ADAPTIVE CONTROL SYSTEM DEVELOPMENT OF OIL PREPARATION PROCESS FOR OPTIMIZING TECHNICAL AND ECONOMIC PARAMETERS

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The article is about the conception of carrying out the adaptive control system of oil preparation that provides the optimum realization of technological processes, including oil production, its transportation, division into stock-tank oil and commercial water and also the degassing. The parameters of the quality performance production (watered oil, oil content in commercial water and etc.) and the technical and economic parameters (technological cost price, profit, proceeds etc.) are serving as a criterion. The optimization of processes is offered to be provided on a gradient of the profit in space of varied technological parameters. The effect from apply of such control system is the increase of the technological profit up to dozens of times in percents.

INTRODUCTION

Usually the tasks of management on parameters of technical and economic efficiency (PTEE) reference to tasks of management by the enterprise (ERP-system) and solve at the top levels of the automated control systems of the enterprise (CAM-system).

At the same time, the large opportunities of increasing the efficiency management processes by PTEE are connected with the low level of the process control system (PCS). Let's emphasize, that the opportunities of modern engineering and management technologies allow to put and to solve tasks of operative management production for PTEE.

As follows from [1, 2, 3 etc.], the economic benefit of the solving tasks of operative management of oil processing settings by PTEE is within the limits of 0.3 - 1 dollar on cubic meter of the made production, and in relative figures the increase of efficiency is usually 2 - 8 %.

In this connection the doubtless interest is represented by the tasks of the estimation of the economic efficiency of the operative management processes of oil preparation by PTEE and by the questions of development PCS, that can solve such tasks.

MATERIALS AND METHODS

In [4] is offered the using of the structure of an adaptive control system (ACS) for construction of PCS the installation of oil preparation on the type devices "Maloney", including the definition and optimization management procedures by PTEE (see fig. 1).

In the fig. 1 the next designations are accepted: R - set of managing devices (regulators); M - model of PCS; A - the adaptation and optimization procedure; W_T, W_{QP} and W_{PTEE} - technological part of the object of management (OM) and the quality parameters (QP) definition procedure and PTEE accordingly; U, Y, P and T - vectors of managing effects, controllable parameters, QP and PTEE; Z_R, Z_P and Z_M – corrective actions on R, QP and M; P ' – set of QP, determined in an operative mode or laboratory; V_w - vector of wanted QP and PTEE; U_M and V_M - simulated vectors U and V, where V = <Y, P, T> - set of output parameters of OM. Thus, object of management is the technological part (technological processes) with procedures W_{QP} and W_{PTEE}.

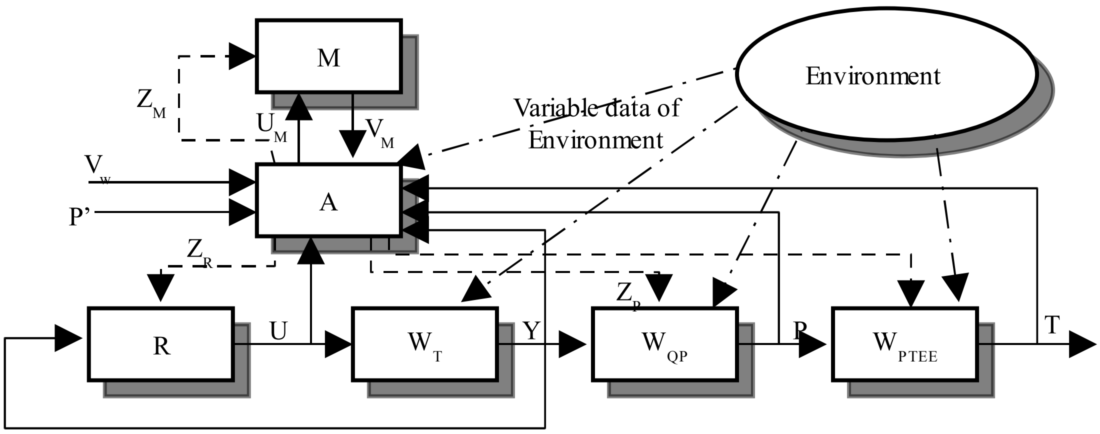

Figure 1. Structure of the adaptive control system

The procedure of adaptation consists of the development of the corrective actions (parametrical and structural) by PCS and the model on the basis of the analysis of the acting information about controllable and design parameters. The model is the combination of three models:

$$\boldsymbol{M = <M_Y, M_P, M_T>} \quad (1)$$

i.e, the model OM (M_Y) and the account of QP (M_P) and PTEE (M_T). An output of the model is the set of simulated (model-based) parameters (see fig. 2).

