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When trenyy obrazuyutsya New uporyadochennыe structure with rehulyruemыm urovnem entropy. This effect can и быt yspolzovan for regulation friction characteristics of the contact. Yspolzuya Principles termodynamyky neravnovesnыh processes in systems otkrытыh proven something couple trenyya udovletvoryaet principles of self-organization.

Эnerhetycheskaya Theory trenyya, vtorychnыe structure, abrazyvnoe yznashyvanye, entropy.

At friction new ordered structures with adjustable level of entropy are formed. This effect can be used for regulation of frictional characteristics of contact. Using principles of thermodynamics of noneguilibrium processes in open systems it is proved, that friction pair satisfies to self-organising principies.

Energetics theory friction, secondary structure, abrasive wear, entropy.

UDC 631,371

Mathematical model HIDROREAKTYVNOYI blade mixers biodiesel production

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Improved mathematical model to determine the parameters hidroreaktyvnoyi blade mixers in the production of biodiesel.

Biodiesel, hidroreaktyvna blade mixer, viscous environment,

the angle of the blades, diameter nozzles.

Problem. In the production of biodiesel a key process steps are mixing vegetable oil and potassium methylate during esterification, which directly affects the quantity and quality biodiesel output. Mixing of the components required for biodiesel can be performed using hydrodynamic cavitation and mechanical stirrer hidroreaktyvnoyi. To ensure completeness passage esterification process should be used hidroreaktyvnu blade mixer that mixes the emulsion by hidroreaktyvnoho stream from nozzles located at the ends of the blades set at an angle. The issue of determining the parameters hidroreaktyvnoyi blade mixers in the performance of manufacturing operations will provide data to optimize equipment in esterification biodiesel.

Analysis of recent research. One of the important contributions to the theoretical study of biodiesel production did Dragnev SV [1], who developed a mathematical model of the process for the esterification of biodiesel production based on the theory of fuzzy sets and fuzzy logic.

Experimental production of biodiesel from the influence of structural and technological parameters on qualitative and quantitative yield biodiesel investigated rope MI [2] M. Mushtruk [3] S. Dragnev [4] and others.

Thus, the need for theoretical study design parameters of equipment for biodiesel production is quite relevant.

The purpose of research is to improve the mathematical model to determine the parameters hidroreaktyvnoyi blade mixers in the production of biodiesel.

Results. In the production of biodiesel using hidroreaktyvnoyi blade mixer impossible to achieve quality indicators biodiesel and minimum specific energy consumption without justification parameters.

The main parameters hidroreaktyvnoyi blade mixer is the speed of rotation, diameter nozzles and blades angle. The interaction of viscous medium blades can happen when braking point blades than reactive power. To prevent this, the supply of viscous fluid nozzles diameter and angle blades should be chosen so as to ensure mixing. To consider the interaction hidroreaktyvnoyi blades blade mixer with viscous medium (components for biodiesel) use the scheme, which is shown in Fig. 1.

