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Development Of Dynamic Mathematical Model Of Process Of Cottonseed Oil Evaporation

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Abstract: *The article covers the tasks of creation of mathematical model of the process of cottonseed oil evaporation based on equation of heat exchange process. Taking into consideration the peculiarities of evaporation of cottonseed oil, as well as assumptions characteristic of the object under consideration, a mathematical model was obtained in the form of system of differential equations, showing the dependence of temperature change on change in the consumption of direct water vapor. Based on this expression, a computer model has been developed in order to check the adequacy of the model to the real process.*

Keywords: *Deodorization process, high heat treatment, highly volatile components, cottonseed oil, heat exchanger, live steam, model, MATLAB / Simulink.*

Introduction. Cottonseed oil is one of the most widespread food products of the population. Cottonseed oil is widely used in the food industry. As a result, cotton oils are unstable in storage and high heat treatment, leading to a deterioration in their quality, a decrease in nutritional value and even their unsuitability for human consumption.

Cottonseed oil contains not only useful substances, but also such substances that worsening the quality of the oil, at the same time have a purely negative effect on the human body. Cottonseed oil is a chemically pure substance; it is a mixture of organic substances of various composition. These substances may include: compounds of toxic nature (polycyclic aromatic hydrocarbons, pesticides and other toxic chemicals), components of the lipid complex (gossypol and its derivatives, free fatty acids, some odor substances), as well as compounds arising from technological exposure or adverse storage conditions (products of hydrolysis and oxidation of triglycerides). One of the ways to remove them is neutralization of harmful impurities by deodorizing cottonseed oil [1]

Method of solution. The deodorization process is one of the methods of distillation of liquids with counter movement of phases. The deodorization process consists of three stages: diffusion of highly volatile components from the liquid volume to the evaporation surface; evaporation of highly volatile components; removal of evaporated volatile components from the evaporation zone.

The vapor tension of highly volatile substances increases by increasing the temperature of cottonseed oil, which specify their more volatility. However, excessive increase in the temperature of the deodorization process is also inappropriate, since there is a danger of polymerization and oxidation of cottonseed oil by air. At oil temperatures above 250^0C, its thermal decomposition intensifies and losses increase because of distillation of low molecular weight triglycerides. Therefore, to conduct the deodorization process, i.e. distillation of highly volatile substances, the effect of creating a vacuum in the apparatus is used when hot water vapor is fed into the volume of cottonseed oil in order to reduce the temperature. [3]

To carry out the deodorization process, i.e., with the interaction of counter liquid and gas phases, the amount of supplied direct water steam and the duration of deodorization are important. The above parameters also depend, in turn, on the initial concentration of volatile components, the total pressure in the apparatus and the amount of deodorized oil. The supplied hot water steam helps to reduce the partial pressure of highly volatile components, thereby reducing the temperature of the deodorization process. Direct steam supplied from the bottom of the apparatus is in contact with a counter-moving liquid-oil. After ingression into the oil in the form of small bubbles, it forms a vapor-fat mixture with a large surface of contact between vapor bubbles and oil. In this case, the deodorization process is accelerated due to the diffusion of highly volatile components of the oil to the surface of the drop and mixing it with water steam.

The following assumptions were taken into account when constructing a dynamic mathematical model (MM) of the heat exchange process in the evaporation of cotton oil:

- there is no longitudinal mixing in each of the coolant streams, i.e., the physical media in the apparatus move in the ideal displacement mode;

- transverse mixing in coolant flows is considered as ideal.

- thermal resistance of the evaporator walls is relatively small. The fulfillment of this condition means that the temperature of the wall separating the heat transfer fluids is constant over the wall thickness.

