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THE CHOICE OF FACTORS OF INFLUENCE ON VIBRO-CENTRIC SEPARATION OF LIQUID INHOMOGENEOUS RAW MATERSALS

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The development of modern equipment and technology leads to healthy competition, which in turn allows you to freely choose a machine or installation for the separation of liquid inhomogeneous systems. Each production when choosing equipment takes into account the relevant factors and its specifics.

Mathematical and statistical planning of a multifactorial experiment was used to refine the glycerin quality indicators and determine their weight.

The article constructs the response surfaces of the optimization criteria, which allow us to clearly illustrate the dependences of the values of the mass fraction of pure glycerin and energy consumption on individual optimization parameters. The research method includes the selection of optimal modes of operation of the vibrocentric machine for purification of liquid glycerol-containing raw materials according to technical and economic criteria for evaluation and determination of quality indicators of purified glycerol with variation of processing time, process temperature, etc. During the study, special attention was paid to the main operating parameters of this vibrating machine, namely: amplitude-frequency, power and energy.

The efficiency of the process of vibration-based purification of crude glycerol was evaluated on such parameters as vibration control, angular rate of flow, rate of temperature. The recommendations of the second basic parameters of the lateral period were determined in accordance with the second set of the second order.

Analyzing the results of studies of vibration-centrifugal separation of liquid inhomogeneous raw materials, it can be argued that the most influential factors in the separation of these products are the rotor speed, vibration shaft speed, oscillation amplitude, power, temperature and processing time.

Keywords: *raw glycerin, vibration-centrifugal separation, liquid inhomogeneous system, multifactor experiment, optimization parameters.*

F. 9. Table. 2. Fig. 2. Ref. 12.

1. Problem formulation

Currently, one of the important problems in the food and processing industries is the process of purification (separation) of liquid inhomogeneous raw materials, in particular crude glycerin, which is in great demand. In purified form, glycerin is used in the food and pharmaceutical industries, as well as in the production of explosives, tobacco products, which justifies the relevance of this scientific work.

The development of structural schemes of machines for cleaning inhomogeneous liquid raw materials can be called a vibration-centrifugal unit, which has a combined effect on the technological load (vibration movement of the container and the rotational movement of the perforated drum), which significantly reduces energy consumption

With the development of alternative energy sources, especially diesel fuel, there is a problem of transfer and purification of glycerol as a by-product of the day. As a rule, these problems were written with the help of traditional methods of separation: settling, filtering, cyclization, under the action of percentage [1, 3, 4, 5].

The combined influence of these factors constitutes a potential for increasing the productivity of machines. It also improves the quality parameters of the operation and partially creates a reserve for energy conservation.

Therefore, the introduction of advanced technological processing and the use of secondary raw materials with the help of the combined use of physical and mechanical methods of processing the air, namely, the combination of the combined action of vibration and centrifugal [6, 7].

2. Analysis of last researches and publications

Among the main factors influencing the process of separation of inhomogeneous liquid substances, it is possible to note: temperature, density, viscosity of the medium, time of the experiment. The fluidity of the marked factors can lead to a qualitative change in the basic physical and mechanical properties of the substance. To determine the qualitative characteristics of the studied environment, it is necessary to include some physico-mechanical properties of the product that have an impact on quality. In previous works [3-6], it was presented that the use of flood perforations with a certain effect influences the increase in the productivity of the process of separation of a liquid inhomogeneous suspension.

The increase in the frequency of flooding has a nonlinear character, that is, at a certain limit the productivity of the centrifuge decreases sharply.

In other studies [7], the maximum value of purity and yield of the heavy fraction was observed at the optimal values of the parameters of the process and setting: the frequency of oscillations of the working surface, the specific load on the working surface and the coefficient of anisotropy.

3. Purpose of the research

To create a methodology for calculating and constructing audit equipment, as well as to determine the optimal parameters of raw material processing during the audit. At the same time, it is necessary to establish the possibility of increasing the mass fraction of pure glycerol depending on the main indicators that characterize the efficiency (vibration acceleration a, the angular velocity of the flood $\omega_{rot,}$ glycerin temperature, t_{gl} and processing time τ).