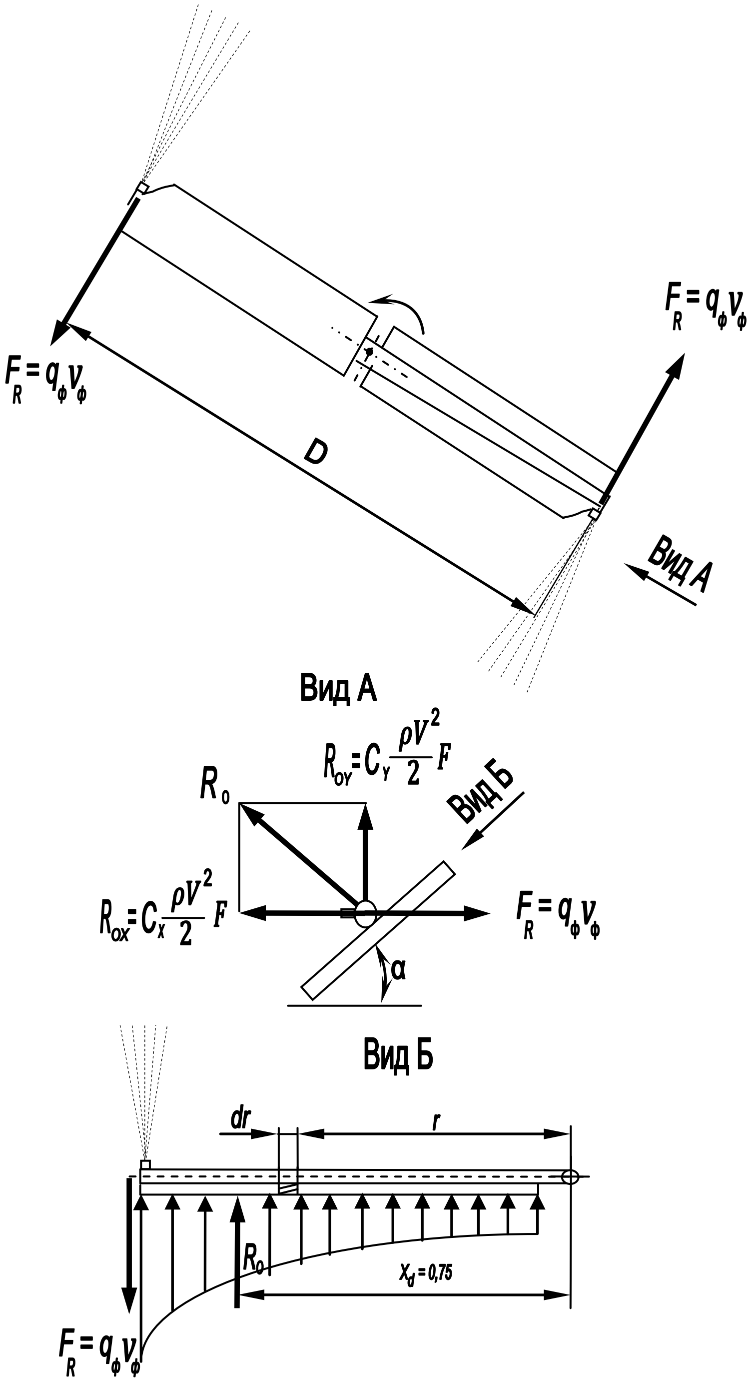

Fig. 1. Scheme of interaction blade blades hidroreaktyvnoyi **mixer with viscous medium.**

Shoulder hidroreaktyvnoyi blade mixers, generally set at an angle α to the direction of the blades. The movement of the blade is under the influence of reactive force jet ejected from nozzles mounted on the ends of the pipeline and are fed a mixture of oil with potassium methylate. Viscous environment (components for biodiesel) prevents movement of the blade that moves under the influence of reactive force jet. As you know, on the shoulder are normal components of the reaction medium viscous resistance. This horizontal component normal reaction medium viscous resistance movement opposing blade, and creates a vertical lift acting on the shoulder.

Reactive power jet that creates torque hidroreaktyvnoyi blade mixers define the second law of Isaac Newton, which he formulated in the following way (momentum of the body is Impulse) [5] at a constant speed jet flight:

$$dm_{\Phi} v_{\Phi} = F_R dt \text{ or } F_R = \frac{dm_{\Phi}}{dt} v_{\Phi}.$$

where dm_{Φ} – mass of fluid passing through the nozzle, kg; v_{Φ} – Departure speed jet through the nozzle, m / s; F_R – reactive power jet, N; dt – time for which is given through the nozzle fluid mass, c; q_{Φ} – mass flow rate of fluid through the nozzle, kg / s.

When applying viscous medium pump displacement mass flow rate remains unchanged, and the reactive force of the jet will be:

$$F_R = q_{\Phi} v_{\Phi}, \tag{1}$$

Usually designs hidroreaktyvnyh mixers involved several nozzles. In this case, the mass flow rate of fluid through the nozzle can be defined as follows:

$$q_{\Phi} = \frac{q_H n_H \rho}{60} 10^{-6}, \tag{2}$$

where q_H – feed pump (pump for stooge taken by specification) [6], cm3 / rev .; 10.6 m3 / cm3 - the number of cubic feet in a cubic centimeter; n_H – rotational speed of the pump, rev. / min .; 60 p / min. - The number of seconds in one minute; ρ – density of the liquid, kg / m3.

