

Investigation of the continuous mode of mixing when changing the rotation frequency of the impeller of the mixing plant

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Abstract. With the development of farms, by analogy with developed Western countries with well-established agricultural production, certain hopes are placed on solving the domestic food problem. It has been established that there are very few power tools for small-scale mechanization and agricultural implements for them. However, the domestic industry can provide almost complete mechanization of processes and bring it to a comprehensive one. It is also known that without solving this problem, that is, without a high level of mechanization of production processes, it is impossible to achieve high performance in the functioning of the farm. The domestic industry has now developed and put into production various power tools for small-scale mechanization. As new equipment is developed and put into production, both the quantitative and qualitative (type and structure) composition of the power equipment fleet and the set of agricultural machines for them change. The article deals with the installation for the preparation of liquid feed mixtures with the continuous introduction of components. This mode is one of the modes of any mixer.

1 Introduction

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The information on the development and production of energy products by the domestic industry was studied and the situation on the availability of these funds in farms was analyzed. But at the same time, the approach lies in the theoretical research and explanation of the process of mixing liquid feed in an experimental setup.

In various studies of mixing plants, it is distinguished that the main indicators (factors) are: the rotational speed of various mixing devices, installation angles, the height of the blades, if it concerns paddle mixers, the number of fixed blades, the temperature of the medium or one of the components. Of course, the rotational speed of the working body is the most significant indicator, because not only the quality of the mixture, but also the energy performance of the work depends on it.

2 Theoretical, methodological and empirical base

A study of installations based on vane pumps [1,2,3,4,5,6,7,8], it was found that the rotational speed n from 1750 to 3000 min^{-1} is not always effective, although even with these values high performance indicators. Therefore, in experimental studies, we proceed from the fact that we take synchronous speeds of rotation of the electric motor (respectively, it will be the same for the impeller) $n = 750, 1000$ and 1500 min^{-1} , but for more accurate readings we take a step of 250 min^{-1} , respectively, points will be next $n=750, 1000, 1250, 1500$ and 1750 min^{-1} .

The experimental part was carried out on a specially designed stand [2,3,4], which allows sampling in two modes: continuous and periodic.

The quality of the mixture obtained by mixing the components is determined using the degree of homogeneity according to the methods described in the literature [7,8,9,10,11], while maintaining the ratio of 1:8 ... 1:10, that is, for 8 liters of water 1 kg of milk replacer, the deviation is permissible $\Delta = \pm 20\%$.

3 Results and discussion

The first stage of the study is to obtain quality indicators with continuous mixing of the components, we study the dependence of the degree of uniformity on the speed of the impeller, that is, $\Theta = f(n)$, while the parameter that will change will be the water temperature t , which will be in the interval $t=20, 30$ and 40 oC . Figure 1 shows the dependence of the degree of homogeneity on the speed of the impeller, with the number of fixed blades $Z=12$ pcs.

The graph shows that the degree of uniformity will increase at water temperatures $t=20$ and $30 \text{ }^\circ\text{C}$, and at a temperature of $t=40 \text{ }^\circ\text{C}$, it decreases. Such a change is possibly due to the fact that the viscosity of the liquid at high temperatures is less than at $20 \text{ }^\circ\text{C}$, therefore, with greater interaction of the impeller with fixed blades, the mixture is ejected to the periphery of the working chamber, and the feed particles do not have time to mix with water.

The graph (Figure 2) shows that the degree of homogeneity has the form of a parabola at almost every temperature. And with an increase in the number of blades (Figure 3), the nature of the dependence is in the form of parabolic curves, which decrease in value.