$$\boldsymbol{V_M = <Y_M, P_M, T_M>} \quad (2)$$

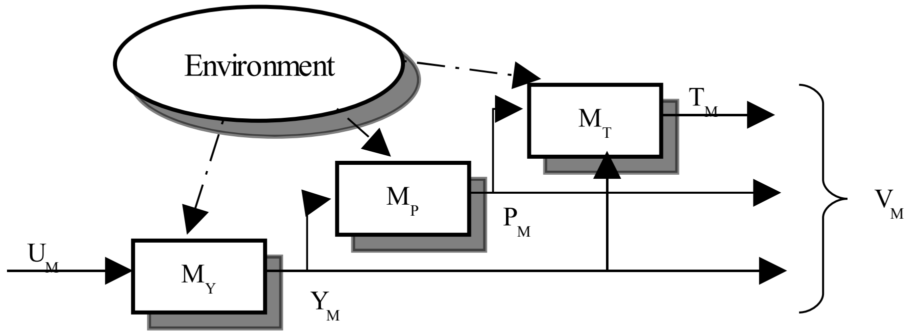

Figure 2

The particular feature of PTEE for the purposes of operative managements is connected with such parameters as profit and the profitability that are calculated for the whole level of the enterprise and for the rather large time intervals. Therefore for operative management of separate technological processes by PTEE, it is offered to calculate PTEE, analogous to these parameters, but without the calculation of some conditionally constant expenses [5].

The oil preparation expenses sum up from the fixed and variable charges. During the operative management of technological process the fixed charges are: the salary of the workers; amortization; department costs; living expenses of the management personnel. The variable charges are: demulsifying agent consumption and auxiliary materials, energy and fuel consumption. It is very important to mention about the repair bills. It is the category of conditional - variable charges, as its depend on the intensity of equipment use and the overhaul run of the equipment.

Let's analyze the parameters of the technological receipts (TR),the technological cost price (TCP) and the technological profit (TP) are in the ratio [5]:

$$TP = TR - TCP \qquad (3)$$

The technological receipts are determined:

$$\grave{O}R = G_{oil} * P_{oil} \qquad (4)$$

where, G_{oil} – charge of the separated oil (oil output); P_{oil} – constructed value price of separated oil. The parameter G_{oil} is calculated by the control system of technological parameters. The size P_{oil} is determined by the price of the sale of stock-tank oil (P_s) and watered oil, that is produced by DM (η_{oil}).

$$P_{oil} = \begin{cases} \left(\dfrac{\eta^{st}}{\eta_{oil}} \right)^{\hat{e}} * P_S, & if \quad \eta_{oil} < \eta_{\lim} \\ 0, & if \quad \eta_{oil} > \eta_{\lim} \end{cases}, \tag{5}$$

where, η^{st} - parameter point of watered oil, that is set periodically for each system and oil grade; $\boldsymbol{k}$ - factor describes the degree of influence of water oil on charges for the further swapping and processing; $\boldsymbol{P_s}$ - price of the sale of watered oil, according to the standard.

The increase of the watered oil gives the increase of the cost oil price due to incremental portion of water in transported water-oiled liquid and necessity of recurring realization of preparing oil process for its high quality.

The increase of the cost oil price due to incremental portion of water is caused by the following:

- the immutability of variable charges on transportation of 1 tone of a liquid (watered oil liquid) and increase of its watering gives the advance of the cost price on transportation of 1 tone of oil;

- the presence of water in transported liquid increases the deterioration of the equipment and, as a consequence, to its stop working;

- the high watering causes the necessity of charges on preparation of oil in the refinery.

In the refining the charges on additional oil dehydration can be taken into account at fixing of the price of the crude oil.

The parameter TCP calculates with the given frequency on specified time and reflects the level of charges on preparation of oil in a mode of on-line.