Departure speed jet through the nozzle can be defined as follows [7]:

$$v_{\Phi} = \frac{Q_H}{\mu S_{\Phi} n_{\Phi}} = \frac{q_H n_H}{60 \mu S_{\Phi} n_{\Phi}} 10^{-6}, \tag{3}$$

where Q_H – flow rate of fluid through the nozzle, m3 / s; μ – Reduction factor sectional area of the jet at the nozzle of leakage, relative. units. [8]; S_{Φ} – actual sectional area of the nozzle, m2; n_{Φ} – number of nozzles, pcs.

Thus, the total reactive power of the jets when applying viscous medium pump displacement will be:

$$F_R = \left(\frac{q_H n_H}{60} 10^{-6} \right)^2 \frac{\rho}{\mu S_{\Phi} n_{\Phi}}. \tag{4}$$

Newton in his work "Mathematical Principles of Natural Philosophy" theoretically calculated the force perpendicular to the plane of the plate, which acts on it in a fluid stream:

$$R = \rho v^2 A \sin^2 \alpha \,, \tag{5}$$

where $R -$ full aerodynamic force, N; $A -$ plate area, m2; $v -$ velocity of the fluid relative to the plate or vice versa, m / s; $\alpha -$ angle plate relative to the fluid velocity, deg.

Resultant force resistance (full aerodynamic force) can be decomposed into two components R_{OX} and R_{OY} Who are called to aerodynamics drag (force pressure) and a lifting capacity [9]:

$$R_{OX} = R\cos\alpha = \rho v^2 A \sin^2 \alpha \cos\alpha \,; \tag{6}$$

$$R_{OY} = R\sin\alpha = \rho v^2 A \sin^3 \alpha \,, \tag{7}$$

In aerodynamics, these forces recorded the coefficients in the following form [10]:

$$R_{OX} = C_X \frac{\rho v^2}{2} A \,; \tag{8}$$

$$R_{OY} = C_Y \frac{\rho v^2}{2} A \,, \tag{9}$$

where C_X, C_Y $-$ coefficients under the drag and lift blades, ratio. units.

Viscous environment (components for biodiesel) prevents movement of the blades, moving under the action of forces jet jets. When moving the blade in a real fluid, in addition to the pressure forces on the blades, which is perpendicular to the surface of the blade and applied pressure in the center, there will be friction and the resistance due to finite size blades, which are directed along the blade. To take account of these forces, and other unexplored factors have brought changes dimensionless coefficients of lift blades k_Y and drag k_X. Then the components of a complete aerodynamic forces can be written as follows:

$$R_{OX} = C_X k_X \frac{\rho v^2}{2} A \,; \tag{10}$$

$$R_{OY} = C_Y k_Y \frac{\rho v^2}{2} A \,, \tag{11}$$

Rewrite this equation, taking into account the rotational motion of blades:

$$R_{OX} = C_X k_X \frac{\rho \omega^2 r^2}{2} A \,; \tag{12}$$

$$R_{OY} = C_Y k_Y \frac{\rho\omega^2 r^2}{2} A\,, \tag{13}$$

where $\omega -$angular velocity of the blades, rad / s; $r -$distance from the center of rotation to the point of application of force, m.