Taking these assumptions into account, a model of the process was compiled in the form of a system of first-order differential equations, taking into account the design of the evaporation device:

$$\begin{aligned} \frac{\partial \theta_{ДГ}}{\partial t} &= \upsilon_{ДГ} \frac{\partial \theta_{ДГ}}{\partial x} - R_{ДГ}(\theta_{ДГ} - \theta_{СТ}); \\ \frac{\partial \theta_{Ж}}{\partial t} &= \upsilon_{Ж} \frac{\partial \theta_{Ж}}{\partial x} + R_{Ж}(\theta_{СТ} - \theta_{Ж}); \\ \frac{\partial \theta_{СТ}}{\partial t} &= R_{ДГСТ}(\theta_{ДГ} - \theta_{СТ}) - R_{ЖСТ}(\theta_{СТ} - \theta_{Ж}), \end{aligned} \quad (1)$$

where $\theta_{ДГ}$, $\theta_{Ж}$, $\theta_{СТ}$ - liquid phase and wall temperatures; $\upsilon_{ДГ}$, $\upsilon_{Ж}$,- speed of liquid phase; $R_{ДГ}, R_{Ж}, R_{ДГСТ}, R_{ЖСТ}$ — physical-technological coefficients depending on the physical properties of the liquid.

Initial temperature distributions of heat-transfer agents:

$$\theta_{ДГ0}(x) = \theta_{ДГ}(x,t)\big|_{t=0}, \theta_{Ж0}(x) = \theta_{Ж}(x,t)\big|_{t=0};$$

Boundary conditions:

$$\theta_{ДГ}(x)\big|_{x=t} = \theta_{ДГ}^{BX}(t), \theta_{Ж}(x)\big|_{x=0} = \theta_{Ж}^{BX}(t).$$

The disturbances for the evaporation process are:

- change in consumption of initial mixture;
- change in composition of initial mixture, since the boiling temperature of liquid uniquely depends on the concentration of liquid at constant pressure. [5]

To reach the set temperature, it is necessary to regulate the temperature of the supplied heating agent. The temperature of the heating agent can be regulated by changing the ratio of the air and fuel gas flow rates in the evaporator burner.

Let us compose a mathematical description of evaporation device in which cottonseed oil is heated by steam (steam consumption F_n^m) to temperature $T_n^0 C$. The output highlighted is the temperature change at the top of the evaporator, and the input is the change of steam consumption.

When deriving the equation for the dynamics of the evaporator unit, we take the following assumptions: the evaporator unit has lumped parameters, i.e, the oil temperature in the evaporator unit $T_ж$ is constant at all points in the volume; the temperature of heat transfer walls $T_{ст}$ is the same at all points; their thermal resistance is negligible; the heat transfer coefficient a, a, J/(m^2-s-deg) between the liquid and the surface of the metal walls, as well as the specific heat capacities of the liquid $c_ж$ and the material of the walls $c_{ст}$, are constant over time.

Taking into account the assumptions made, the heat balance equation for the heat transfer walls of the heat exchanger in time dt:

$$F_{П} r dt = \mathrm{W}_{\mathrm{CT}} C_{CT} dT_{CT} + \alpha A(T_{CT} - T_{Ж})dt; \quad (2)$$

where r — phase transition heat, J/kg; $W_{ст}$ — mass of heat transfer walls, kg; A — total wall surface, m^2.

The heat supplied to the heat exchanger by water vapor is spent to increase the temperature of the oil $dT_ж$, which is in the apparatus and leaving it during the same period of time. Then the heat balance equation for oil:

$$F_{ж} c_{ж} T_{ж}' dt + \alpha A(T_{CT} - T_{ж}) = F_{ж} c_{ж} T_{ж} dt; \quad (3)$$

where $W_{ж}$ — mass of liquid in the heat exchanger, kg.