The cost price of oil transportation of 1 tone is calculated under the following formula:

$$C_{oil} = \frac{\tilde{N}_L}{1 - \eta_L} \tag{6}$$

where, $\boldsymbol{C_{oil}}$ - cost price of 1 ton of transported oil; $\boldsymbol{C_L}$ - cost price of 1 tone of transported liquid.

For calculation of TCP is capable to use the following:

$$\boldsymbol{TCP = E_{de} + E_f + E_{en} + E_{fc} + E_r,} \tag{7}$$

here $\boldsymbol{E_{de}}$ - demulsifying agent consumption; $\boldsymbol{E_f}$ - fuel consumption; $\boldsymbol{E_{en}}$ - energy consumption; $\boldsymbol{E_{fc}}$ - fixed charges; $\boldsymbol{E_r}$ - repair bills.

Demulsifying agent consumption, fuel and electric consumption calculate using the following formulas:

$$E_{de} = G_{de}*P_{de}, \quad E_f = G_f*P_f, \quad E_{en} = G_{en}*P_{en}, \qquad (8)$$

here, G_{de}, G_{en}, G_f - mass demulsifying agent consumption, electric and fuel consumption is accordingly; P_{de}, P_f, P_{en} - price for unit of demulsifying agent, fuel and electric power accordingly.

On the device the accompanying gas is used as fuel which is realized to gas consumer. The part of this gas comes back to the device and is used as fuel for heating water-oil liquid. The use of gas by consumers decreases the proceeds from its sale. For the construction of model of operative management on technical and economic parameters we shall consider, that the gas acting from outside buys by the price of realization and we shall include gas charges in group of variable charges for calculation of the technological cost price.

The electric power consumption sums up of the electric power consumption on swapping water – oil liquid to device (G_{en}^{L}), the electric power consumption for the work of the device (G_{en}^{d}), the electric power consumption on swapping of water from device (G_{en}^{w}), the electric power consumption on swapping of oil from device (G_{en}^{oil}):

$$G_{en} = G_{en}^{L} + G_{en}^{d} + G_{en}^{w} + G_{en}^{oil} \qquad (9)$$

The rectangular components:

$$G_{en}^{L} = G_L * C_L \,, \; G_{en}^{w} = G_w * \tilde{N}_w \,, \; G_{en}^{oil} = G_{oil} * \tilde{N}_{oil} * k_{en} \,, \qquad (10)$$

here G_L, G_w, G_{oil} - charge of a liquid to the device, water and oil from the device accordingly; C_L, C_w, C_{oil} - discharge intensity of the electric power on transportation of 1 tone of a liquid, water and oil accordingly; кэ - factor which is taking into account the increase of electric power consumption as a result of increase of viscosity of oil from watering increase.

The parameter G_{en}^{d} undertakes on the basis of the data of the last month and is recalculated on volume of oil planned to processing in the current month:

$$G_{en}^{d} = \overline{G}_{en}^{d} * \frac{G_L^{cur}}{G_L^{last}} \qquad (11)$$

here $\overline{G}_{en}^{d}$ - the electric power consumption to device for the last month; G_L^{cur} - the liquid consumption passing through the device during the current month; G_L^{last} - the liquid consumption, passed through the device in the last month.

The fixed charges are counted on basis of calculation of the cost price. These charges do not depend on changes of a technological mode, they do not influence the parameter ***TP***, however they are in the calculation as to preserve the conformity between parameters ***TR*** and ***TCP*** and their adequacy to similar parameters of business accounting:

$$E_{fc} = A + PW + DC + EM \tag{12}$$

here ***A*** - sum of amortization, ***PW*** - sum of personnel wages, ***DC*** – department cost, ***EM*** – the maintenance costs of the management personnel.

The main feature of oil preparation processes is the nonlinear dependence of an economic efficiency of manufacture on quality parameters of the prepared oil.

The counted parametrical models of QP and PTEE are used for optimization of process from a condition of a maximum of the technological profit:

$$\frac{\partial \grave{O}P}{\partial Y} = 0, \ \frac{\partial^2 \grave{O}P}{\partial^2 Y} < 0 \tag{13}$$

here ***Y*** - vector of changeable technological parameters, to which is concern the liquid consumption Q_L, temperature in device t_d, relative demulsifying agent consumption g_{de} etc.