4. Results of the research

Vibrating machines for separation of inhomogeneous systems are characterized by insignificant influence of mass of technological loading on dynamics of movement of executive parts of oscillating system. For these machines, the combined action of vibration with all mechanical and electromagnetic types of separation is effective.

The use of filtering through perforated surfaces at a certain vibration frequency is no exception [4]. During such complex processes, where many factors are involved (frequency of flood rotation, frequency of rotation of the shaft of the exciter, amplitude of oscillations, time of rotation, temperature of glycerol, etc.), it is impossible to build a simple mathematical model.

To study the qualitative indicators of quality and their quantitative assessment of the marked processes, it is necessary to use the mathematical planning of a multifactorial experiment [2, 8].

Based on the results of previous experimental data of the studied process, a statistical analysis of energy parameters and parameters of its quality was performed. The process of separation of the liquid inhomogeneous medium was carried out with the help of a subdivided verification machine.

After conducting theoretical research, vibrocentric separation, it can be argued that the most influential factors in the separation of these products are the rotor speed, vibration shaft speed, oscillation amplitude, power, temperature and processing time.

The quality parameters used to evaluate the mass fraction of pure glycerol in raw glycerol X_{cl}, %, as a function of the basic factors were determined in the studied process.

$$X_{cl.gl.} = f\,(A\omega_{dr.s}^{2},\ \omega_{rot},\ \tau,\ t_{gl}), \quad (1)$$

where $A\omega_{dr.s}^{2}$ – vibration acceleration, m/s^2.

$$N_{tot.} = f\,(A\omega_{dr.s}^{2},\ \omega_{rot},\ \tau,\ t_{gl}), \quad (2)$$

where $N_{tot.}$ – total energy consumption, W.

All the factors that are part of the studied process have their own significance, and their meanings have different orders. In order to obtain an adequate response rate, we perform coding of functions, which is a linear transformation of the factual process.

We divide the meaning of the levels of facts as follows: upper +1; current 0; lower -1; star upper + a; star lower -a. Based on the results of the theoretical and practical analysis, the following conclusions were chosen as influential factors of the process of visitor-centric division (table 1).

Investigation of the influence of the above-mentioned factors on the technological and energy parameters of the studied processes during the conduct of multifactorial processes.

Table 1

Values of factor levels and intervals for varying the process of vibrocentric separation

Factors			Levels of variation					
№	Name	Marking	Variation interval	–a	–1	0	+1	+a
1	Vibration acceleration	A^2, m/s^2	5	15,3	18	19,3	20,1	26,2
2	Angular speed of the rotor	$_{rot}$, s^{-1}	50	115	126	136	146	157
3	Processing time	τ, s	60	240	360	480	600	720
4	Glycerin temperature	t_{gl},˚C	10	60	70	80	90	100

Therefore, it is advisable to conduct a statistical analysis to obtain a functional dependence in the form of detailed central-compositional planning (DCCP) of a multifactor experiment under the condition of multiple regression [6, 10, 11, 12].

The method allows to obtain more accurately the mathematical description of the distribution of data for the increase in the number of experiments in the central points of the matrix «star value».

The planner will receive the equation of the multiple order of the 2nd order.

$$y=b_0+\sum_{i=1}^{n} b_i\ x_i+\sum_{i=1}^{n} b_{ij}x_i^2+\sum_{i=1}^{n} b_{ij}x_{ij}x_i, \quad (3)$$

where y – feedback function, $X_{cl.gl.}$, $N_{tot.}$; b_0, b_i, b_{ij} – regression coefficients.