Let us rewrite equations (2) and (3) in the following form:

$$\mathrm{W}_{\mathrm{CT}} C_{CT} \frac{dT_{CT}}{dt} + \alpha A T_{CT} = F_{П} r + \alpha A T_{ж}; \quad (4)$$

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$$C_{ж}\frac{dT_{ж}}{dt}+\left(F_{ж}c_{ж}+\alpha A\right)T_{ж}=F_{ж}c_{ж}T_{ж}'+\alpha AT_{CT}; \qquad (5)$$

Replacing the variables in equations (4) and (5) by their finite increments, referred to the basic values of the variables ($T_{CT_0}, F_{n0}, T_{ж0}, F_{ж0}$ и $T'_{ж0}$), and introducing the notations

$$y=\frac{\Delta T_{Ж}}{T_{Ж0}}; \qquad y_{CT}=\frac{\Delta T_{CT}}{T_{CT0}}; \qquad x=\frac{\Delta F_{П}}{F_{П0}};$$

$$x_1=\frac{\Delta F_{Ж}}{F_{Ж0}}; \qquad z=\frac{\Delta T_{Ж}''}{T'_{Ж0}};$$

we obtain

$$W_{CT}C_{CT}T_{CT0}\frac{dy_{CT}}{dt}+\alpha AT_{CT0}y_{CT}=F_{П0}rx+\alpha AT_{ж0}y; \qquad (6)$$

$$\begin{gathered}C_{Ж}T_{Ж0}\frac{dy}{dt}+\left(F_{Ж0}c_{Ж}+\alpha A\right)T_{Ж0}y= \\ -F_{Ж0}c_{Ж}\left(T_{Ж0}-T'_{Ж0}\right)x_1+F_{Ж0}c_{Ж}T'_{Ж0}z+\alpha AT_{CT0}y_{CT};\end{gathered} \qquad (7)$$

or

$$T^*\frac{dy_{CT}}{dt}+y_{CT}=k_3x+k_5y; \qquad (8)$$

$$T^{**}\frac{dy}{dt}+y=-k_1x_1+k_2z+k_4y_{CT}; \qquad (9)$$

where

$$T\frac{W_{CT}c_{CT}}{\alpha A}; \qquad T\frac{c_{Ж}}{F_{Ж0}c_{Ж}+\alpha A};$$

$$k_1=\frac{F_{Ж0}c_{Ж}\left(T_{Ж0}-T'_{Ж0}\right)}{\left(F_{Ж0}c_{Ж}+\alpha A\right)T_{Ж0}}; \qquad k_2=\frac{F_{Ж0}c_{Ж}T'_{Ж0}}{\left(F_{Ж0}c_{Ж}+\alpha A\right)T_{Ж0}};$$

$$k_3=\frac{F_{П0}r}{\alpha A_{CT0}}; \qquad k_4=\frac{\alpha AT_{CT0}}{\left(F_{Ж0}c_{Ж}+\alpha A\right)T_{Ж0}}; \qquad k_5=\frac{T_{Ж0}}{T_{CT0}};$$

Moreover, the coefficients *k1, k2, k3, k4* and k_5 are less than one. To exclude the variable $y_{ст}$ from equations (8) and (9), we differentiate the second one in time and express the derivative dy_{CT}/dt, and also the variable $y_{ст}$ from equation (9). The obtained expressions for для y_{CT} and dy_{CT}/dt are substituted into equation (8). Dividing all the terms of the resulting equation by the coefficient at *y*, equal to $F_{Ж0}c_{Ж}T_{Ж0}/\left(\alpha AT_{CT0}\right)$, and taking into account the equality

$$F_{ПO}r=\alpha A\left(T_{CT0}-T_{Ж0}\right)=F_{Ж0}c_{Ж}\left(T_{Ж0}-T'_{Ж0}\right);$$

we obtain the required equation for the dynamics of the heat exchanger

$$T_1^2\frac{d^2y}{dt^2}+T_2\frac{dy}{dt}+y=kx-k\left(T_3\frac{dx_1}{dt}+x_1\right)+(1-k)\left(T_3\frac{dz}{dt}+z\right); \qquad (10)$$

where

$$T_3=\frac{W_{CT}c_{CT}}{\alpha A}; \qquad k=\frac{(T_{Ж0}-T'_{Ж0})}{T_{Ж0}};$$

Considered heat exchanger is a stable object of the 2nd order. Equation (10) confirms that an increase in the vapor consumption *x* and liquid temperature at the inlet *z* will lead to an increase in its temperature at the outlet *y*, and an increase in the liquid consumption x_1 will lead to a decrease in the value of *y*.