The best value ***TP*** can be determined by the gradient of the profit in space of varied parameters: temperatures in device and demulsifying agent consumption. The liquid consumption and its’ watering are not the varied parameters, as are determined by a oil-field.

Let's analyzed the character of dependence of operative PTEE from parameters of a technological mode by the results of the imitating experiments, that are carried out with the use of models and calculated for one device of oil preparation.

Using the experimental data the functions of watering were found by the technique of least squares:

$$\eta_{oil} = 60{,}8045 + 6{,}5*\eta_L - 2{,}0024*t_d + 0{,}0156*t_d^2 - 56000*g_{de} + \\ + 4{,}815*10^8*g_{de}^2 - 1010*g_{de}*t_d + 8{,}09*10^{-8}*Q_L. \tag{14}$$

The fuel charge functions was found by approximation:

$$E_f = 508,47*(0,000379*G_L - 26,6111*t_d + 0,59111*t_d^2). \quad (15)$$

The electric power consumption for transportation of the stock-tank oil and water was found after transformations:

$$E_{en} = P_{en}*(0,0070038*G_w + 0,0203*G_{oil}). \quad (16)$$

DISCUSSION

The dependence of oil watering from the demulsifying agent consumption is shown at temperatures in device 35 ºC and 50 ºC in the fig. 3. With increase of the demulsifying agent consumption up to 100 g/t, the oil watering is reducing, but the efficiency of the demulsifying agent is falling down. The further increase of the charge results the increase of oil watering.

Based on the market oil prices of different oil watering factor k in function of the price of stock-tank oil is accepted equal to 0,12 (see fig. 4).

With the use of the given ratio there were made the dependences of total expenses at temperature in device and at various norm of the demulsifying agent (see fig. 5). The given dependence is not monotonous.

Nowadays on West Siberia's craft at the researched device there is supported t_d = 50 ºC temperature that corresponds to a minimum of expenses. At lower temperatures the expenses are higher, because the expenses are higher for transportations of oil, containing the high rate of water. At higher temperatures the expenses are increase for swapping of water and fuel.

However, the given temperature is not optimum from the point of view of TR (see fig. 6). The dependence TR from temperature has a maximum at temperature 65 ºC. At lower temperatures the high oil watering reduces the oil price, accordingly, the proceeds. At higher temperature the oil watering either changes lightly, or grows. Thus, under the influence of the temperature the light ends more evaporate and the output of oil decreases.

The dependence TP from temperature is given in a fig. 7. There is the maximum of TP at temperature in device t_d 65 ºC.

At temperature t_d up to 40 ºC the increase of temperature reduce the oil watering and its expenses, so the price increases. TP reduces, as the output of oil is also reduces.

At temperature from 40 ºC up to 65 ºC TP grows, as continues the oil watering reducing, the price grows, and the expenses do not change practically.

At temperature higher than 65 ºC oil watering begins to grow, the price reduces, thus the output of oil reduces, as a result of loosing the light ends, and the expenses of the fuel and electric power consumption are grow. At temperature higher than 80 ºC the expenses begin to exceed the proceeds as a result the manufacture becomes unprofitable.

The dependence TP from the demulsifying agent consumption is given in a fig.8.

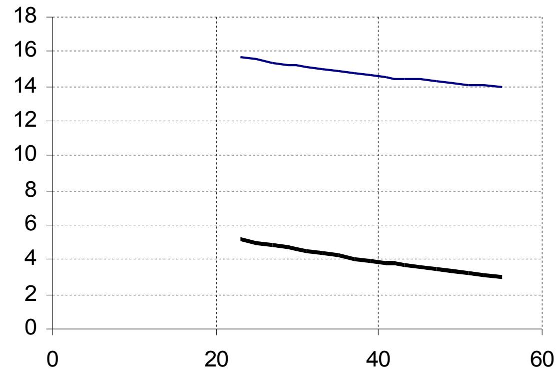

Figure 3. Dependence of oil watering from the demulsifying agent consumption (upper curve – at t_d = 35 ºC, lower – at t_d = 50 ºC)