The adequacy of pectoral models was verified by Fisher's criterion [6, 9].

$$F=\frac{S_{ad}^2}{S_{rep}^2}\le[F(f_1,f_2)], \quad (4)$$

where S_{ad} – dispersion of adequacy; S_{rep} – dispersion of reproducibility. $[F(f_1, f_2)]$ – critical value of the fisher criterion, which is equal to the value of the Fisher distribution; $f_1 = n - d$ – number of degrees of freedom of the adequacy variance; $f_2 = n - 1$ – number of degrees of freedom of the reproducibility dispersion; d – number of significant regression coefficients; n – number of previous repeated experiments performed for the mean (zero) level of factors.

The calculated value of criterion F was compared with the critical and at $F \le [F(f_1, f_2)]$ the regression model was considered adequate.

The reproducibility dispersion is determined by formulas 5 and 6.

$$S_{rep}^2=\frac{1}{f_1}\sum_{i=1}^{n}(y_i-\tilde{y_i})^2, \quad (5)$$

where y_i – result of the i-th repeated experiment; $\tilde{y_i}$ – arithmetic mean of the results of n-repeated experiments.

The dispersion adequacy was determined by formula [6]:

$$S_{ad}^2=\frac{1}{f_1}\sum_{i=1}^{n}(y_{im}-\widetilde{y_{im}})^2, \quad (6)$$

where $y_i\ m$ – result of the i-th experiment conducted on the planning matrix; $\tilde{y_i}\ m$ – result of the i-th value of the experiment predicted by the regression model (2).

The significance of the regression coefficients was carried out according to Student's t-criterion [8, 12].

$$t_i=\frac{b_i}{S_{rep}\sqrt{c_{i,j}}}\ge[t(f_2)], \quad (7)$$

where $[t(f_2)]$ – critical value of the Student's t-criterion, which is equal to the value of the Student's distribution; c_{ij} – appropriate element of the matrix.

Calculated value of the criterion t_i was compared with the critical and i-th regression coefficient was considered insignificant.

As a result of processing experimental data in the statistical environment STATISTICA 6.0 for the response functions $X_{cl.gl.} = f\ (a, \omega_{rot}, \tau, t_{gl})$, and $N_{tot.} = f\ (a, \omega_{rot}, \tau, t_{gl})$, the coefficients of complex multiple regression equations of the 2nd order were obtained.

$$X_{cl.gl.} = -78{,}65 - 3{,}2\cdot a + 0{,}15\cdot \omega_{rot} + 0{,}051\cdot t + 1{,}76\cdot\tau - 0{,}08\cdot a^2 - 0{,}0001\cdot\omega^2_{rot} - 0{,}0135\cdot\tau^2 + 0{,}0038\times$$
$$\times\ a\cdot\omega_{rot} + 0{,}0005\cdot a\cdot t + 0{,}0229\cdot a\cdot\tau + 0{,}0001\cdot\omega_{rot}\cdot\tau - 0{,}0003\cdot t\cdot\tau. \quad (8)$$

$$N_{tot.} = 13980 - 212{,}14\cdot a - 11{,}88\cdot\omega_{rot} - 3{,}11\cdot t - 74{,}58\cdot\tau + 3{,}41\cdot a^2 + 0{,}47\cdot\tau^2 + 0{,}08\cdot a\cdot\omega_{rot} \quad (9)$$

The calculated values of the criterion evaluation are shown in table 2.

Table 2

Values of the calculated criteria to the obtained regression models

Evaluation criteria	Designation of the criterion	Response function	
		$X_{cl.gl.}$, %	$N_{tot.}$, W
Coefficient of determination	R^2	0,48	0,49
Dispersion of adequacy	S_{ad}	81,83	118703
Dispersion of reproducibility	S_{rep}	88,31	122757
Fisher's criterion	F	0,92	0,96
Critical value of Fisher's criterion, which is equal to the value of Fischer's division	$F_{a,\, f1,\, f2}$	$2{,}84_{0{,}05;4;21}$	$2{,}84_{0{,}05;4;21}$

As can be seen from table 2, all regression equations were adequate.