Thus, the rotation of blades available a change in the drag and lift, depending on the radius of rotation of the blades. Define basic drag and lift force acting on the elementary area of the blade length dr Located at a distance r from the axis of rotation, considering the size of the blade according Fig. 2 and at a constant speed of rotation:

$$dR_{OX} = C_X k_X \frac{\rho\omega^2 r^2}{2} hdr\,; \tag{14}$$

$$dR_{OY} = C_Y k_Y \frac{\rho\omega^2 r^2}{2} hdr\,, \tag{15}$$

where $h -$width blades, m, and elemental resistance moment dM_R That creates an elementary force drag acting on the elementary area of the blade length dr Located at a distance r from the axis of rotation:

$$dM_R = dR_{OX} r = C_X k_X \frac{\rho\omega^2 r^3}{2} hdr\,. \tag{16}$$

Integrating basic expressions for the drag force and moment elemental resistance, due to the elemental forces of drag, we obtain the values of the drag and moment resistance depending radius of rotation of the blade:

$$R_{OX} = C_X k_X \frac{\rho\omega^2}{2} h\int r^2 dr\,; \tag{17}$$

$$M_R = C_X k_X \frac{\rho\omega^2}{2} h\int r^3 dr\,, \tag{18}$$

or

$$R_{OX} = C_X k_X \frac{\rho\omega^2}{6} hr_{\max}^3\,; \tag{19}$$

$$M_R = C_X k_X \frac{\rho\omega^2}{8} hr_{\max}^4\,, \tag{20}$$

where $r_{\max} -$maximum radius of the blade, m.

The design hidroreaktyvnoyi blade mixers should be made so that the blades create lift directed upwards, thus compensating for the weight of the mixer and providing a reduction or elimination of load on bearings. We use the equations for dynamic modeling hidroreaktyvnoyi blade mixers, which will have the following form:

$$J\frac{d\omega}{dt}=\left(\frac{q_H n_H}{60}10^{-6}\right)^2\frac{\rho}{\mu S_{\Phi} n_{\Phi}}\sum_{i=1}^{n} r_{\Phi i}-C_X k_X\frac{\rho\omega^2}{8}h\sum_{i=1}^{n} r_{\max i}^4 \quad (21)$$

where $r_{\Phi i}$ – radius install the i-th nozzle, m; n – number of nozzles, pcs .; $r_{\max i}$ – maximum radius of the i-th blade, m,
or

$$J\frac{d\omega}{dt}=\beta-\gamma\omega^2, \quad (22)$$

where J – moment of inertia hidroreaktyvnoyi blade mixers, kg m2; dt – time change after the mixing pump, c; $\beta=\left(\frac{q_H n_H}{60}10^{-6}\right)^2\frac{\rho}{\mu S_{\Phi} n_{\Phi}}\sum_{i=1}^{n} r_{\Phi i}$ – torque due to reactive power current when applying viscous medium pump displacement, which depends on the flow and rotational speed of the pump, fluid density, the number of nozzles and nozzle-sectional area and the conditions thereof leakage of fluid, NM; $\gamma=C_X k_X\frac{\rho}{8}h\sum_{i=1}^{n} r_{\max i}^4$ – moment of resistance when working hidroreaktyvnoyi blade mixers, kg m2.

Rewrite the differential equation as follows:

$$\frac{d\omega}{dt}=\frac{\beta}{J}-\frac{\gamma}{J}\omega^2,$$

or

$$\frac{d\omega}{\frac{\beta}{J}-\frac{\gamma}{J}\omega^2}=dt. \quad (23)$$

Marking $\frac{\beta}{J}=a$ and $\frac{\gamma}{J}=b$ We obtain

$$\frac{d\omega}{a-b\omega^2}=dt.$$

The general solution of the differential equation we find in the following form [11]:

$$\frac{1}{2\sqrt{ab}}\ln\frac{\sqrt{a}+\sqrt{b}\omega}{\sqrt{a}-\sqrt{b}\omega}=t. \quad (24)$$

