Strategy for Optimizing the Functioning of the Vacuum Block at the Technolohical Equipments

E.A. Melikov, T.M. Magerramova

Azerbaijan State Oil and Industry University (Azadlig ave. 16/21, Baku, AZ 1010, Azerbaijan)

For correspondence:
Melikov Elchin / e-mail: elchin03@mail.ru

Abstract

In the submitted article, on the basis of a comprehensive analysis and study of the peculiarities for the complex processes occurring at the oil primary processing installation, (electro-desalting plant of atmospheric-vacuum tube type) the issues of developing a mathematical statement of the optimization problem for one of the important technological blocks of the investigated technological complex - the vacuum block are considered. The experience of operating a process installation in recent years shows that changes in both the quality and consumption of processed oil over a wide range are random in time. The main reason for this is that oil, as a raw material, supplied for processing to the installation from different wells, has different quality indicators. Therefore, the necessity of using, in this case, the approach and method of stochastic programming to the problem for the optimizing the functioning of the object under study with probabilistic constraints is substantiated.

Keywords: primary processing, optimization problem, mathematical statement, technological process, probabilistic nature, mathematical model.

DOI 10.52171/2076-0515_2023_15_02_110_115

Accepted: *10.02.2022*
Revised *19.06.2023*
Accepted *21.06.2023*

For citation:
Melikov E.A., Magerramova T.M.
[Strategy for optimizing the functioning of the vacuum block at the technolohical equipments]
Herald of the Azerbaijan Engineering Academy, 2023, vol. 15, no. 2, pp. 110-115 *(in English)*

Texnoloji qurğuların vakuum blokunun fəaliyyətinin optimallaşdırılması strategiyası

E.A. Məlikov, T.M. Məhərrəmova
Azərbaycan Dövlət Neft və Sənaye Universiteti (Azadlıq pr. 16/21, Bakı ş., AZ1010, Azərbaycan)

Yazışma üçün: Məlikov Elçin / e-mail: elchin03@rambler.ru

Xülasə
Təqdim edilən məqalə ELOU-AVT neftin ilkin emalı qurğusunda baş verən mürəkkəb proseslərin xüsusiyyətlərinin hərtərəfli təhlili və tədqiqi əsasında texnoloji kompleksin mühüm texnoloji aparatlarından biri olan vakuum bloku üçün optimallaşdırılma məsələsinin riyazi qoyuluşunun işlənib hazırlanmasına həsr edilmişdir. Texnoloji qurğunun son illərdə istismar təcrübəsi göstərir ki, emala verilən xam neftin istər keyfiyyət göstəricilərinin və istərsə də sərfinin dəyişməsi geniş diapazonda olmaqla bərabər müəyyən zaman kəsiyində təsadüfi xarakter daşıyır. Bunun da əsas səbəbi xammal kimi qurğuya emala verilən neftin müxtəlif mədələnlərdən müxtəlif keyfiyyət göstəricilərinə malik olmasıdır. Buna görə, tədqiq olunan obyektin işlənməsinin ehtimal məhdudiyyətləri ilə optimallaşdırılması məsələsinə və stoxastik proqramlaşdırma metodundan istifadə zərurəti əsaslandırılmışdır.

Açar sözlər: ilkin emal, optimallaşdırılma məsələsi, riyazi qoyuluşu, texnoloji proses, ehtimal xarakteri, riyazi model, vakuum bloku.

DOI 10.52171/2076-0515_2023_15_02_110_115

УДК 681.513.2

Стратегия оптимизации функционирования вакуумного блока технологических установок

Э.А. Меликов, Т.М. Магеррамова
Азербайджанский государственный университет нефти и промышленности (пр. Азадлыг, 16/21, Баку, AZ1010, Азербайджан)

Для переписки:
Меликов Эльчин / e-mail: elchin03@mail.ru

Аннотация
В статье на основе всестороннего анализа и исследования особенностей сложных процессов, протекающих на установке первичной переработки ЭЛОУ-АВТ, рассматриваются вопросы разработки математической постановки задачи оптимизации одного из важных технологических аппаратов исследуемого технологического комплекса – вакуумного блока. Опыт эксплуатации технологической установки в последние годы показывает, что изменения качества и расхода перерабатываемой нефти в широком диапазоне носят случайный во времени характер. Основная причина этого состоит в том, что нефть, подаваемая в качестве сырья для переработки на установку с разных скважин, имеет различные показатели качества. Поэтому в данном случае обосновывается необходимость использования подхода и метода стохастического программирования к задаче оптимизации функционирования исследуемого объекта с вероятностными ограничениями.