In fig. 1, 2 show the response surfaces of the optimization criteria and the dependence of the mass fraction of pure glycerol $X_{cl.gl.} = f\,(a, \omega_{rot}, \tau, t_{gl})$ and energy consumption $N_{tot.} = f\,(a, \omega_{rot}, \tau, t_{gl})$, on individual actual values of the optimization parameters: a, ω_{rot}, τ, t_{gl}.

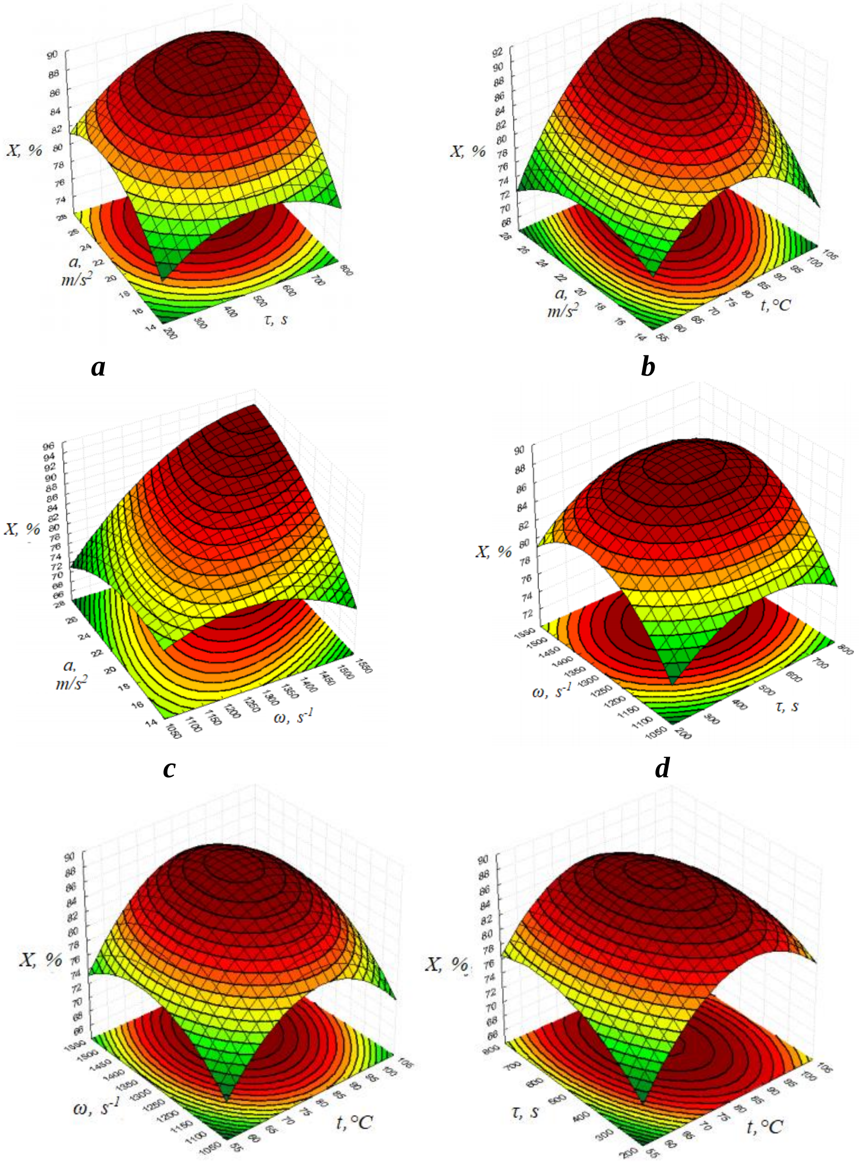

Fig. 1. Surface responses characterizing the mass fraction of pure glycerol from:
a) $X_{cl.gl.} = f\,(a, \tau)$; b) $X_{cl.gl.} = f\,(a, t_{gl})$; c) $X_{cl.gl.} = f\,(a, \omega_{rot})$; d) $X_{cl.gl.} = f\,(\omega_{rot}, \tau)$;
e) $X_{cl.gl.} = f\,(\omega_{rot}, t_{gl})$; f) $X_{cl.gl.} = f\,(\tau, t_{gl})$