Let us give the transfer functions of the heat exchanger without derivation: along the *x*-*y* channel

$$W_{x(p)}=\frac{k}{T_1^2p^2+T_2p+1}; \qquad (11)$$

По каналу x_1-y

$$W_{x_1(p)}=\frac{k(T_3p+1)}{T_1^2p^2+T_2p+1}; \qquad (12)$$

Along the $z-y$ channel

$$W_{x(p)}=\frac{k}{T_1^2p^2+T_2p+1};$$

The output value of heat exchanger in operator form $Y(p)$ can be determined from the dependence

$$Y(p)=W_x(p)X(p)+W_{x1}(p)X_1(p)+W_z(p)z(p); \qquad (13)$$

where $X(p)$, $X_1(p)$ and $Z(p)$ are operator forms of notation of quantities x x_1 и z.

Result of solution. Based on the obtained ratios, we make a computational diagram of evaporation process (Fig. 1). The result of process modeling (Figure 2) in the MATLAB/Simulink software environment showed the adequacy of developed model to experimental data obtained from real object. [4]

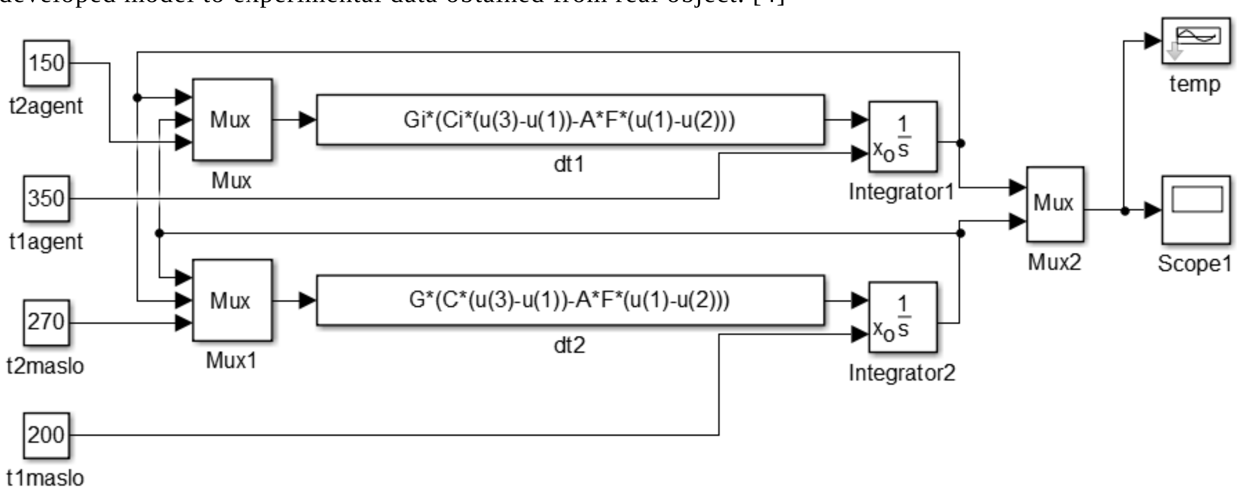

Fig. 2 Computer model of process of evaporation of cottonseed oil.

