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

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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 $\tau$).

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 $X_{cl,gl}$, %, as a function of the basic factors were determined in the studied process.

$$X_{cl,gl} = f(a_0, \omega_{rot}, \tau, t_{gl})$$

(1)

where $a_0$ – vibration acceleration, m/s$^2$.

$$N_{tot} = f(a_0, \omega_{rot}, \tau, t_{gl})$$

(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.
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»

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

\[ y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} x_i x_j + \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} b_{ijk} x_i x_j x_k, \]

where \( y \) – feedback function, \( X_{clgl} \), \( N_{tot} \); \( b_0, b_i, b_{ij} \) – regression coefficients.

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

\[ F = \frac{S_{ad}^2}{S_{rep}^2} \leq [F(f_1, f_2)]. \]

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 \( F \leq [F(f_1, f_2)] \) the regression model was considered adequate.

The reproducibility dispersion is determined by formulas 5 and 6.

\[ S_{rep}^2 = \frac{1}{f_2} \sum_{i=1}^{n} (y_i - \bar{y}_i)^2, \]

where \( y_i \) – result of the i-th repeated experiment; \( \bar{y}_i \) – arithmetic mean of the results of n-repeated experiments.

The dispersion adequacy was determined by formula [6]:

\[ S_{ad}^2 = \frac{1}{f_1} \sum_{i=1}^{m} (y_{im} - \bar{y}_{im})^2, \]

where \( y, m \) – result of the i-th experiment conducted on the planning matrix; \( \bar{y}_i \) \( m \) – 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].

\[ t_i = \frac{b_i}{S_{rep} \sqrt{c_{ij}}} \geq [t(f_2)]. \]

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 \( t \) 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 \( X_{clgl} = f(a, \omega_{rot}, \tau, t_{cl}), \) and \( N_{tot} = f(a, \omega_{rot}, \tau, t_{cl}), \) the coefficients of complex multiple regression equations of the 2nd order were obtained.

\[
X_{clgl} = -78.65 - 3.2 \cdot a + 0.15 \cdot \omega_{rot} + 0.051 \cdot t + 1.76 \cdot \tau - 0.08 \cdot a^2 - 0.0001 \cdot \omega_{rot}^2 - 0.0135 \cdot \tau^2 + 0.0038 \times \\
\times a \cdot \omega_{rot} + 0.0005 \cdot a \cdot t + 0.0229 \cdot a \cdot \tau + 0.0001 \cdot \omega_{rot} \cdot \tau - 0.0003 \cdot t \cdot \tau. \quad (8)
\]

\[
N_{tot} = 13980 - 212.14 \cdot a - 11.88 \cdot \omega_{rot} - 3.11 \cdot t - 74.58 \cdot \tau + 3.41 \cdot a^2 + 0.47 \cdot \tau^2 + 0.08 \cdot a \cdot \omega_{rot} \quad (9)
\]
The calculated values of the criterion evaluation are shown in table 2.

**Table 2**

| Evaluation criteria                      | Designation of the criterion | Response function |
|-----------------------------------------|------------------------------|------------------|
| Coefficient of determination            | $R^2$                        | $X_{cl.gl.}$, %  |
| Dispersion of adequacy                  | $S_{ad}$                     | $N_{tot.}$, W    |
| Dispersion of reproducibility           | $S_{rep}$                    |                  |
| Fisher's criterion                      | $F$                          |                  |
| Critical value of Fisher's criterion, which is equal to the value of Fischer's division | $F_{a, f_1.f_2}$            |                  |

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: $a, \omega_{rot}, \tau, t_{gl}$.

![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) $N_{\text{tot.}} = f (a, \omega_{\text{rot}})$,
b) $N_{\text{tot.}} = f (a, \tau)$;
c) $N_{\text{tot.}} = f (a, t_{\text{gl}})$,
d) $N_{\text{tot.}} = f (\omega_{\text{rot}}, \tau)$

5. Conclusions

The constructed surfaces of responses of optimization criteria allow to illustrate visually dependences of values of mass fraction of glycerin $X_{c,gl}$ and the consumed energy $N_{\text{tot.}}$ 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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ВИБОР ФАКТОРІВ ВПЛИВУ НА ВИБРОЦЕНТРОБЕЖНЕ РОЗДІЛЕННЯ ЖИДКОГО НЕОДНОРДНОГО СЫРЬЯ

Розвиток сучасного обладнання та технологій призводить до здорової конкуренції, що в свою чергу, дает можливость вибирать машину чи установку для разделения жидких неоднородных систем. Каждое производство при выборе оборудования учитывает соответствующие факторы и свою специфику.

Для уточнення показателей качества гліцерина и определения их значимости использовали математико-статистическое планирование многофакторного эксперимента.

В статье построены поверхности отзывов критериев оптимизации, которые позволяют наглядно иллюстрировать зависимости значений массовой доли чистого гліцерина и потребляемой энергии от отдельных параметров оптимизации. Методика исследования включает в себя выбор оптимальных режимов работы вибросепараторных машин и очистки жидкого гліцеринового сырья по технико-экономическим критериям оценки и определения показателей качества очищенного гліцерина при варировании 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 вибросепараторной очистки сырового гліцерина оценивали по таким параметрам, как виброскорения, угловая скорость ротора, температура гліцерина, время обработки. Используя получено уравнение множественной регрессии 2-го порядка были определены рекомендации по основным параметрам рабочего режима исследуемого процесса.

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

**Ключеве слова:** сыров гліцерин, вибросепараторное разделения, жидкая неоднородная система, многофакторный эксперимент, параметры оптимизации.

**Ф. 9. Таб. 2. Рис. 2. Лит. 12.**
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 віброзвідцентрового очищення сирого глицерину оцінювала за такими параметрами, як віброрискорення, кутова швидкість ротора, температура глицерину, час обробки. Використовуючи отримане рівняння множинної регресії 2-го порядку від були визначені рекомендації стосовно основних параметрів робочого режиму досліджуваного процесу.

Проаналізувавши результати досліджень віброзвідцентрового розділення рідкої неоднорідної сировини можна стверджувати, що найбільш важливими факторами при розділенні даний продукції є частота обертання ротора, частота обертання валу віброзвбуджувача, амплітуда коливань, потужність, температура та час обробки.

Ключові слова: сирий глицерин, віброзвідцентрове розділення, рідка неоднорідна система, багатофакторний експеримент, параметри оптимізації.

Ф. 9. Таб. 2. Рис. 2. Літ. 12.