Меликов Эльчин Адил, доцент,
Азербайджанский Государственный Университет
Нефти и Промышленности
Melikov Elchin Adil, associate professor,
Azerbaijan State University of Oil and Industry

Гаджиев Вюсал Фахраддин,
Азербайджанский Государственный Университет
Нефти и Промышленности
Hajiyev Vusal Fakhraddin**,** master,
Azerbaijan State University of Oil and Industry

МАТЕМАТИЧЕСКАЯ ПОСТАНОВКА ЗАДАЧИ ОПТИМИЗАЦИИ ДЛЯ УСТАНОВКИ КАТАЛИТИЧЕСКОГО РИФОРМИНГА
MATHEMATICAL FORMULATION OF THE OPTIMIZATION PROBLEM FOR A CATALYTIC REFORMING UNIT

Аннотация. В статье рассматриваются вопросы разработки математической постановки задачи оптимизации функционирования одного из основных аппаратов исследуемой установки, а именно реакторного блока. Реакторы риформинга критически важны для нефтепереработки, поскольку они производят компоненты, без которых невозможно получить современный высококачественный бензин. Проблемы формулировки эффективной постановки задачи оптимального управления и поиска оптимальных режимов функционирования сложных установок относятся к числу весьма актуальных задач. На практике выполнение этих задач для сложных комплексов осложняется прежде тем, что они характеризуются сложностью, многокомпонентностью, многосвязностью параметров, многокритериальностью, а также неполнотой и неопределенностью исходной информации

Abstract. The article examines the development of a mathematical formulation for the optimization problem, the operation of one of the main apparatuses of the installation under study, namely the reactor block. Reforming reactors are critical to oil refining because they produce components essential to producing modern, high-quality gasoline. The problems of formulating an effective statement of the optimal control problem and searching for optimal operating modes of complex installations are among the most pressing issues. In practice, the implementation of these problems for complex systems is complicated primarily by the fact that they are characterized by complexity, multi-component nature, multi-connectedness of parameters, multi-criteria, as well as. incompleteness and uncertainty of the initial information.

Ключевые слова: Оптимальное управление, технологический аппарат, задача оптимизации, установка каталитического риформинга, реакторный блок.

Keywords: Optimal control, technological apparatus, optimization problem, catalytic reforming unit, reactor block.

It is known that to deepen the oil refining process and ensure that the resulting commodity products meet international standards, modernization of existing oil installations and optimal control of these technological installations are necessary. Since the gasoline produced at this facility is intended for direct sale as a final product, it is subject to strict regulatory requirements. To ensure compliance with global product quality standards, optimal process control at this facility is a critical

and actual problem. One of the most important technological systems within the fuel and energy complex, particularly the oil refining complex, is the catalytic reforming unit [1-5]. The primary purpose of the installation's operation is to produce high-octane gasoline with high-quality indicators from low-octane gasoline. An analysis of scientific papers devoted to the study of control systems for catalytic reforming units has shown that these technological systems, from the point of view of the control object, represent a complex technological system that connects multidimensional technological aggregates, interconnected by numerous technological links. Each technological apparatus in this complex system operates in a wide range of changes in input and output technological parameters.

In addition, unlike other technological processes occurring in oil refining installations, the raw materials entering the catalytic reforming unit for its processing vary over a wide range of qualitative and quantitative indicators. The reason for this is that the original gasoline is obtained from oil, coming from various oil fields, and these raw materials vary greatly in quality. Naturally, this, in turn, leads to the need to set certain restrictive requirements for the range of changes in the quality indicators of the original oil. It is known that specific quality indicators of the feedstock correspond to a narrow operating process mode. Because of this, to ensure a given control accuracy, the development of a more complex, effective approach and control algorithm for the installation under study is required [6-9].