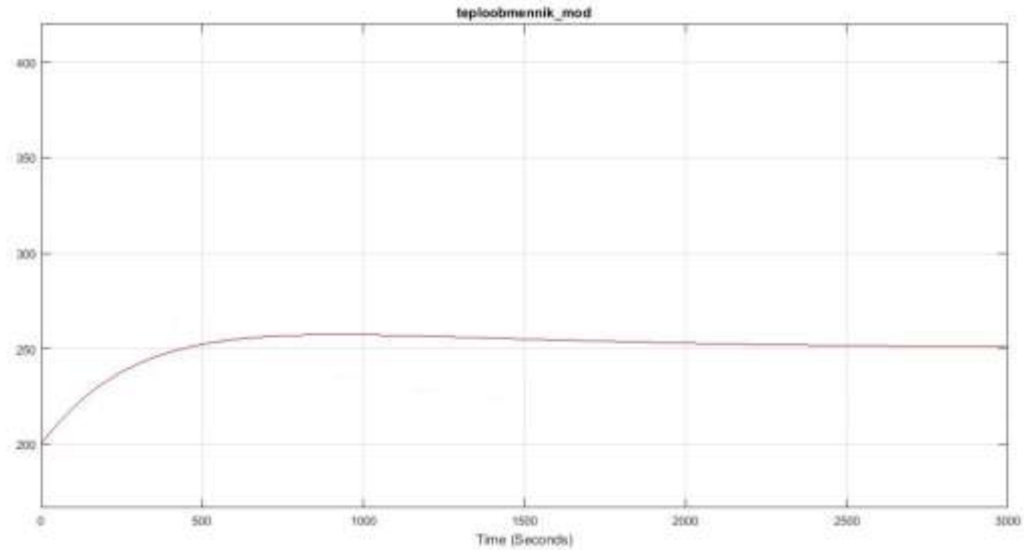

Fig. 3 Graph of transient in process of oil temperature change.

Conclusions. Creation of a mathematical model of the process of evaporation of cottonseed oil based on the equation of the heat exchange process is described in the work, when constructing dynamic mathematical model of heat exchange process in evaporation of cottonseed oil, the features were taken into account, as well as assumptions characteristic of the object under consideration, mathematical model was obtained in the form of system of differential equation showing the dependence of change of temperature of the change in consumption of direct water steam, the transfer functions of heat exchanger are given. Based on this expression, a computer model has been developed in order to check the adequacy of model to the real process. The results of modeling the process in MATLAB/Simulink software environment show that the developed model is adequate to the experimental data obtained from the real object.

References.

1. R.R. Safin, R.G. Safin, N.R. Galyavedinov, R.M. Imanaev. Research of combined drying-impregnation of massive capillary-porous colloidal materials // Bulletin of Kazan technological university. 2006. No.6, p. 78-85
2. Norenkova I.P. Systems of computer-aided design: Tutorial for technical higher educational institutions: In 9 vol. / Edited by I.P. Norenkov - M.: Higher school, 2010.
3. V.N. Volkova, V.N. Kozlov. System analysis and decision-making. Tutorial for higher educational institutions. M.: Higher school, 2004, p. 616.
4. Siddikov I.Kh., Fayziev Sh.I., Ismoyilov Kh.B., Uvayzov S.K. Synthesis of the neuro-fuzzy adaptive control system of a dynamic object// The Journal of Test Engineering and Management. Volume 83. pp. 11236-11246
5. Introduction to Intelligent Robotics / Herman Bruyninckx and Joris De Schutter - Katholieke Universiteit Leuven.
6. Rotach, V.Ya. Teoriya avtomaticheskogo upravleniya [Automatic control theory] / V.Ya. Rotach Moscow, 2008.
7. A.Yu. Nechetkoe modelirovanie v srede Matlab i fuzzyTech [Fuzzy modeling in Matlab and fuzzyTech environment] / A.Yu. Leonenkov. St. Petersburg, 2003.
8. Gostev, V.I. Nechetkie regulyatory v sistemakh avtomaticheskogo upravleniya [Fuzzy controllers in automatic control systems] / V.I. Gostev. Kyiv, 2008.