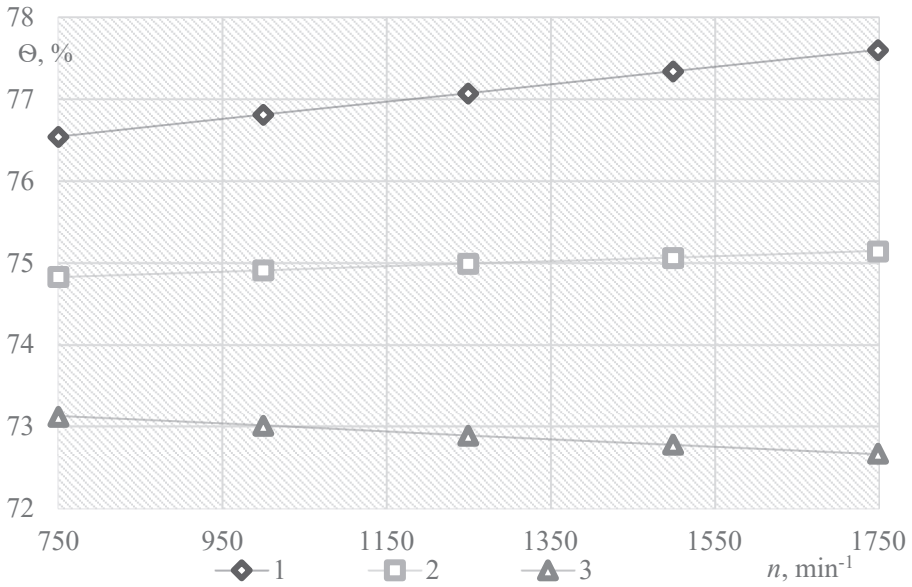


Fig. 1. Graph of the degree of homogeneity Θ , % at different speeds n , min⁻¹ of the impeller, at different temperatures t , °C water ($Z = 12$ pcs.). 1 – temperature $t=20$ °C; 2 – temperature $t=30$ °C; 3 – temperature $t=40$ °C.

Further studies were carried out at the same parameters of rotation frequency and water temperature, but the number of fixed blades $Z=18$ and 24 pieces was increased. The resulting dependencies are shown in Figures 2 and 3, respectively.

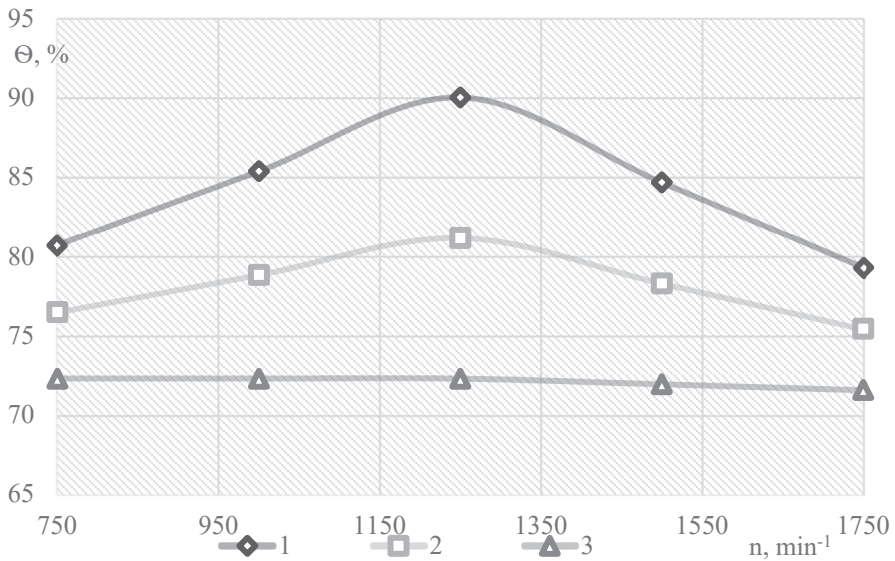


Fig. 2. Graph of the degree of homogeneity Θ , % at different speeds n , min⁻¹ of the impeller, at different temperatures t , °C water ($Z = 18$ pcs.). 1 – temperature $t=20$ °C; 2 – temperature $t=30$ °C; 3 – temperature $t=40$ °C.

