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Construction of an Optimal Control System for Rectification Columns in Methanol Production

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ABSTRACT: This paper deals with the creation of a control scheme for rectification columns in the production of methanol. The main aspects for the creation of a control scheme for distillation columns in the production of methanol in OA Navoiyazot were determined, on their basis, controlled and adjustable variables for a two-product distillation column were established to establish the control configuration. The functioning of the control system of the rectification columns in the dynamic mode is analyzed. Temperature profiles have been built, which are indispensable for composition control; in operation, the composition of the distillate is controlled by measuring the temperature on the upper control plate.

KEY WORDS: Control system, rectification column, temperature profile, temperature controller, rectification process..

I.INTRODUCTION

The study of the static and dynamic characteristics of the process allows you to build mathematical models and use them in the development of control systems .

As an object of control, rectification processes are multifactorial and are characterized by a large number of parameters interconnected by complex dependencies. Most of the parameters are a function of temporal and spatial coordinates.

Technological process control consists in the purposeful selection and maintenance of these variables or a certain part of them at a given level. An analysis of the operation of a large group of rectification columns and their complexes shows that in industrial conditions the columns operate in a dynamic mode, i.e. over time, the composition of the raw material, its quantity, the value of product flows, irrigation, etc. change. In addition, the control system acts on the column. Therefore, to study the processes of rectification, a mathematical model is needed that reflects the dynamics of the process under the influence of disturbances in various parameters.

II. PRACTICAL

The main control functions are: 1) stabilization of the output variables of the control object (OC) - the characteristics of the rectification process, which determine the output coefficient and, accordingly, the production efficiency; 2) regulation of expenditures of material flows, which form the state of the control object.

- The main aspects for creating a control scheme for rectification columns in methanol production, presented in Figure 1 [1-2], are:
- - the columns are connected in series, therefore, for each column it is possible to create an independent control scheme (the value of the recycle flow entering the preliminary rectification column is only 3% (75 cubic dm/h) of the mass fraction of methanol in the raw methanol, and therefore can be ignored);
- two product streams are removed from each column;
- both streams are liquid (full-acting condenser);
- the dephlegmator is partially filled (the level in the dephlegmator must be measured and
- regulated);
- the column cube is heated with deaf steam.

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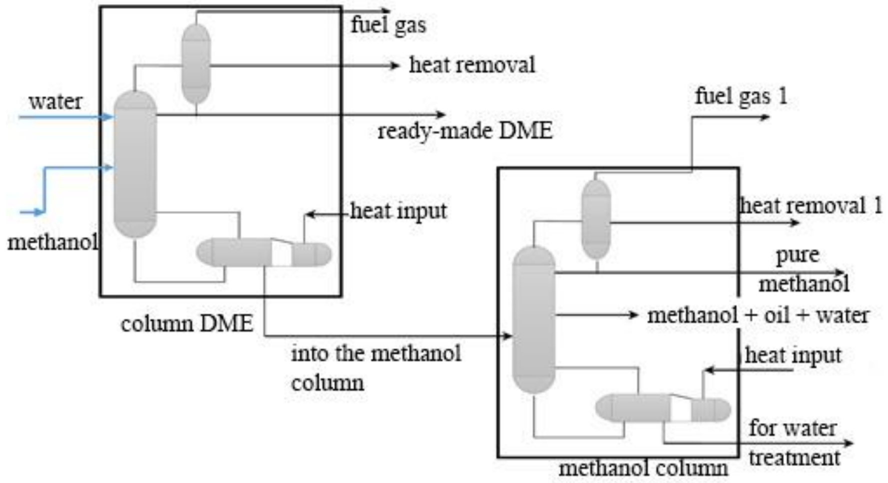
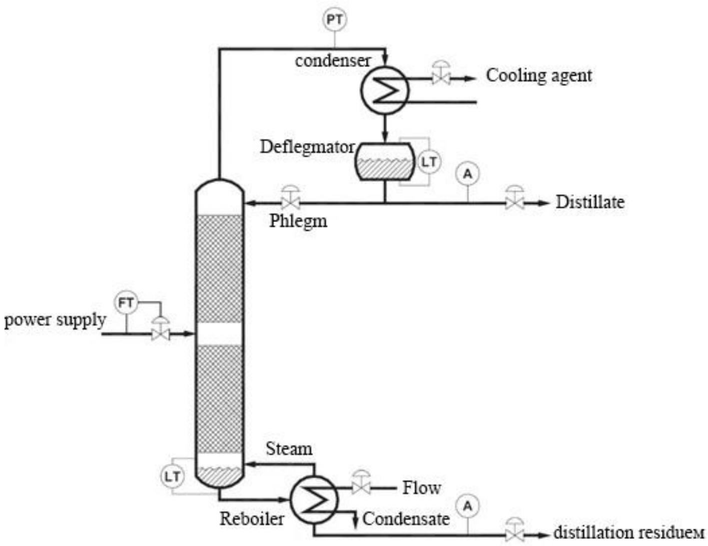


Fig. 1.Schematic diagram of a methanol production unit.