The technological installation of catalytic reforming is characterized by a high rate of change in the process, as well as a rapid change in the mode of transition from one type of raw material to another. Under such conditions, the requirements for rapid changes in the system as a whole become more stringent. The presented article considers the problem of developing a mathematical formulation for the optimization of the control system for the reactor block of a catalytic reforming unit. Here, I, II, III, and IV are the corresponding reactors, U_{R_I} is the inlet temperature of reactor I, $U_{R_{II}}$ is the inlet temperature of reactor II, $U_{R_{III}}$ is the inlet temperature of reactor III, $U_{R_{IV}}$ is the inlet temperature of reactor IV, and X_0 is the flow rate of low-octane gasoline entering the column. Then, the input parameters of the reactor block under consideration are characterized by the following vector:

$$X_0 = \{X_1, X_2\} \tag{1}$$

where X_1 is the gasoline consumption, X_2 is its quality indicator.

In this case, the control actions vector:

$$U_k = \{U_{R_I}, U_{R_{II}}, U_{R_{III}}, U_{R_{IV}}\} \tag{2}$$

And the vector of output parameters for the technological block:

$$Y = \{Y_1, Y_2\} \tag{3}$$

where Y_1 is the platformate consumption (quantitative indicator), Y_2 is the octane number of platformate (quality indicator).

It should be noted that, at the same time, the output coordinate of the parameter Y_1 is characterized by the quality indicator g_i, where $i = \overline{1,6}$.

Mathematically, this can be written as follows:

$$g_i(X_0, U_r, \xi_l) \leq 0 \tag{4}$$

After the technological definition of the catalytic reforming unit as a control object, let us consider the formulation of the problem for its operation optimization.

Let us assume that the mathematical model for each element of the technological system under consideration is presented in the form below:

$$Y_j^i = f_j^i(X_s^i, U_r^i, \xi_l^i), \quad j = \overline{1,n}, i = \overline{1,m}, r = \overline{1,q}, l = \overline{1,z}. \tag{5}$$

where Y_j^i is the j-th output vector in the i-th apparatus, $s \in E(i)$, $E(i)$ is the index of the input flow in the i-th apparatus, U_r^i is the vector of control parameters in the i-th apparatus, and ξ_l^i characterizes the disturbing effects controlled in the i-th apparatus.

The limitations placed on the quality indicators of products obtained in the technological process are recorded as follows:

$$g_j^i(X_s^i, U_r^i, \xi_l^i) \leq 0 \quad j = \overline{1,n}, \; i = \overline{1,m}, \; r = \overline{1,q}, \; l = \overline{1,z}, \; s \in E(i) \quad (6)$$

Mathematical models describing the states of technological apparatuses for the process under study and its production and economic indicators also include the following restrictive conditions:

$$\text{a)} \; X_j^i \geq A_j^i, \quad \text{for everyone} \; j \in B(i), \quad (7)$$

where A_j^i is the plan set for the output of the j-th product in the i-th apparatus;

b) for non-targeted products:

$$X_j^i \leq C_j^i, \quad \text{for everyone} \; j \in \Gamma(i), \quad (8)$$

where C_j^i is the upper limit value of the j-th non-target product in the i-th apparatus, $\Gamma(i)$ is the non-target products set;

c) condition of restriction on raw materials supplied to the installation:

$$X_{0min} \leq X_0 \leq X_{omax} \quad (9)$$

where X_0 is the amount of raw material supplied to the installation, X_{0min} and X_{omax} are its minimum and maximum values, respectively;

d) the condition of the limitation imposed on the material balance of apparatuses:

$$\sum_{s \in E(i)} X_s^i - \sum_{j \in K(i)} X_j^i \geq 0 \quad K(i) = E(i) \cup \Gamma(i), \quad (10)$$

where $K(i)$ is the index of the output parameters set.

e) the limiting conditions imposed on the change range of control parameters in each technological apparatus:

$$\{U_r^i, X_s^i, \forall j \in E(i)\} \in G_i \quad (11)$$

where G_i is the any closed area.