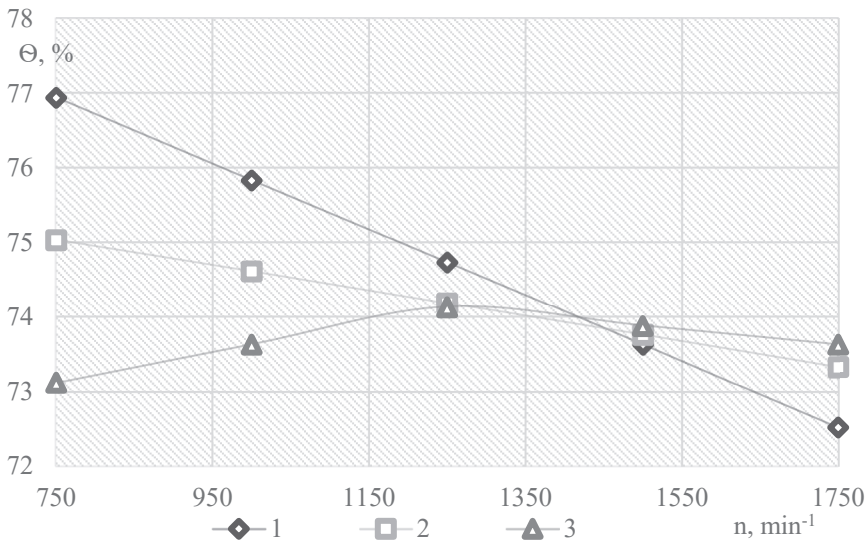


Fig. 3. Graph of the degree of homogeneity Θ , % at different speeds n , min^{-1} of the impeller, at different temperatures t , $^{\circ}\text{C}$ water ($Z=24$ pcs.). 1 – temperature $t=20$ $^{\circ}\text{C}$; 2 – temperature $t=30$ $^{\circ}\text{C}$; 3 – temperature $t=40$ $^{\circ}\text{C}$.

To optimize the speed parameters, we implement a plan on a hexagon, where the factor x_1 will be the speed n , min^{-1} , which will change at five levels, and the temperature of the mixture t , $^{\circ}\text{C}$ will be the factor x_2 . The optimization criterion will be the degree of homogeneity Θ , % (y_1).

Table 1 presents the design of the experiment for 2 variable factors, so it will be an integral part of the full factorial experiment (FFE). And the second part is the so-called "star points". Obviously, with the number of factors k , there are $2k$ star points, so the total number of experiments will be equal to:

$$N = 2^k + 2 \cdot k. \tag{1}$$

Table 1. Factors and levels of variation.

Factors	Normalized	Levels of variation		
		lower (-1)	basic (0)	upper (+1)
Impeller speed n , min^{-1}	x_1	750	1250	1750
Water temperature t , $^{\circ}\text{C}$	x_2	20	30	40

After implementing the experiments according to the plan and processing the experimental data, a mathematical model of the workflow was obtained:

$$y_1 = 81.15 - 0.52 \cdot x_1 - 5.65 \cdot x_2 - 5.19 \cdot x_1^2 + 0.17 \cdot x_1 \cdot x_2 - 0.003 \cdot x_2^2. \tag{2}$$

The analysis of the mathematical model allows us to conclude that the degree of homogeneity is most affected by the rotation frequency n ($b_1 = -0.52$), since it has the smallest value, and the water temperature makes a significant contribution.

For clarity of the results obtained, two-dimensional sections (Figure 4) of the response surface were constructed, for which two factors were left in the original equation.

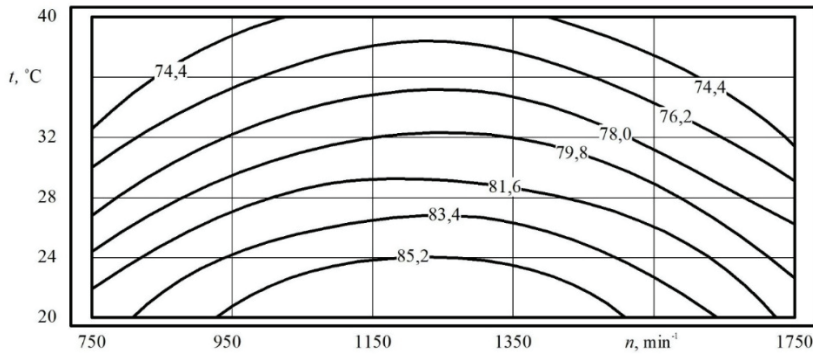


Fig. 4. Two-dimensional section of the response surface of the degree of homogeneity Θ , % depending on the rotational speed n , min⁻¹ and water temperature t , °C.

4 Conclusions

Optimal data were obtained, so the two-dimensional section shows that the highest value of the degree of homogeneity is 85.2% at a rotation frequency of $n=950\dots1490$ min⁻¹, and the water temperature is $t=20\dots24$ °C. Accordingly, to optimize the design of the installation, these basic indicators can be used.

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