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MODELING OF PRIMARY DISTILLATION PROCESS OF VEGETABLE OIL MICCELLA

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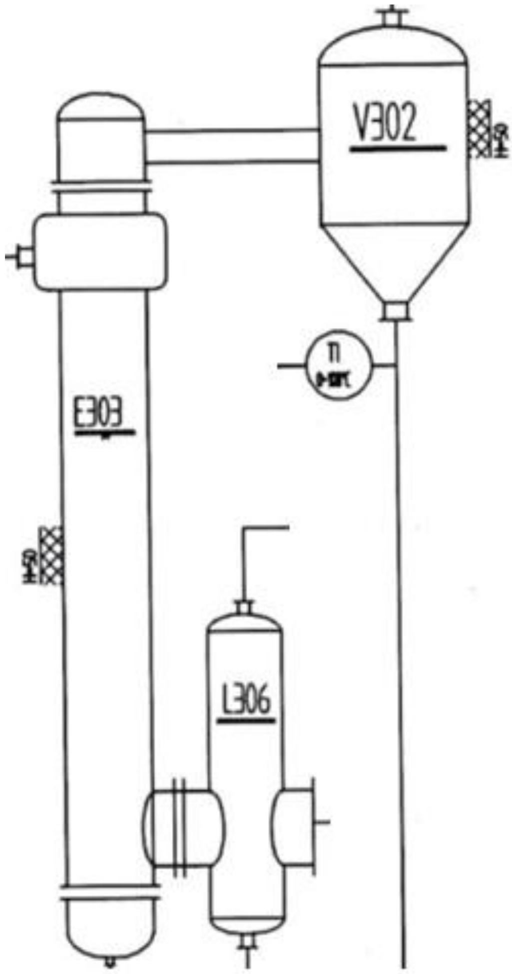
Abstract: This article describes the behavior of the water vapor-liquid system and the basics of building a mathematical model of the process during the initial distillation of cottonseed oil miccella. By building a mathematical model of the process, the selection of optimal process parameters and the acceleration of the heat exchange process in the water-vapor-liquid system were studied. Automation of the distillation process ensures control of the water vapor-finished product concentration. Coupling the studied process through mathematical expressions helps in more precise analysis of the cottonseed oil miccella distillation process. Based on the main goal of the research work, mathematical modeling of the final miccella distillation process and optimization of technological schemes, developed models and algorithms for their solution are designed to perform the functions of calculating individual elements of the scheme and therefore its components are a general algorithm for synthesizing an effective technological scheme for the separation of target products. The division of a complex system into separate functional subsystems allows for the most rational detailed study of the technological process and the most effective identification of the object based on a complete mathematical description of the object, obtaining a reliable, realistic idea. Methods of carrying out the process in stable and unstable conditions help to solve optimization issues at the level of technological complexes as modes of its occurrence and chemical-technological systems.

Keywords: final distillation, sub-vapor, condensation, first distiller, three-stage distillation, liquid flow, vapor flow, heating chamber, automation, actuator, adjusting body, condensate film, wall, film thickness, vapor-liquid phase, mathematical modeling, equation.

Introduction. MEZ, ND-1250, as well as modern Chinese extraction line distillers are widely used in oil extraction enterprises, where the solvent is completely expelled from the miccella during the final distillation. This process also occurs in the form of boiling and evaporation. In the primary distillation, the solvent is distilled using closed water vapor at atmospheric pressure, and in the final distillation, the solvent is distilled using open water vapor under vacuum. Miccella is processed at low temperatures in order to maintain the quality indicators of the oil.

The primary distillers of vegetable oil mistella are distinguished by their characteristics in terms of automation. Usually the concentration of the solution leaving the final stills is controlled by the open water vapor supply and the vacuum value. From this point of view, the final distiller along the "water vapor - concentration of the finished product" channel can be divided into the following parts: the adjusting body of the executive mechanism, the heating chamber, the vapor space, the condenser space, the heating wall of the device, the surface covered with the vapor-liquid layer.



In the adjusting body installed in the control object, the fluid flow entering the device as a hydrodynamic capacity through the movement of the valve is changed by the throttled flow field. This is where steam accumulates and condensation occurs. Thus, it is possible to divide into two elementary processes in the vapor space:

1) the process of changing the vapor pressure in the vapor space, which leads to a change in the condensation temperature of the saturated vapor;

2) steam condensation process on the vertical wall.