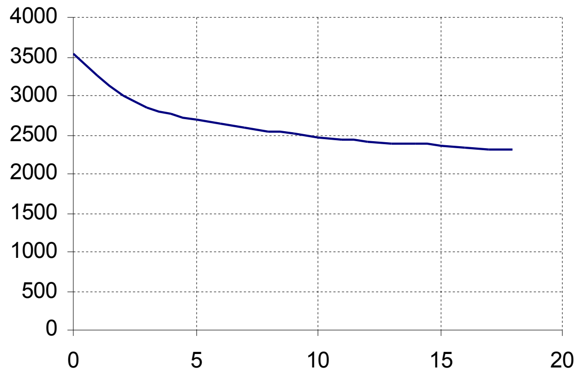

Figure 4. Dependence of market oil prices from oil watering (k = 0,12)

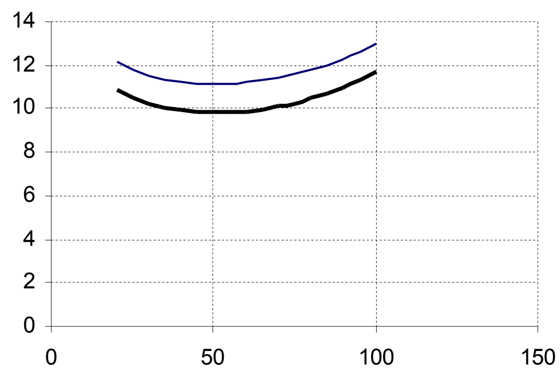

Figure 5. Dependences of total expenses from temperature in device (upper curve – at demulsifying agent consumption 35 g/t, lower - at 23 g/t)

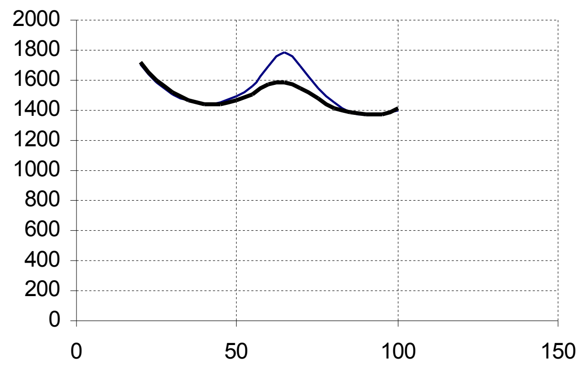

Figure 6. Dependence of technological receipts from temperature in device (upper curve – at demulsifying agent consumption 35 g/t, lower - at 23 g/t)

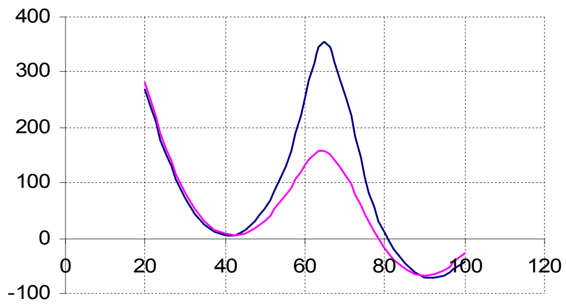

Figure 7. Dependence of technological profit from temperature in device (upper curve – at demulsifying agent consumption 35 g/t,lower - at 23 g/t)

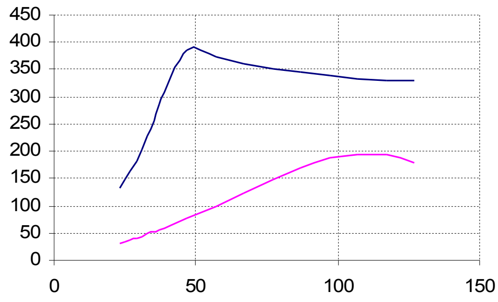

Figure 8. Dependence of technological profit from demulsifyi0ng agent consumption (upper curve – at t_d = 60 ºC, lower – at t_d = 50 ºC)

CONCLUSIONS

The adaptive control system will provide an optimality of the corresponding parameters in dependence of chosen PTEE. The possible meanings of increase of efficiency can be in limits from percents up to tens percents, that determines the expediency of automation of processes of operative management of oil preparation.

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