Ключевые слова: первичная переработка, задача оптимизации, математическая постановка, технологический процесс, вероятностный характер, математическая модель, вакуумный блок.

Intoduction

It is known that the process installation for primary oil refining is greatly influenced by the mode of each process apparatus operation for the system under study, both in terms of productivity and in ensuring the quality indicators of each final product.

Therefore, it would be more correct in the matter of developing a mathematical statement for the optimization problem, mathematical modeling of the vacuum block and developing an optimal control system, to consider it as a whole as an electro-desalting plant of atmospheric-vacuum tube type installation, consisting of a large number of different apparatus interconnected by various technological and complex interconnections, and also as a complex and mixed technological system [1, 2].

Already all over the world, due to the lack of technical conditions and methods of operational control in industrial conditions, the quality indicators of light oil products are determined by traditional methods, i.e. only in the factory.

The purpose of the work

For technological complexes with probabilistic characteristics of output target products, develop a universal physically justified statement of the problem in order to develop an optimal strategy for the functioning of the object under study.

However, an analysis of this type installation, one of the large-scale techno-logical processes of primary oil refining operated at an oil refinery, shows that even after its modernization, the amount of crude oil supplied to these units for processing and its quality indicators vary over a very wide range according to random patterns.

In connection with the above circumstances, the existing local systems for monitoring and stabilizing the regime parameters of the main apparatus, built on a single-loop principle, cannot provide the necessary technical and economic indicators. Therefore, as a result of real operation experience under production conditions of the electro-desalting plant of atmospheric-vacuum tube technological complex, which performs primary oil processing, we can conclude that a more correct and appropriate approach is to research and study complex technological systems of this type as control objects operating under conditions uncertainty [3-5]. Therefore, the development of complex mathematical models, the mathematical statement of the optimization problem taking into account the stochastic properties of state coordinates, the development of an algorithm for the numerical solution of the stochastic programming problem and the synthesis of controller regime coordinates of amultilevel control system for a technological complex of primary oil refining at the level of automatic control is an urgent task both scientifically and and from an economic point of view [6].

Taking into account the indicated specific features, a number of mathematical models and a method for optimizing the stochastic regime at the level of operational management are proposed.

For a physically justified mathematical formulation of optimal control problem for the vacuum block of this technological installation, we directly use the general simplified basic structural diagram of the primary oil refining processing plant (fig.).