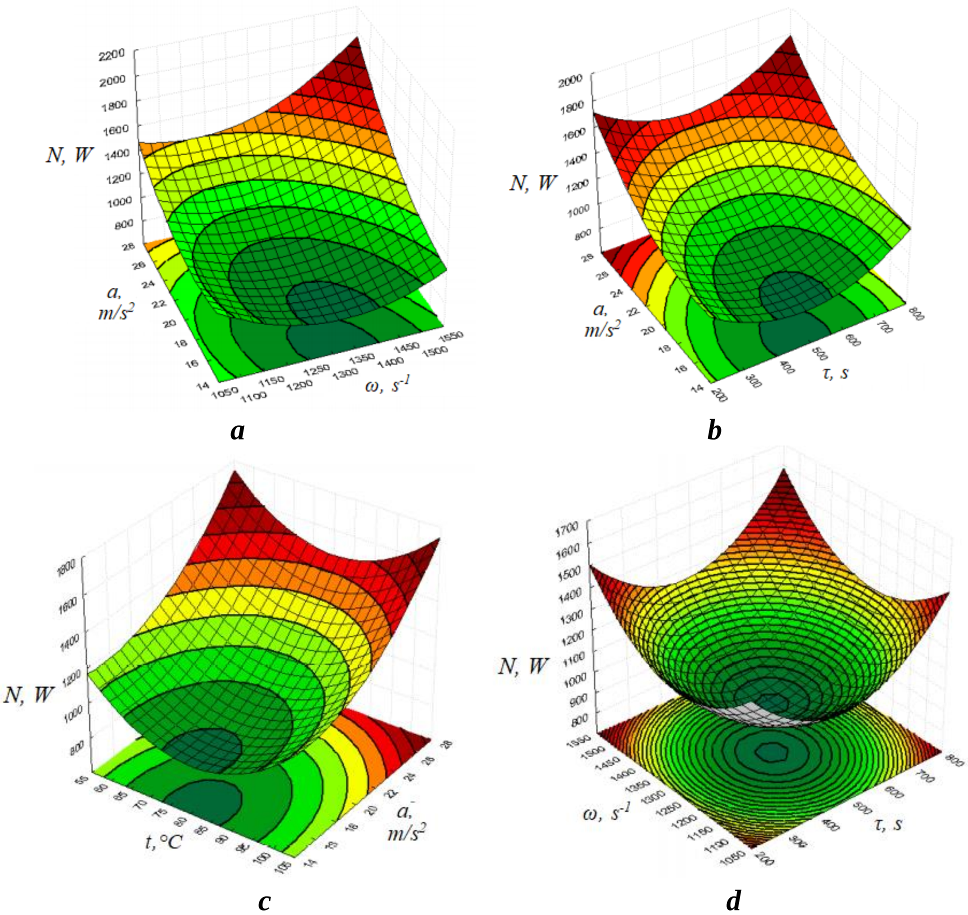

Fig. 2. Surface feedback characterizing energy costs from:
a) $N_{tot.} = f\,(a,\,\omega_{rot})$, b) $N_{tot.} = f\,(a,\,\tau)$; c) $N_{tot.} = f\,(a,\,t_{gl})$, d) $N_{tot.} = f\,(\omega_{rot},\,\tau)$

5. Conclusions

The constructed surfaces of responses of optimization criteria allow to illustrate visually dependences of values of mass fraction of glycerin $X_{cl.gl.}$ and the consumed energy $N_{tot.}$ on separate parameters of optimization and location of optimums.

The mass fraction of pure glycerol acquires the maximum value at the following parameters: glycerin temperature 60-80°C, processing time 6-8 m, angular speed of the rotor 140-150 s^{-1} and vibration speed of the container m/s^2.

