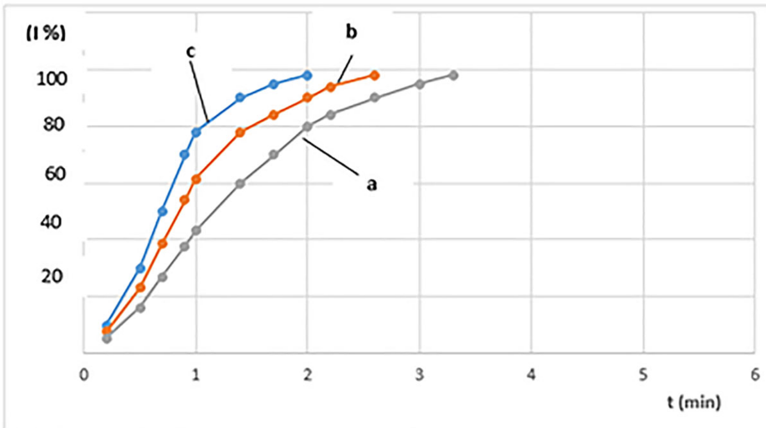

Fig. 4. The degree of mixing related to the mixer device.

The degree of mixing of the product in the device depends on the mixing design and time is shown in the graph. When mixing with the construction of the figure (c), the degree of mixing reaches 97-98% for 2 minutes. (b) reaches 97-98% in 2.6 minutes, respectively, when mixed with the construction shown. If mixed with the construction in (a) view, it reaches 97-98 % during 3.3. It can be seen that the efficiency of the mixing process varies depending on the mixer design.

During the mixing process, a certain amount of energy is consumed in obtaining the product. Of course, in order to achieve productivity, it is necessary to take into account the energy consumption. During the preparation of the mixture by moistening the dry dispersion product in the mixing device, the energy in the mixers is mainly used to overcome the frictional resistance during the rotation of the blades, as well as to continuously rotate the product.

The dry spreadable product is wet mixed and has a high viscosity in the form of a uniform mixture. Their physico-chemical state is described by Newton's equation.

$$\tau = \tau_0 + \mu \, dv/dy$$

here, τ – is the force of friction between the layers of the mixture, N; τ_0 – the highest shear strength, characterizing structural bonds N; μ – is the dynamic viscosity of the mixture, Pa·s; $dv/dy -$ is the velocity gradient of the mixture layer, m/s [11].

Due to the complexity of the hydrodynamic behavior of the mixture in mixers and the variability of some of their properties, it is desirable to solve the equations of motion in the criterion form using the criteria of hydrodynamic similarity. When mixing, frontal pressure, friction and gravity forces prevail. Expressing them in the form of a criterion, that is, in relation to their inertia forces, the mixing process is characterized by power functions:

$$Eu = (Re)^x \cdot (Fr)^y$$

here, Eu-Euler's criterion is the ratio of frontal pressure forces to inertial forces; Re - Reynolds criterion is the ratio of internal friction forces to inertial forces; Fr -Froude's criterion is the ratio of gravity to inertial forces.

The power criterion (modified Euler's criterion) is equal to

$$Eu \approx \frac{\Delta P}{\rho} \cdot n^2 \cdot d \approx N/\rho \cdot n^3 \cdot d^5$$

Since the pressure drop ΔP occurs in the flow is difficult to determine in practice, Euler's criterion is modified by introducing an easily measured mixing power N instead of ΔP.

The modified case for mixers is as follows.

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$$N/\rho \cdot n^3 \cdot d^5 \approx c\left(\frac{\rho \cdot n \cdot d^2}{\mu}\right)^x \cdot \left(\frac{n^2 \cdot d}{g}\right)^y$$

The amount of power required for the rotation of the blade is calculated from the following formula:

$$N = K_N \cdot \rho \cdot d^5 \cdot n^3$$

Angular velocity at the blade tip $\omega = \pi dn$ (where n is the number of revolutions of the mixer in 1 s).

here, $\rho -$ the density of the product being mixed, kg/m^3 g=9.81 m/s^2 free fall acceleration [12].

Criterion equations for calculating the total power consumed by the mixer:

$$K_N = (Re, Fe,\ \Gamma_D, \Gamma_b, \Gamma_{H_0}, \dots)$$

here, $\Gamma_D = D/d$; $\Gamma_b = b/d$; $\Gamma_{H_0} = H_0\ /d$ the ratio of the full geometric dimensions of the mixer; b - width of the sheet, m; *D*-mixer diameter, m; H_0-mixed product layer height, m [13].

When calculating the power consumed by the mixer, it was calculated based on the above formulas. All parameters are taken into account in the design of the device and the energy required during the wet mixing of the dry product until the product is mixed. It is possible to change the frequency of rotation of the blades of the mixing device, and the device consumes different power at different frequencies. The power required by the mixing device varies depending on the frequency of rotation. Therefore, the required power for different rotation frequency is calculated.

Table 1. Dependence of mixer power on mixing frequency.