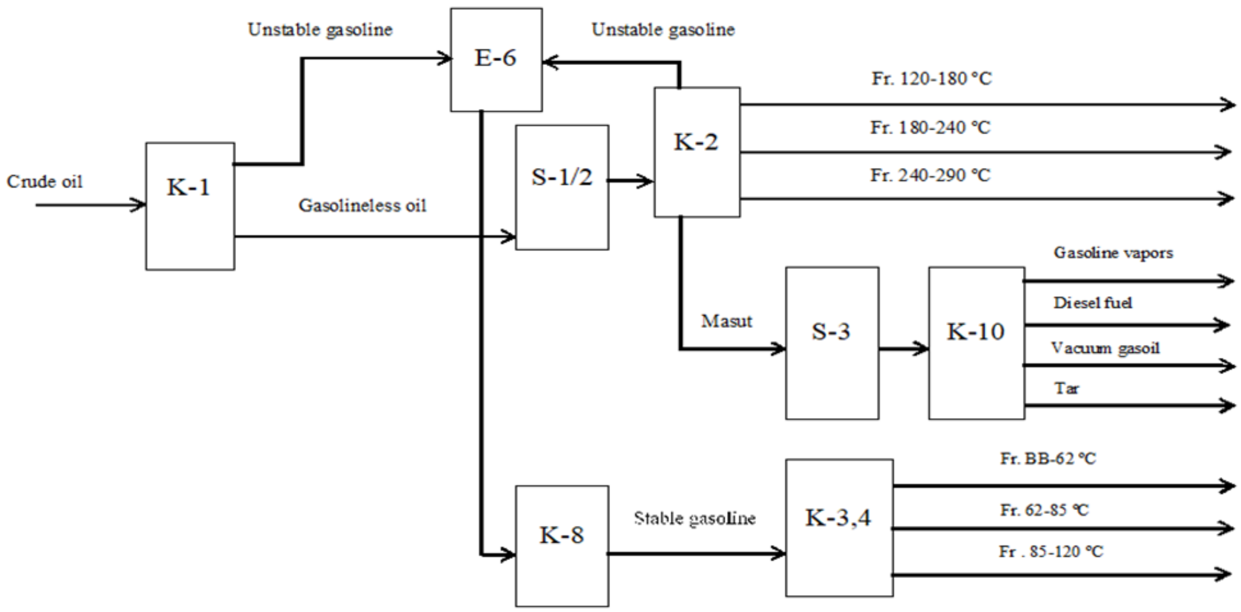

Figure – Schematic diagram for the technological installation of the electro-desalting plant of atmospheric-vacuum tube

This structure consists of four main blocks listed below:

- I block - distillation column K-1;
- II block - distillation (atmospheric) column K-2;
- III block - distillation (vacuum) column K-10;
- IV block - stabilization column K-8 and distillation columns K-3 and K-4.

Before giving a mathematical statement of optimizing problem considered technological complex (electro-desalting plant of atmospheric-vacuum tube), we present mathematical models that characterize the quantitative and qualitative parameters of the output fractions in the form:

$$y_k = \bar{f}_k(x, \rho, u_q) + \xi_k, q = \overline{1, r}, k = \overline{1, l} \quad (1)$$
$$v_k = \bar{g}_k(x, \rho, u_q) + \xi'_k, i = \overline{1, m}, k = \overline{1, l} \quad (2)$$

Here y_k and v_k are respectively the flow rate and quality indicators in accordance with the fractions of oil, x is the flow rate of crude oil fed to the processing plant, ρ is the quality indicator (specific gravity) of crude oil, u_q are the control parameters in the distillation columns (temperature, pressure, level, etc. at different points), and ξ_k and ξ'_k are random variables characterizing errors, the average estimates of which are equal to zero.

Problem solution

It can be seen from expressions (1) and (2) that the functions are also determined with certain errors, and therefore, $\bar{f}_k(x, \rho, u_q)$ and $\bar{g}_k(x, \rho, u_q)$ the average values of the functions are calculated using the regression dependence. In this regard, the solution of the optimization problem based on the average indicators of target oil products cannot be considered correct, such an approach can lead to significant losses.

Restrictions on quality indicators for any fraction of oil produced at the technological facility of primary oil refining (based on specific technical conditions and standards) can be written in the following mathematical form:

$$\underline{b}_{ik} \leq \nu_{ik} = \bar{g}_{ik}(x, \rho, u_q, \xi'_k) \leq \overline{b}_{ik}, \quad i = \overline{1,m}, 1 \leq q \leq r, k = \overline{1,l} \tag{3}$$

Here $\underline{b}_{ik}$ and $\overline{b}_{ik}$ are indicators of light oil products quality characterizing the permissible extreme values. All this determines the probabilistic nature for the functional restrictions imposed on the quality indicators of light petroleum products for the intended purpose. Then one can write that

$$P(\nu_{ik}) \geq \alpha_i,\ i = \overline{1,m} \tag{4}$$
$$0 \leq \alpha_i \leq 1$$

The values of restrictions on the quantity and quality for the light oil products and the possibility of their implementation are determined by the process operator in accordance with the regulations of the process under consideration.