Partial find solutions based on the initial conditions: at $t=0$ angular velocity hidroreaktyvnoyi blade mixer is the initial angular velocity, ie $\omega=\omega_{\Pi}$:

$$\frac{1}{2\sqrt{ab}}\left(\ln\frac{\sqrt{a}+\sqrt{b}\omega}{\sqrt{a}-\sqrt{b}\omega}-\ln\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\right)=t; \qquad (25)$$

$$\ln\frac{\sqrt{a}+\sqrt{b}\omega}{\sqrt{a}-\sqrt{b}\omega}-\ln\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}=2t\sqrt{ab};$$

$$\ln\frac{\left(\sqrt{a}+\sqrt{b}\omega\right)\left(\sqrt{a}-\sqrt{b}\omega_{П}\right)}{\left(\sqrt{a}-\sqrt{b}\omega\right)\left(\sqrt{a}+\sqrt{b}\omega_{П}\right)}=2t\sqrt{ab};$$

$$\frac{\left(\sqrt{a}+\sqrt{b}\omega\right)\left(\sqrt{a}-\sqrt{b}\omega_{П}\right)}{\left(\sqrt{a}-\sqrt{b}\omega\right)\left(\sqrt{a}+\sqrt{b}\omega_{П}\right)}=\exp\left(2t\sqrt{ab}\right);$$

$$\frac{\sqrt{a}+\sqrt{b}\omega}{\sqrt{a}-\sqrt{b}\omega}=\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right);$$

$$\sqrt{a}+\sqrt{b}\omega=\sqrt{a}\,\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right)-$$

$$-\sqrt{b}\omega\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right)$$

$$\sqrt{b}\omega+\sqrt{b}\omega\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right)=$$

$$=\sqrt{a}\,\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right)-\sqrt{a}$$

$$\omega\sqrt{b}\left[1+\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right)\right]=$$

$$=\sqrt{a}\left[\frac{\sqrt{a}+\sqrt{b}\omega_{П}}{\sqrt{a}-\sqrt{b}\omega_{П}}\exp\left(2t\sqrt{ab}\right)-1\right]$$

So finally we get the expression for determining the dynamics of the angular velocity hidroreaktyvnoyi blade mixer, which is as follows:

$$\omega = \sqrt{\frac{a}{b}} \frac{\left[\frac{\sqrt{a} + \sqrt{b}\omega_П}{\sqrt{a} - \sqrt{b}\omega_П} \exp\left(2t\sqrt{ab}\right) - 1 \right]}{\left[1 + \frac{\sqrt{a} + \sqrt{b}\omega_П}{\sqrt{a} - \sqrt{b}\omega_П} \exp\left(2t\sqrt{ab}\right) \right]}. \quad (26)$$

In steady rotation hidroreaktyvnoyi blade mixer, its angular velocity is:

$$\omega_У = \sqrt{\frac{a}{b}}. \quad (27)$$

Fig. 2 shows the acceleration curves hidroreaktyvnoyi blade mixers, depending on the speed of the pump installation at an angle of blades 60°.

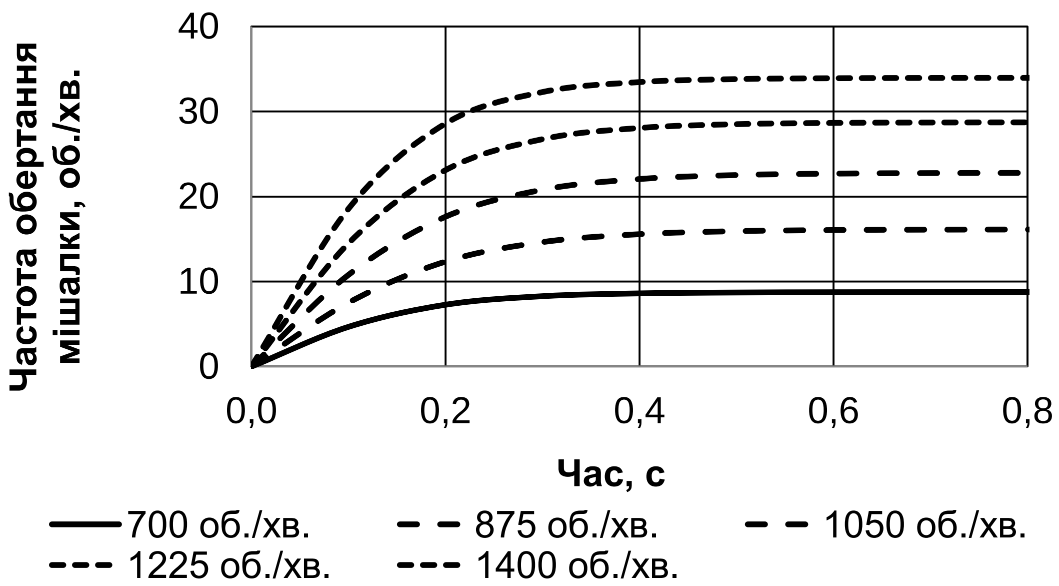

Fig. 2. Curves acceleration hidroreaktyvnoyi blade mixers, depending on the speed of the pump installation at an angle of blades 60°.