Based on the above aspects, the control object can be depicted in the form of a diagram shown in Figure 2.



There are five controlled and five controlled variables in this scheme. This amounts to a 5 × 5 multivariate control configuration:

Controlled variable	Manipulated variable
Level in a cube	Distillate flow D
Level in the dephlegmator	Cube flow W
The pressure in the column	Phlegm flow L
The composition of the distillate	Steam flow from above (in the condenser)V_C
Composition of the cube	Steam flow in a cube V

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With a single-circuit approach to column control, a PID controller is configured for each of the controlled variables. The output of the regulator should go to one of the control valves, but which one? The choice of the control scheme should take into account the degree of interaction between the two composition contours [2].

The single-circuit (simple) approach consists of separate regulation of two compositions. However, there is always some interaction between the distillate composition control circuits and the cubecomposition. There is a method [4] known as" relative gain " that allows us to estimate this degree of interaction. The purpose of the method is to find a control scheme with a low degree of interaction. The interaction assessment can be based either on the product compositions or the temperatures on the control plates.

Figure 3.shows the control scheme for two product flows of the column, as required by the technological regulations for the production of methanol.

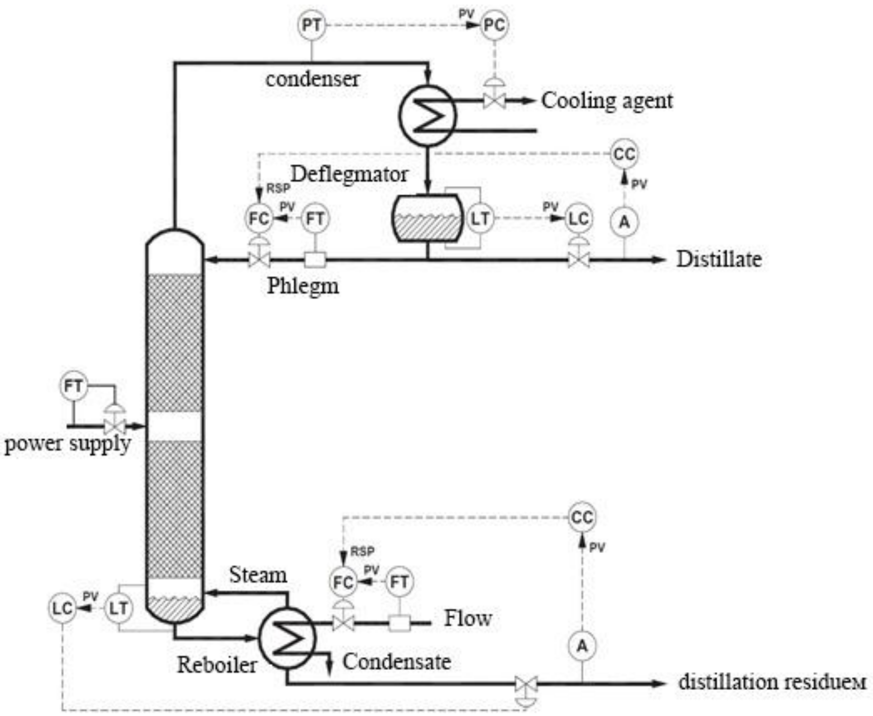

Fig. 3.L, V – configuration

Five parameters are subject to management: the level in the cube, the level in the deflegmator; the pressure in the column; the composition of the distillate; the composition of the cubic residue. The pressure in columns with liquid product flows is almost always controlled by regulating the rate of heat removal from the condenser. With this in mind, there remain four controlled and four regulated variables, of which the most important loop is the composition control [5,6].

The pressure control circuit must be fast, especially if the temperature control circuit is used instead of the composition control circuit. In most cases, the level control circuits are faster relative to the composition control circuits. In fact, there is a reasonable dynamic separation between the composition control circuits and other control circuits. This allows you to select a pair of polygons as follows:

* Determine the appropriate controlled variable for each of the composition control loops.

* Use the remaining controlled variables to control the two levels (provided that the pressure in the column is controlled by regulating the rate of heat removal from the condenser).