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ВЫБОР ФАКТОРОВ ВЛИЯНИЯ НА ВИБРОЦЕНТРОБЕЖНОЕ РАЗДЕЛЕНИЕ ЖИДКОГО НЕОДНОРОДНОГО СЫРЬЯ

Развитие современного оборудования и технологий приводит к здоровой конкуренции, что в свою очередь, дает возможность выбирать машину или установку для разделения жидких неоднородных систем. Каждое производство при выборе оборудования учитывает соответствующие факторы и свою специфику.

Для уточнения показателей качества глицерина и определения их значимости использовали математически-статистическое планирование многофакторного эксперимента.

В статье построены поверхности отзывов критериев оптимизации, которые позволяют наглядно иллюстрировать зависимости значений массовой доли чистого глицерина и потребляемой энергии от отдельных параметров оптимизации. Методика исследования включает в себя выбор оптимальных режимов работы виброцентробежных машины для очистки жидкого глицеринового сырья по технико-экономическим критериям оценки и определения показателей качества очищенного глицерина при варьировании времени обработки, температуры технологической среды и т. д. При исследовании особое внимание уделялось основным рабочим параметрам данной вибромашины, а именно на: амплитудно-частотные, силовые и энергетические.

Эффективность процесса виброцентробежной очистки сырого глицерина оценивали по таким параметрам, как виброускорения, угловая скорость ротора, температура глицерина, время обработки. Используя полученное уравнение множественной регрессии 2-го порядка были определены рекомендации по основным параметрам рабочего режима исследуемого процесса.

Проанализировав результаты исследований виброцентробежного разделения жидкого неоднородного сырья можно утверждать, что наиболее влиятельными факторами при разделении указанной продукции является частота вращения ротора, частота вращения вала вибровозбудителя, амплитуда колебаний, мощность, температура и время обработки.

Ключевые слова: *сырой глицерин, виброцентробежное разделения, жидкая неоднородная система, многофакторный эксперимент, параметры оптимизации.*

Ф. 9. Таб. 2. Рис. 2. Лит. 12.

ВИБІР ФАКТОРІВ ВПЛИВУ НА ВІБРОВІДЦЕНТРОВЕ РОЗДІЛЕННЯ РІДКОЇ НЕОДНОРІДНОЇ СИРОВИНИ

Розвиток сучасного обладнання та технологій призводить до здорової конкуренції, що в свою чергу, дає можливість вільно вибирати машину чи установку для розділення рідких неоднорідних систем. Кожне виробництво при виборі обладнання враховує відповідні фактори та свою специфіку.

Для уточнення показників якості гліцерину та визначення їх вагомості використовували математично-статистичне планування багатофакторного експерименту.

В статті побудовані поверхні відгуків критеріїв оптимізації, які дозволяють наглядно ілюструвати залежності значень масової долі чистого гліцерину та спожитої енергії від окремих параметрів оптимізації. Методика дослідження включає в себе вибір оптимальних режимів роботи вібровідцентрової машини для очищення рідкої гліцериномісткої сировини за техніко-економічними критеріями оцінки та визначення показників якості очищеного гліцерину при варіюванні часу обробки, *температури технологічного середовища і т. д. При дослідженні особлива увага приділялась основним робочим параметрам даної вібромашини, а саме на: амплітудно-частотні, силові та енергетичні.*

Ефективність процесу вібровідцентрового очищення сирого гліцерину оцінювали за такими параметрами, як віброприскорення, кутова швидкість ротора, температура гліцерину, час обробки. Використовуючи отримане рівняння множинної регресії 2-го порядку були визначені рекомендації стосовно основних параметрів робочого режиму досліджуваного процесу.

Проаналізувавши результати досліджень вібровідцентрового розділення рідкої неоднорідної сировини можна стверджувати, що найбільш впливовими факторами при розділенні означеної продукції є частота обертання ротора, частота обертання вала вібробуджувача, амплітуда коливань, потужність, температура та час обробки.

Ключові слова: *сирий гліцерин, вібровідцентрове розділення, рідка неоднорідна система, багатофакторний експеримент, параметри оптимізації.*

Ф. 9. Таб. 2. Рис. 2. Літ. 12.

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