Each light oil fraction produced at the process facility under study must be no less than the potential value of the thick crude oil included, i.e.:

$$y_k = \bar{f}_k(x, \rho, u_k, \xi_k) \geq Q_k, \quad q = \overline{1,r}, k = \overline{1,l} \tag{5}$$

Due to the presence in expressions (3) and (5) of random variables ξ_k, changes in the x and ρ parameters will also be random variables. And this means that the provision of the above conditions for the restriction can be provided with a certain probability.

Thus, in the matter of optimizing the modes for the primary oil refining plant within the framework of the regulation that characterizes any technological mode of operation for the plant under study and is installed at any value of its parameters x and ρ, it is required to calculate the values of the controls u_k so that the qualitative parameters of the resulting target oil product are provided with a predetermined probability P_0, but their number should not be close to the minimum amount (limit) of the potential value Q_k for crude oil entering the installation:

$$P(y_k \geq Q_k, \nu_{ik} \in B_{ik}, \quad i = \overline{1,m}, k = \overline{1,l}) \geq P_0 \tag{6}$$

$$y_k \geq Q_k, k = \overline{1,l}, \qquad P(\nu_{ik} \in B_{ik}, \quad i = \overline{1,m}, k = \overline{1,l}, \underline{b}_{ik}, \overline{b}_{ik} \in B_{ik}) \geq 0.94 \tag{7}$$

Here, B_{ik} is a set of performance ratings for oil fractions, $P_0 = 0.94$ - probability of fulfilling restrictive conditions.

In this case, as a criterion in the optimization problem, you can use the maximization of the mathematical expectation of the profit received from the target light fractions:

$$\Phi = \max_{u_q \in \overline{U}} E\left\{\sum_{k=1}^{l} c_k y_k - s(x)\right\}, \tag{8}$$

where *E(·)* is the mathematical expectation, *s(x)* is a function that characterizes the cost of raw energy, raw materials and etc. to an oil refinery, *s(x)* – linear in variables function, c_k is the price per unit of the *k*-th type for the light oil product for its intended purpose.

Conclusion

From the above, we can conclude that the optimization problem (1)÷(8) by its nature can be considered a non-linear stochastic programming problem. To solve this problem, a preliminary decision was made that the restrictive conditions of the flows are determined, and the restrictions characterizing the qualitative parameters for the resulting target oil products are of a probabilistic nature. In addition, the analysis of the obtained experimental results shows that $y_k,\ k = \overline{1,l}$, v_{ik}, $i = \overline{1,m}$ participating in the process under consideration, obey the normal distribution law.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

REFERENCES

1. **Səfərova A.A.** Neftin ilkin email texnoloji kompleksinin əsas aparatları üçün eksperimentlərin təşkili. Azərbaycan Mühəndislik Akademiyasının Xəbərləri, Bakı, 2019, cild 11, №2, səh. 104-107 *(in Azerbaijan).*
2. **Parks P.S., Scaufelberger W., Schimid Chr., Unbenhauen H.** Application of adaptive control systems. Methods and application in adaptive control, berl. Heudelb., N.Y.: Spring – Verlag, 2005, pp. 181-193 *(in Germany).*
3. **Kumar P.R.** A survey of some results on Stochastic adaptive control. SIAM J. Control and Optimal, 2010. V. 23. №3, pp. 329-380 (in USA). *(in English)*
4. **Liu W.K., Besterfield G., Mani A.** Probabilistic finite element methods in nonlinear structural dynamics // Computer Methods in Applied Mechanics and Engineering, 1986. Vol. 56 (1). P. 61-81 *(in Netherlands).*
5. **Arsenjev D.G., Ivanov V.M., Kulchitsky O.Yu.** Adaptive calculating mathematics based on the stochastic programming methods // VII International Conference on Stochastic Programming, Naharia, Israel, 1995, pp.159-164 *(in Russian).*
6. **Melikov E.A.** The problem of optimal control for the technological process of primary oil refining. Proceedings of the International Scientific and Practical Conference “Oil and Gas Processing-2011”, Ufa-2011, pp. 261-*262 (in Russian)*