From the graph shows that increasing the rotational speed of the pump has virtually no effect on the rate of acceleration and achieve the established rotation frequency hidroreaktyvnoyi blade mixers. For example, the speed of rotation of the pump 700 rev. / Min., Established rotational speed hidroreaktyvnoyi blade mixer is about 8.76. / Min., And at speed pump 1400 rev. / Min. - 34 rev. / Min.

Fig. 3 shows the dependence of the established rotation frequency hidroreaktyvnoyi blade mixers, depending on the speed of the pump at an angle settings blades 600. From graph shows that increasing the rotational speed of the pump leads to an increase in the frequency of rotation established hidroreaktyvnoyi blade mixers. For example, the speed of rotation of the pump 700 rev. / Min., The values established hidroreaktyvnoyi blade rotation frequency mixer is about 8.76. / Min., And at speed pump 1400 rev. / Min. - 34 rev. / Min .

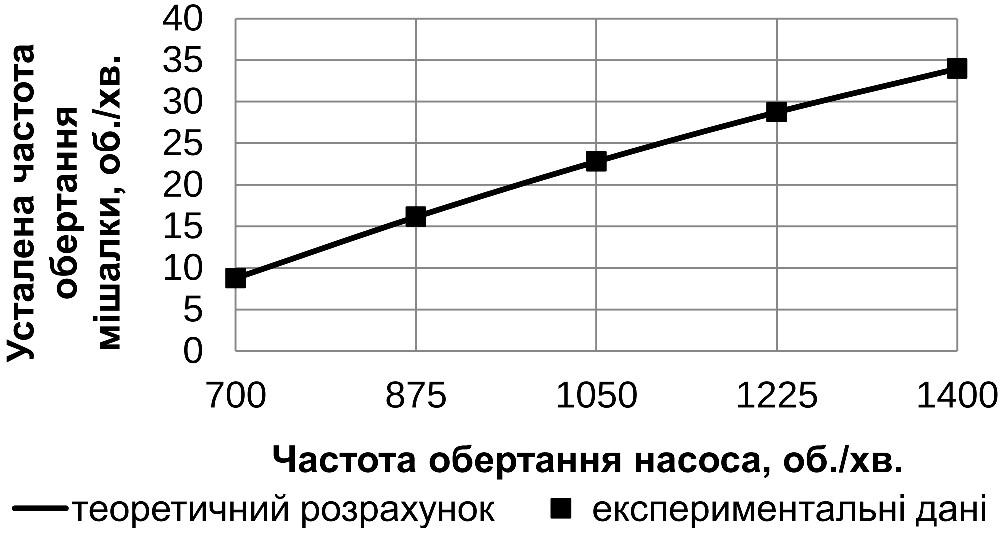

Fig. 3. Dependence of the established rotation frequency hidroreaktyvnoyi blade mixers, depending on the speed of the pump installation at an angle of blades 60°.

Fig. 4 shows the dependence of the established rotation frequency hidroreaktyvnoyi blade mixers, depending on the angle of installation of blades at speed pump 1050 rev. / Min.

From the graph shows that increasing the angle of installation of blades leads to a decrease in the frequency of rotation established hidroreaktyvnoyi blade mixers. For example, at an angle of installation of blades 30°, Established the theoretical value of rotational speed hidroreaktyvnoyi blade mixer is about 26.76. / Min., Experimental - 27.63 rev. / Min., And at an angle of installation of blades 90° - 21.02 rev. / Min. and 21.58 vol. / min., respectively. Mean deviation from experimental theoretical values less than 2%.