The economically justified global measure of the process control system is the maximization of the target product's yield, that is

$$\Phi = \sum \sum Z_{j \in B(i)} Z_j^i \, Y_j^i(X_s^i, U_r^i, \xi_l^i) \to max \quad (12)$$

where Z_j^i is the quantity of the output commodity product.

The solution to the optimization problem (1)÷(12) of the catalytic reforming process based on its mathematical models (5) consists of determining the values that ensure the limiting conditions of the control parameters (11) in each technological apparatus of this process, for given values of the quantitative and qualitative indicators of low-octane gasoline X_0 supplied to the installation [2, 3]. In this case, fulfilling the conditions of the limitations (6)÷(10) ensures the criterion maximum (12), which characterizes the yield of the commodity product.

Thus, along with the optimization problem, formulating a mathematical statement of the problem and modeling are important stages in both the theory and practice of managing complex processes, such as a catalytic reforming installation. Without developing an effective, physically sound mathematical statement, it is impossible to achieve an optimal solution to either the optimization problem, the control of any process, or the development of an effective control system for it.

References:

1. Melikov E.A., Veliyeva S.K. The choice of goals and criteria for control the catalytic reforming process. Materials of VIII International scientific and practical conference ("Readings of A.I. Bulatov"), Publisher: "Publishing House – South" LLC, Russian Federation, Krasnodar, March 31, 2020, ISSN 2587-8913, vol. 5, pp. 166-168.

2. Melikov E.A. Koncepciya razrabotki logiko-lingvisticheskogo opisaniya ustanovki kataliticheskogo riforminga. Vestnik Rossijskogo Novogo Universiteta. Seriya "Slozhnye sistemy: modeli, analiz i upravlenie", No. 1, 2019, pp. 64-68.

3. Guseinov I.A., Kurbanov Z.G., Melikov E.A., Efendiev A.I., Efendiev I.R. Nonstationary Multistage Process Control in the Petrochemical Industry. Journal of Computer and Systems Sciences International, Pleiades Publishing, Ltd., 2014, Vol. 53, No. 4, pp. 556-564. https://doi.org/10.1134/S1064230714030095

4. Melikov E.A., Maharramova T.M. Optimization of the reactor block functioning in oil refining. Proceedings of Azerbaijan High Technical Educational Institutions (PAHTEI). Multidisciplinary Journal, Refereed & Reviewed Journal, E-ISSN: 2674-5224, Vol. 46 (05), No. 11, 2024, pp. 248-260. https://doi.org/10.36962/PAHTEI46112024-28

5. Efendiev I.R. One optimization problem for nostationary chemical reactors. Automation and remonts control, New York, July 15, 2006, p. 115.

6. Melikov E.A., Ragimli K.I. Zadacha optimizacii funkcionirovaniya ustanovki kataliticheskogo riforminga. Materialy V Mezhdunarodnoj konferenciya "Proizvodstvo & mekhatronnye sistemy" (M&MS-2021), Ukraina, 2021, pp. 61-63.

7. Guseinov I.A., Khanbutaeva N.A., Melikov E.A., Efendiev I.R. Models and Algorithms for a Multilevel Control Systems of Primary Oil Refinery Installations. Journal of Computer and Systems Sciences International, Pleiades Publishing, Ltd., 2012, Vol. 51, No. 1, pp. 138-146. https://doi.org/10.1134/S1064230711060098

8. Melikov E.A., Safarova A.A., Magerramova T.M. Features of modelling in automation for the primary oil refining technological process. In Third International Conference on Digital Technologies, Optics, and Materials Science (DTIEE 2024), SPIE, Vol. 13217, pp. 125-130. https://doi.org/10.1117/12.3035889

9. Safarova A.A., Melikov E.A., Magerramova T.M. Optimal control of the alkylation process reactors. Operational Research in Engineering Sciences: Theory and Applications (ORESTA), Belgrade, Serbia, Vol. 6, Issue 1, 2023, pp. 312-321. https://doi.org/10.31181/oresta/0601130.