180 rpm	160 rpm	140 rpm	80 rpm
255 W	156 W	110 W	20 W

Some products generate heat during mixing and need to be cooled or kept at the same temperature without changing the temperature. If the heat is not removed, the mixing process will be adversely affected or the process will not take place. Therefore, as a result of installing a cooling shell on the mixer device, we have the possibility of cooling. Dry production of peroxide compounds requires a cooling shell in the mixing unit. During the mixing process, heat is released during the reaction, and it is necessary to maintain this process at 13-15 °C. Cooling is done with water. How much cold water circulates in the shell in a certain time and what is the mode of movement. How much cooling is consumed during the mixing of the mixture. Calculation of the heat exchange surface, temperature difference, etc. is calculated using the following formulas:

$Q = \alpha\ (t_w - t_i) dF d\tau$ [J]

here, Q - amount of heat given, α - coefficient of heat transfer, F - surface of heat exchange, $t_w t_i -$ the temperature difference of the inner and outer shell of the device $d\tau -$ duration of the process.

$Q = G_c \cdot c_c(t_2 - t_1)$ [J]

here, Q - is the amount of heat supplied, G_c- mass consumption, $\boldsymbol{c}_c$- specific heat capacity of water, $t_2,\ t_1 -$ temperatures at the inlet and outlet of the shell [14,15].

When calculating the heat balance, it is possible to determine the consumption of the cooling product by finding the amount of heat consumed and pouring it into the Heat balance formula.

First, we determine the amount of heat consumed in the mixing process. we use the following formula for it.

$Q = \alpha\ (t_w - t_i) dF d\tau$ [J]

α =600 W/m^2K - heat transfer coefficient of water

$t_W = 13$ °C, $t_i = 10$ °C mixture and cooling water temperatures,
F=0,35 $м^2$ the wall surface that separates the mixture and the cooling water,
$\tau = 1800\ c,$ time taken for the mixture to be ready in seconds,
$Q = \alpha\ (t_w - t_i)dFd\tau$ =600·(13-10)·0.35·1800=1134000
The amount of heat consumed in the mixing process is Q=1134000 J
We use the heat balance formula to determine the consumption of the cooling product.

$$Q = G_w c_w (t_2 - t_1)$$

$c_w = 4180\ \frac{J}{кg\cdot K}$ - specific heat capacity of water,
$t_2 = 12$ °C, $t_1 = 10$ °C - temperatures at the inlet and outlet of the shell,

$$G_w = \frac{Q}{c_w(t_2 - t_1)} = \frac{1134000}{4180 \cdot 2} = 136\ kg$$

G_w=136 kg for 30 minutes and 272 kg for one hour.

In the process of mixing dry dispersible substances, the consumption of cooling water was determined through the heat balance, and the dependence of the temperature of the mixture on the consumption of cooling water was studied[16]. Based on this, it was represented by a graph.

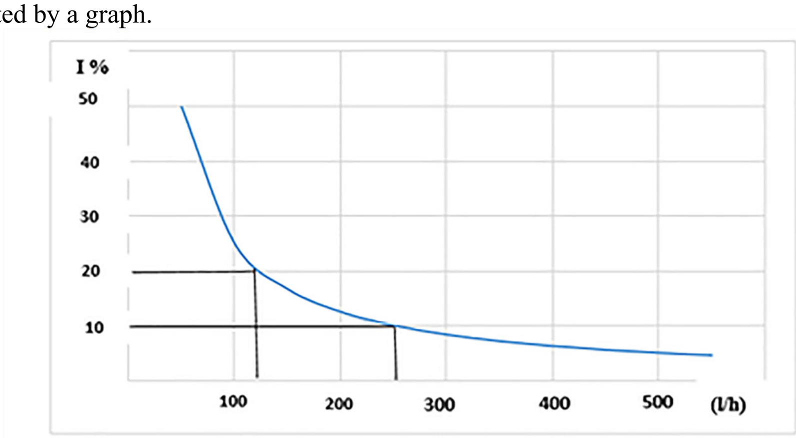

Fig. 5. Dependence of the mixture temperature on the consumption of cooling water.

In the process of mixing dry dispersants. Temperature control is carried out by the consumption of cooling water, the higher the consumption, the lower the temperature of the mixture. The curve on the graph represents the temperature of the mixture. When the cooling water consumption for the mixture is increased to 120-250 l/h, the temperature of the mixture decreases to 20-10 °C, and this temperature is considered as a suitable temperature for carrying out the mixing process. If the cooling water consumption is increased to 550 l/h, the mixture temperature will decrease to 5 °C. If the cooling water consumption is reduced by 50 l/h. If the cooling water consumption is reduced to 50 l/h, the temperature of the mixture will rise to 50 °C, which is not suitable for the mixing process. This leads to a decrease in the efficiency of the process. Therefore, the consumption of cooling water is high and the cooling of the mixing process is accelerated.

4 Conclusions

As a result of the experiments, it was found that the product mixed in the created mixing device fully meets the requirements. It is also possible to cool the dry spreadable products during wet mixing. The degree of mixing depends on the design of the device, which is a consideration when choosing a mixer design. Accordingly, the power required by the mixer will also depend on the design of the device. Therefore, the selection of the device is based on the type of raw materials to be mixed and the state of the resulting product. When choosing a device, the type of metal, optimal and efficient, as well as the creation of a device that requires less energy is an important factor. In the production of dry dispersable substances or use as a raw material. The product produced on the basis of the application of mixing and heat exchange process is economically efficient. In production, import-substituting products are produced. The product manufactured on the basis of the conducted experiments fully meets the requirements of GOST 32387-2013. It can be used as a bleaching agent for clothes, cleaning, oxidizing dyes and cleaning fabrics in the textile and chemical industries, as a disinfectant, and as a disinfectant.

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