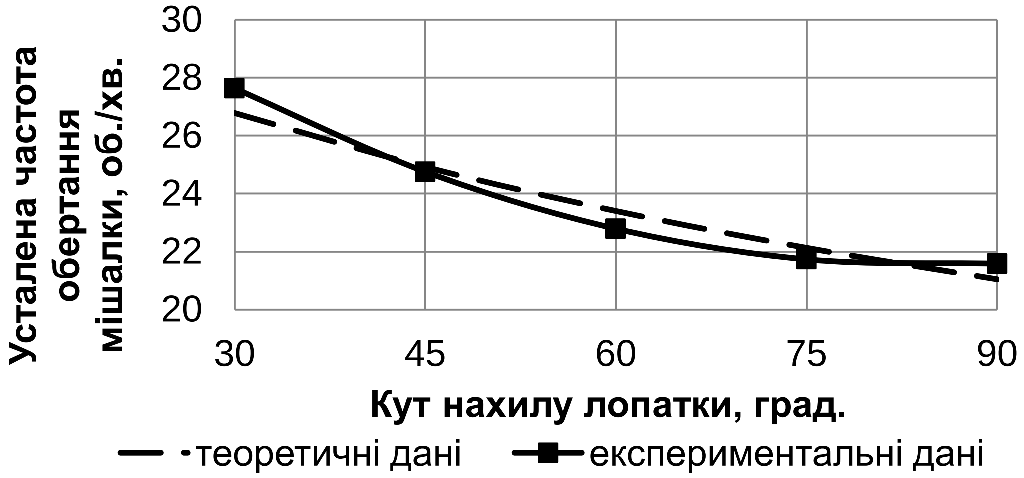

Fig. 4. Dependence of the established rotation frequency hidroreaktyvnoyi blade mixers depending on the angle of installation of blades at speed pump 1050 rev. / Min.

The power required for supplying fluid to hidroreaktyvnu blade mixer that will ensure its work is determined by the known expression:

$$N_М = \frac{q_Н n_Н}{60\eta_Н} 10^{-6} H_Н, \tag{28}$$

where $N_М$ – pump power, W; η_H - Efficiency pump, ratio. ed .; HH - pump pressure generated, Pa.

Power consumption of the pump drive motor with the power grid will be:

$$N_{ЕЛ} = \frac{N_М}{\eta_{ЕД} \cos\varphi} k_{ЗЕД} = \frac{q_Н n_Н 10^{-6}}{60\eta_Н \eta_{ЕД} \cos\varphi} H_Н k_{ЗЕД}, \tag{29}$$

where $N_{ЕЛ}$ – power consumed by the drive motor of the electric network, W; η_{ED} - Efficiency motor, ratio. ed .; cosφ - The proportion of active power at full capacity motor, ratio. ed .; $k_{ЗЕД}$ - The safety factor of the electric power, ratio. units.

The specific energy consumption for production of biodiesel will be:

$$E = \frac{N_{ЕЛ}}{Q} = \frac{q_Н n_Н 10^{-9}}{60Q\eta_Н \eta_{ЕД} \cos\varphi} H_Н k_{ЗЕД}, \tag{30}$$

where E – Sectionytomi energy consumption for the production of biodiesel, kWh. / m3; Q – performance mixing process, m3 / h.

Conclusion. Advanced mathematical model to determine the parameters hidroreaktyvnoyi blade mixers in the production of biodiesel allows you to calculate the dynamics of dispersal and

established to determine the frequency of rotation depending on the speed and angle of inclination of the pump blades.

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Usovershenstvovano matematycheskuyu model for determining parameters for hydroreaktyvnoy lopastnoy mixer with diesel production byotoplyva.

Diesel byotoplyvo, hydroreaktyvnaya lopastnaya mixer, vyazkaya Wednesday, ugol naklona blades, diameter nozzles.

Mathematical model for determining the parameters of hydro jet paddle mixer in production of biodiesel is improved.

Biodiesel, hydro jet impeller, viscous medium, blade angle, diameter nozzles.