In this case, the traditional approach to the coupling of controlled and regulated variables can be combined into the principle "regulate each variable by the closest valve that has the greatest influence on this variable". For rectification columns, this statement means: "adjust each variable using a controlled variable at the same end of the column (i.e., top or bottom)."

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In this case, the following options are available:-
управлятьсоставомдистиллятаизменениемпотокафлегмы L илирасходомдистиллята D;
- manage the composition of the cubic product by changing the steam consumption per cubic meter V or the flow rate of the cubic remainder W.
At the same time, the General material balance must be observed $F = D + W$, that imposes a restriction on the selection of controlled variables for control loops of composition: and D, and W they can be managed variables, but not both parameters at the same time. There are three options left for managed variables: L, V and D (or W). This gives you three possible options for managing the line-up.
The choice of a suitable control scheme depends on a number of factors, including: product purity; phlegm number (L/D); the ratio of food composition to the composition of shared products.
These factors determine the success of transferring the control circuit from one column to another. The copied scheme should work, provided that all these factors are similar.
Such effects can be analyzed by determining the degree of interaction using a method known as the" relative gain "incombination with the column separation model using the"plate-to-plate" method.
According to this method [7-8], you usually start with three simple schemes that involve processing phlegm flow values L, steam supply to the cube V and either distillate D, or the cubic balance W. If none of them is acceptable, then it is suggested to manipulate the phlegm number $R = L/D$.
In the control scheme shown in figure 2 the distillate composition is controlled by regulating the phlegm flow L, and the composition of the cubic residue is controlled by regulating the flow of the cubic residue W.
From the point of view of the energy balance parameters L and V related to energy. Their relationship (L/V) it is an internal phlegm coefficient that determines the separation provided by the column. Both managed variables affect separation, which leads to interaction.
From the point of view of material balance, these two product flows are controlled variables for level controllers. Each product flow is determined by the difference between the steam flow and the liquid flow, which are controlled variables for the two composition regulators.

III.THE ANALYSIS OF THE FUNCTIONING OF THE RECTIFICATION COLUMN CONTROL SYSTEM IN DYNAMIC MODE IS CARRIED OUT.

The analysis of the calculated temperature profiles along the column height. The traditional approach to controlling the column is based on changing the temperature when moving from one plate to another. From the temperature profile shown in figure 4.it can be seen that the upper control plate should be plate 28 or 30. Temperature profiles are indispensable in cases where the composition control is based on the temperature of the control plate instead of directly measuring the composition. In this paper, the control of the distillate composition is shown in figure 2. eplaced by a temperature measurement on the upper control plate.
The presence of the developed potarelochnoy separation model allows you to take into account other factors when choosing the location of the control plate. The temperature controller on the upper control plate maintains the temperature at the set value by changing the output signal of the controller.

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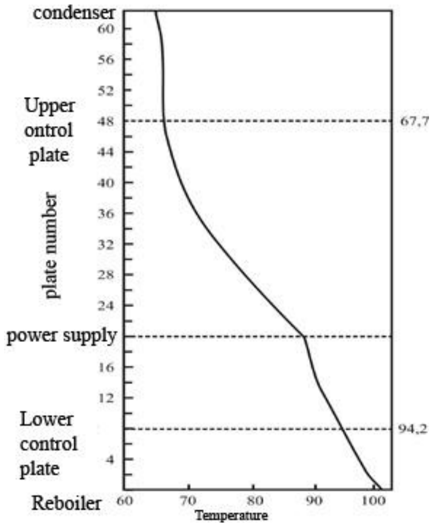

Fig. 4. Temperature profile.

Since the cascade has a normal configuration, the controlled variable for the temperature controller is the setting for the flow controller. A step-by-step separation model can determine the effect of changes in this flow on the temperature profile. In other words, additional profiles can be calculated as follows:
* Increase the output signal of the temperature controller by a certain amount and calculate the temperature profile.
* Decrease the output signal of the temperature controller by the same amount and calculate the temperature profile.

IV. THE ANALYSIS OF THE PROFILES OF TEMPERATURE ALONG THE HEIGHT OF THE COLUMN AT A CONSTANT FLOW OF STEAM TO THE CUBE OF THE COLUMN.

