Solution of the Problem of Optimizing the Reactor Block of a Catalytic Cracking Unit

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Abstract

Effective control of technological systems of complex structure depends on the correct construction of optimal control algorithms based on mathematical models of various classes of technological processes. In process control systems, optimal control or optimization problems are solved depending on the type of technological processes under consideration in order to ensure the selected optimality criteria. In the presented paper, an algorithm for solving an optimization problem based on a mathematical model of the reactor block of a catalytic cracking unit has been developed. This algorithm ensures the conduct of the technological process in the optimal operating mode and the optimal value of the control parameters.

Keywords: catalytic cracking unit, reactor block, regression equation, objective function.

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Katalitik krekinq qurğusunun reaktor bloku üçün optimallaşdırılma məsələsinin həlli

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Xülasə

Mürəkkəb strukturlu texnoloji sistemlərin effektiv idarə olunması müxtəlif sinifdən olan texnoloji proseslərin riyazi modellərin bazası əsasında optimal idarəetmə alqoritmlərinin düzgün qurulmasından asılıdır. Texnoloji proseslərin idarəetmə sistemlərində seçilmiş optimallıq kriteriyalarının təmin edilməsi məqsədi ilə baxılan texnoloji proseslərin tipindən asılı olaraq, optimal idarəetmə və ya optimallaşdırma məsələlərinin həlli yerinə yetirilir. Təqdim olunan məqalədə katalitik krekinq qurğusunun reaktor blokunun riyazi modelinin bazası əsasında optimallaşdırma məsələsinin həlli üçün alqoritm işlənilmişdir. Bu alqoritm texnoloji prosesin optimal iş rejimində aparılmasını, idarəetmə parametrlərinin optimal qiymətini təmin edir.

Açar sözlər: katalitik krekinq qurğusu, reaktor bloku, reqressiya tənliyi, məqsəd funksiyası.

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Решение задачи оптимизации реакторного блока установки каталитического крекинга

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Аннотация

Эффективное управление технологическими системами сложной структуры зависит от правильного построения оптимальных алгоритмов управления на основе математических моделей различных классов технологических процессов. В системах управления технологическими процессами решаются задачи оптимального управления или оптимизации в зависимости от типа рассматриваемых технологических процессов с целью обеспечения выбранных критериев оптимальности. В представленной статье разработан алгоритм решения оптимизационной задачи на основе математической модели реакторного блока установки каталитического крекинга. Этот алгоритм обеспечивает проведение технологического процесса в оптимальном рабочем режиме и оптимальное значение параметров управления.

Ключевые слова: установка каталитического крекинга, реакторный блок, уравнение регрессии, целевая функция.

Introduction

As we have already mentioned, the experience of operating oil refineries operating in our country has shown that there are sources for increasing their economic performance, depending on the current state of automation and control systems. It is known that crude oil for processing in the technological complex of oil refining has a different fractional composition. In addition, the raw material usually consists of oil fractions from individual fields. It should be noted that in real production conditions this technological complex operates in the presence of many random disturbance influences and factors [1, 2]. At the same time, the presence of a number of specific characteristics of such technological systems makes it difficult to solve the issues of their management. Examples of such characteristics are a wide range of regime parameters, large measurement errors of individual parameters, and in some cases the lack of operational means of monitoring their measurement, uncontrolled change in parameters, changes in process characteristics and non-linearity, as well as other features. It is clear that the composition of the vacuum distillate obtained under such conditions - gas oil will be different. Thus, the raw material supplied to the catalytic cracking unit contains fractions with different potentials.

Taking into account the above, it can be concluded that in order to obtain the maximum amount of reaction products (components of high-octane gasolines and diesel fuel) from various fractional feedstock supplied to the catalytic cracking unit, the cracking process should be carried out in different modes, calculated on the composition of the feedstock. All this indicates that today, in a market economy and at a time when higher and more stringent requirements are imposed on the quality indicators of petroleum products, the determination of the optimal operating modes of individual devices at the operational control level in the reactor block of a catalytic cracking unit is a multilevel control that be able coordinating modes of operation of these devices, which will allow the processing of the system.

The experience of operating a catalytic cracking unit has shown that, depending on the current state of automation and control systems, there are sources to increase their economic performance [3]. One of these ways is the development of optimization and optimal control algorithms that allow these technological complexes to be controlled in more optimal modes compared to the current technological modes [4, 5].