The process of steam condensation on a vertical wall is a complex phenomenon. An increase in pressure increases the condensation temperature of steam. As a result, the driving force of the process - the temperature difference between the condensate and the wall - should increase. This increases heat transfer.

On the other hand, an increase in the transferred heat leads to an increase in the amount of condensate, which occurs with an increase in the thickness of the condensate film. This reduces the coefficient of heat transfer from the heating steam to the wall.

Thus, under static conditions, condensate is a heat-conducting film of liquid. It is necessary to take into account certain effects of changes in the film thickness in the dynamics. The wall absorbs heat from condensation causing soot to form. In the vapor-liquid phase, liquid heating and evaporation processes occur. The approach chosen in the research work allows to carry out a more cost-effective calculation of the miccella distillation process, as well as to study its behavior as part of the technological installation of a vegetable oil production complex in its topology, technological operations such as vegetable oil production, miccella distillation and processing of various oils. This means that it will be possible to effectively connect the studied process with the general task of studying technological complexes, that is, it will provide a more reasonable strategy for analysis and synthesis.

The expression of the constriction device can be obtained in two ways depending on the ratio of the pressure of the heating steam in the heating chamber and the steam line $\mathrm{P}_{л}$.

$$\frac{\mathrm{P}_{ик}}{\mathrm{P}_{л}} > 0.53 \ldots \tag{1}$$

Assuming that the liquid flow moves in a turbulent mode, the steam consumption passing through the valve can be expressed as follows:

$$D_p = K\sqrt{(\mathrm{P}_l - \mathrm{P}_{ик})\rho_{б}} \tag{2}$$

in this K - coefficient describing the degree of valve opening; P_l - steam line pressure; Н/м; $\mathrm{P}_{ик}$ - heating chamber pressure, Н/м; $\rho_{б}$- density, кг/м³.

P_{gk} in points with increasing value

$$\frac{\mathrm{P}_{ик}}{\mathrm{P}_{л}} \leq 0.53 \ldots \tag{3}$$

D_n- steam consumption is reduced, it does not depend on the pressure in the heating chamber, $\mathrm{P}_{гк}$ and is defined as follows:

$$D_l = 0.85K\mathrm{P}_l \tag{4}$$

It is recommended to work in the second mode to eliminate the effect of the pressure in the heating chamber on the steam flow.

The mathematical description of the dynamics of the adjusting mechanism of the executive mechanism can be expressed by the first-order periodic link model:

$$\frac{dP}{d\tau} = \frac{D_p}{\rho V_p}(\mathrm{P}_l - \mathrm{P}_{im}) \tag{5}$$

In this: P_{im} - pressure after the executive mechanism, V_p- volume of steam, D_p - steam consumption.

A heating chamber with a hydrodynamic capacity is characterized by the pressure of the heating steam in it. The pressure is usually the same value throughout the volume. Therefore, the complete mixing model can be used in the mathematical representation of the pressure change channel. In this

$$\frac{dP}{d\tau} = \frac{1}{\tau_{g.k}}(P_l - P_{g.k}) \tag{6}$$

When analyzing the processes taking place in the heating chamber, it is possible to work with the average consumption of heating steam.