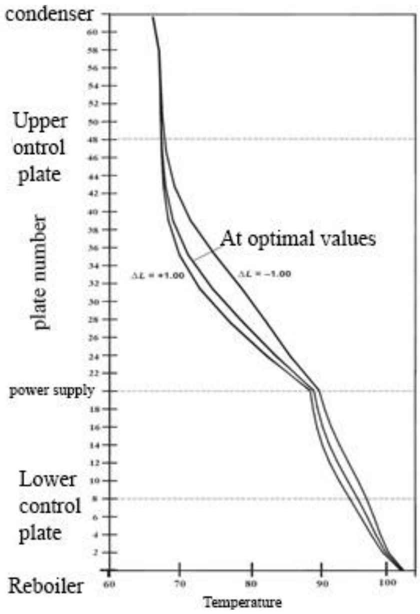

Fig. 5. Influence of phlegm flow on the temperature profile: constant steam flow in the cube

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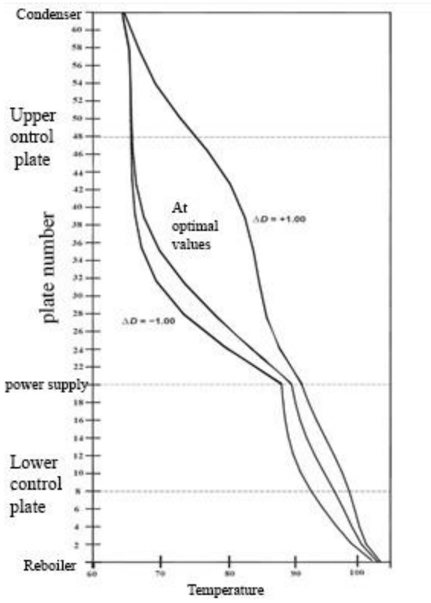

Fig.6. The influence of the selection of distillate in the temperature profile with a constant supply of steam

Figures 5 and 6 show temperature profiles along the column height with constant steam supply to the column cube. Comparing these figures, we can assume that the two control schemes affect the temperature profiles differently, but in facttheir effect is the same. The differences in figures 5 and 6 are due to the amount of changes in the irrigation flow and the amount of distillate selection.
The difference in temperature profiles in figures 5 and 6 is explained by the fact that the change in $\Delta D = \pm 1.00$ in figure 6 has a greater effect on the separation capacity of the column than the change in $\Delta L = \pm 1.00$ in figure [9-10] .

From the temperature profiles shown in figures 5 and 6, it can be seen that on all control plates, the temperature sensitivity to a decrease in the phlegm flow is much higher than the sensitivity to n increase in the phlegm flow. The temperature characterizes the nonlinear character of the
column.

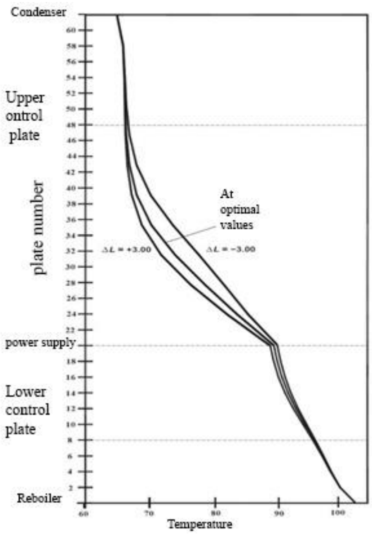

Fig. 7 Influence of phlegm flow on the temperature profile at constant selection of the cube

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The temperature profiles that reflect the influence of the phlegm flow on the temperature profile with constant selection of the cubic product shown in figure 7 also show a higher sensitivity of the separation capacity of the column when the phlegm flow decreases than when it increases .
Figure 7 shows that changes in phlegm flow have virtually no effect on the temperature below the food plate. This is an important circumstance when controlling the composition at the top and bottom of thecolumn. As shown in figures 5 and 6, with a constant supply of steam to the column cube, the temperature change on the upper plate has some effect on the composition in the lower part, which can affect the stability in the control circuit of the cube composition.
However, with a constant flow of phlegm, these fluctuations have little effect on the composition in the lower part and, therefore, will not significantly affect the control of the composition at the bottom of the column.

V. THE CONDUCTED RESEARCH ALLOWS US TO DRAW THE FOLLOWING CONCLUSIONS:

- product compositions (which are a non-linear function of phlegm flow, steam boiler load, power consumption, changes in phlegm flow or steam boiler load) determine the quality of both the cubic product and the distillate;
- the interaction between the product compositions, phlegm flow and the boiler load has a noticeable effect on the composition dynamics;
- based on the analysis of the calculated temperature profiles for the height of the column, it was found that these profiles are important for the control of the composition, based on the calculated values of the temperature on the control plate without direct measurement of the composition;
- the proposed control systems provide stabilization of the main technological parameters and stability of the operation of the rectification process over the entire operating range of changes in the regulated parameters, and increase the purity of separation products.

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