Purpose of the work

In order to ensure the design of an optimal control system for the reactor unit of the catalytic cracking technological complex, the development of an algorithm for optimizing the static modes of the unit and determining the optimal operating mode based on base of a mathematical model that can adequately discribe the current technological state of the main devices of the reactor block.

Problem statement

Taking into account the above, the mathematical formulation of the optimization issue in the catalytic cracking unit can be represented as follows. Objective function:

$$F= B0 + B1X1+ B2 X2 + B3 X3 + \\ + B4 X4+B5 X5+B5 X6 \rightarrow \max \qquad (1)$$

The restriction to the input and control parameters:

$$0.845 \le X_1 \le 0.86$$
$$222 \le X_2 \le 237$$
$$527 \le X_3 \le 542$$
$$1.02 \le X_4 \le 1.17 \quad (2)$$
$$1.2 \le X_5 \le 1.47$$
$$52 \le X_6 \le 66$$
$$120 \le Y \le 135$$

where X1 – raw material quality indicator (its specific weight); X2 – consumption of raw materials; X3 – temperature in the reactor; X4 – pressure in the reactor; X5 – catalyst circulation number; X6 – level in the reactor; Y – reaction products from the reactor (high-octane gasoline).

The issue of optimal control of the reactor block can be formulated as follows: for given values of raw material consumption and quality indicators in the technological block, it is required to find such values of control parameters in the reactor block from the permissible range (2), which in this case satisfies the maximum value of criterion (1), characterizing the optimization problem [6].

Solving of the problem

For solving of optimization problem we use the mathematical program MathCad taking into account the objective function and the limitation to input and control effects.
Here:

B0 = -263,021
B1 = 212,8566
B2 = -0,41509
B3 = 0,416644
B4 = 46,20876
B5 = 13,27996
B6 = 0,213648

are the coefficients of the mathematical model characterizing the production of reaction products in the reactor block.

b0 := −263.0210807

b1 := 212.8565622

b2 := −0.415085582

b3 := 0.416643967

b4 := 46.20875545

b5 := 13.27995681

b6 := 0.213648489

f(x1, x2, x3, x4, x5, x6) := b0 + b1·x1 + b2·x2 + b3·x3 + b4·x4 + b5·x5 + b6·

x1 := 0.847

x2 := 224

x3 := 529

x4 := 1.04

x5 := 1.34

x6 := 54

Given

0.845 < x1 < 0.86

222 < x2 < 237

527 < x3 < 542

1.02 < x4 < 1.17

1.2 < x5 < 1.47

52 < x6 < 66

p := Maximize(f, x1, x2, x3, x4, x5, x6)

$$p = \begin{pmatrix} 0.86 \\ 222 \\ 542 \\ 1.17 \\ 1.47 \\ 66 \end{pmatrix}$$

f(x1, x2, x3, x4, x5, x6) = 122.083

Based on these values, the mathematical model of the reactor block is expressed as follows:

Y= -263,021 + 212,8566 X1 + -0,41509 X2 - 0,41644 X3 + 46,20876 X4 -13,27996 X5 + 0,21348 X6

Optimal base values of parameters:
X1 = 0,86; X2 = 222; X3 = 542; X4 = 1,17; X5= 1,47; X6= 66; Y = 122,083.

The obtaining values are the optimal values of the facility's main mode parameters.

The optimal value of the objective function:
F = 122.083

The results of solving the optimization problem for the reactor block of the catalytic cracking unit are given in table.

Table - Results of optimal solution for reaction products

№	Technological parameters	The real values of the parameters	Optimal values of parameters
1	X1 - raw material quality indicator (its specific weight)	0.847	0.86
2	X2 – consumption of raw materials	224	222
3	X3 – temperature in the reactor	529	542
4	X4 – pressure in the reactor	1.04	1.17
5	X5 – catalyst circulation number	1.34	1.47
6	X6 – level in the reactor	54	66
7	Y – reaction products from the reactor (high-octane gasoline)	122	122.083

Conclusion

Mathematical formalization of the issue of optimal control of the reactor block of the catalytic cracking is performed. An optimization algorithm is developed that allows to calculate the optimal operating modes of the reactor block. Values obtained as a result of solving the optimization problem for reactor block.

Conflict of Interests

The author declares there is no conflict of interests related to the publication of this article.

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