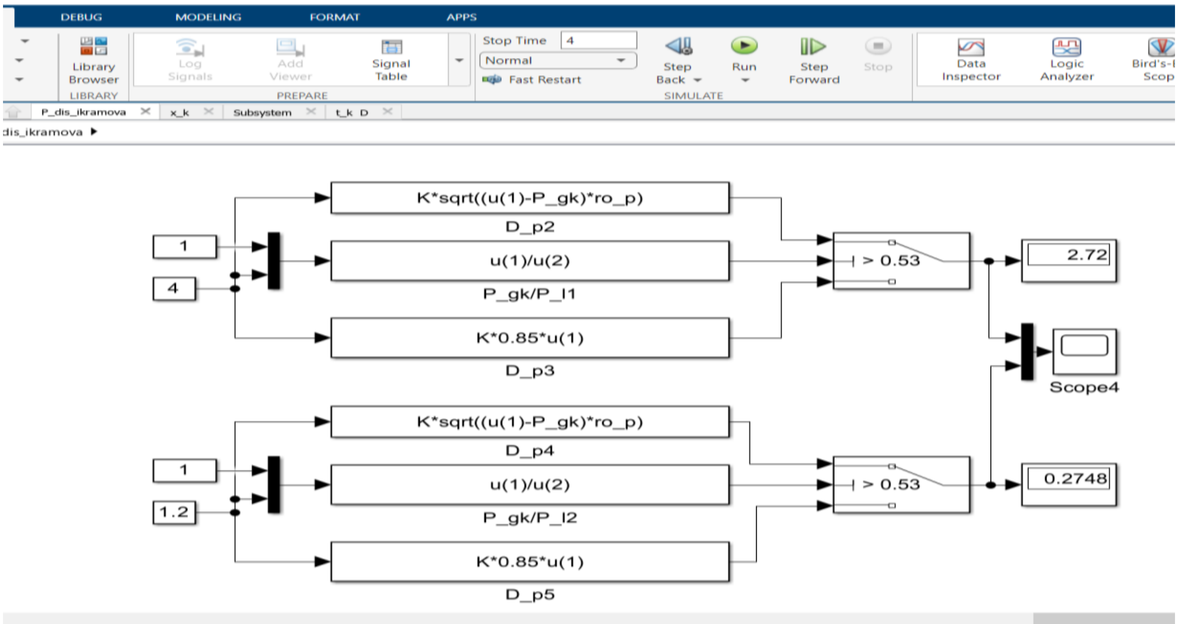
The vapor density for the operating conditions of primary stills can be determined from the Mendeleev-Clapeyron equation:

$$PV = \frac{m}{M}RT \tag{8}$$

From this, the pressure is determined as follows:

$$P = \frac{m}{VM}RT \tag{9}$$

In this: m - vapor mass, M - water vapor molecular mass, R - universal gas constant, T - absolute temperature.



As mentioned above, during the condensation of water vapor in the heating chamber, two elementary processes occur: the process of formation of a condensate film, characterized dynamically by the change in condensate thickness, and the process of heat transfer through the condensing water film.

To create a mathematical description of the dynamics of water condensate formation on a vertical wall, the material balance equation describing the change in condensate volume can be used:

$$\frac{dV\rho_k}{d\tau} = D_p - D_k \tag{10}$$

In this: D_k - condensate consumption in the heating chamber.

Vapor density is determined as follows:

$$\rho = 0.002165\frac{P}{T} \tag{11}$$

The condensation temperature of water vapor has a non-linear dependence:

$$t_k = f(P) \tag{12}$$

The water vapor condensing temperature at the operating conditions of the primary distiller P= 98,14÷390 kPa can be determined using the following equation:

$$t_k = 86 + 0.15 \quad (13)$$

In this: P - pressure, MPa.

For a comparative analysis of the dynamics of the process in the heating chamber of the change of steam pressure in the pipeline to the executive mechanism, the volume of the heating chamber is $V_{g.k} = 1.65\ m^3$, the volume consumption of steam is $Q_p = 0.18$ m^3/s, the time constant of the heating chamber is $\tau_{g.k} = 7.3\ s$. is accepted as

It can be seen that the deviation of the heat transfer coefficient along the height of the boiling pipes from the average value does not exceed 20%, but there is a sharp change in the temperature difference. On the other hand, in primary stills and the literature [28] showed that the value of the overall heat transfer coefficient varies in the values of 200÷300 W/m^2K. The thermal resistance of the condensate does not exceed 8% of the total resistance. When the temperature difference between the heating steam condensing and the boiling liquid temperature is 50°, the temperature difference in the condensate is about 3°.

It can be seen that the dynamics of the condensation process does not significantly change the dynamics of the overall process. With this in mind, for this particular case, this process is considered in the form of a model with unified parameters.

In the analysis of the mathematical description of the condensation process in the primary distillation in the first body of the three-stage distillation, we accept the following initial data:

D = 0.4-0.6 kg/s; H = 4 m; $\mu = 2.84*10^{-4}\ \frac{H.C}{m^2}$; l = 24 m; c = 2.19 $\frac{kJ}{kg*K}$; ρ = 1000 $\frac{kg}{m^2}$; λ = 0.68 $\frac{vt}{m.K}$.

Taking into account that the first primary distiller of three-stage distillation operates at atmospheric pressure and the miccella concentration increases from 10÷15% to 65÷70%, the boiling temperature of cottonseed oil miccella is described by the equation [23] by processing experimental data:

$$t_{kip} = 93 - \frac{283}{a} \quad (14)$$

For this primary still mode of operation, the cross-section of the boiling liquid is 1/3 of the total cross-section of the vapor-liquid phase. In this case, the dynamics of the process in the first primary distiller is described by a simplified equation:

$$x_n^{i+1,j} = x_n^{i+1,j} + \Delta\tau\left(0.43\frac{x_n^{i+1,j} - x_n^{i,j}}{\Delta h} - 0.000175\left(t_{st} - 93 + \frac{283}{x}\right)\right) \quad (15)$$

This equation was calculated in Matlab Simulink on a computer. In this case, it is replaced by the height differential (Dh). A similar model for the four-cell model (N = 4; Δh – 1.0) is shown in Fig. 2. Figure 2 shows the solution of the model for the four-cell model in case of sudden wall temperature fluctuation (t_st=120->110℃); transition curves were obtained separately for each cell.

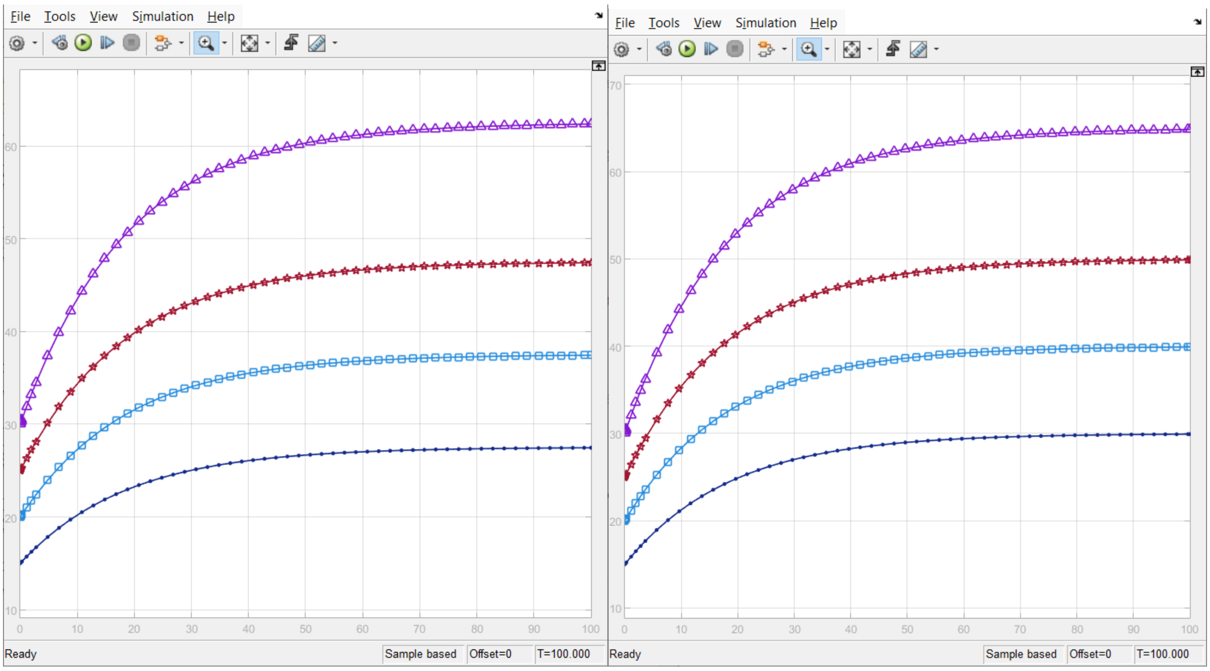


Figure 2. Variation of the concentration of miccella with the height of the device in the primary distillation of vegetable oil: *а) G_0=3.2 кг/с, б) G_0=1.6 кг/с. -4.0, -3.0, -2.0, -1.0.*

As can be seen from Figure 2, the duration of the transition process increases with the increase in the height of the boiling pipe. The output curve corresponding to the height N = 4 m differs from the transition process of the first-order aperiodic link. Using the mathematical description, it is possible to obtain different combinations of the multi-cell model with variable height of the elementary zone. It ensures the distribution of the liquid on the cross-section of the boiling pipe, as well as the heat transfer coefficient on the height of the boiling pipe.

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