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Intellectual Training-System of the Process of Catalytic Cracking of Heavy Oils

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Abstract

A description of a process that depends on a set of parameters is a complex set of functional dependencies. The system is intellectual, because it is based on the actual data on the operation of industrial processes and devices of chemical technology. These data are analyzed, conclusions and recommendations are made. The physico-chemical model is a software-implemented main unit of this system, which includes calculations on the equations of material and thermal balances of hydrocarbon transformations.

Keywords: *Mathematical modelling; Oil refining; Training system; Catalytic cracking; P hysico-chemical model.*

1. Introduction

In the field of catalytic processes of hydrocarbon processing, the integration of Sciences is associated with the transition to system analysis and problem solving using intellectual computer systems as complex systems that combine databases and knowledge bases, as well as program codes built on the basis of predictive models [1-2].

Today in the world, the development of catalytic cracking technology provides a significant proportion of gasoline, diesel fractions and light olefins [3-4]. The development and introduction of the latest designs of catalytic cracking units for the processing of various types of raw materials and modern catalysts provided a significant increase in yield and an improvement in the quality of cracking products during the process of becoming [3,5–13].

At the same time, the technology of catalytic cracking is difficult from the point of view of forecasting and optimal control of a chemical technological object [12,14], the reactor unit includes two interconnected and continuously operating devices that implement the "operation – regeneration" cycle. The effective management of industrial installations requires the introduction of an intellectual training-system, which allows to solve the problem of control and increase the level of knowledge and skills of the engineering and technical personnel of the plant.

The aim of the work was the creation of an intellectual training-system of catalytic cracking of heavy oils. Intellectual system can be used as a computer simulator for training technical personnel to the laws of the catalytic cracking process and research aimed at:

- Forecasting and planning of the optimal mode of operation of the industrial plant, taking into account the basic physical and chemical laws of the catalytic cracking process, as well as research on the effect of technological parameters on the composition and quality of products;
- Improvement of knowledge, skills and competencies of personnel in order to increase the degree of readiness of personnel of technological installations and testing of actions in the detection of malfunctions and emergency and emergency situations.

2. Object of research

The feedstock is characterized by a broad fractional composition of 320–544°C with density of 900–917 kg/m^3. The products of the catalytic cracking are:

- Gasoline fraction (fr. IBP-215°C) directed to redistillation unit of gasoline;
- Gas products: unsaturated gas with a high content of C_3–C_4 hydrocarbons intended for gas fractionation unit after purification from sulfur compounds and fuel gas used as the furnaces fuel after purification from hydrogen sulphide;
- Light catalytic gas oil (fraction 195–350ºC) used for the diesel fuel production;
- Heavy fractions: catalytic gas oil (fraction 350–420ºC) used as the coking feedstock and slops (fraction> 420ºC) directed to the reactor in order to maintain the coke load;
- Coke burned out during the catalyst regeneration and providing the heat balance of the "reactor-regenerator" system (Fig. 1).

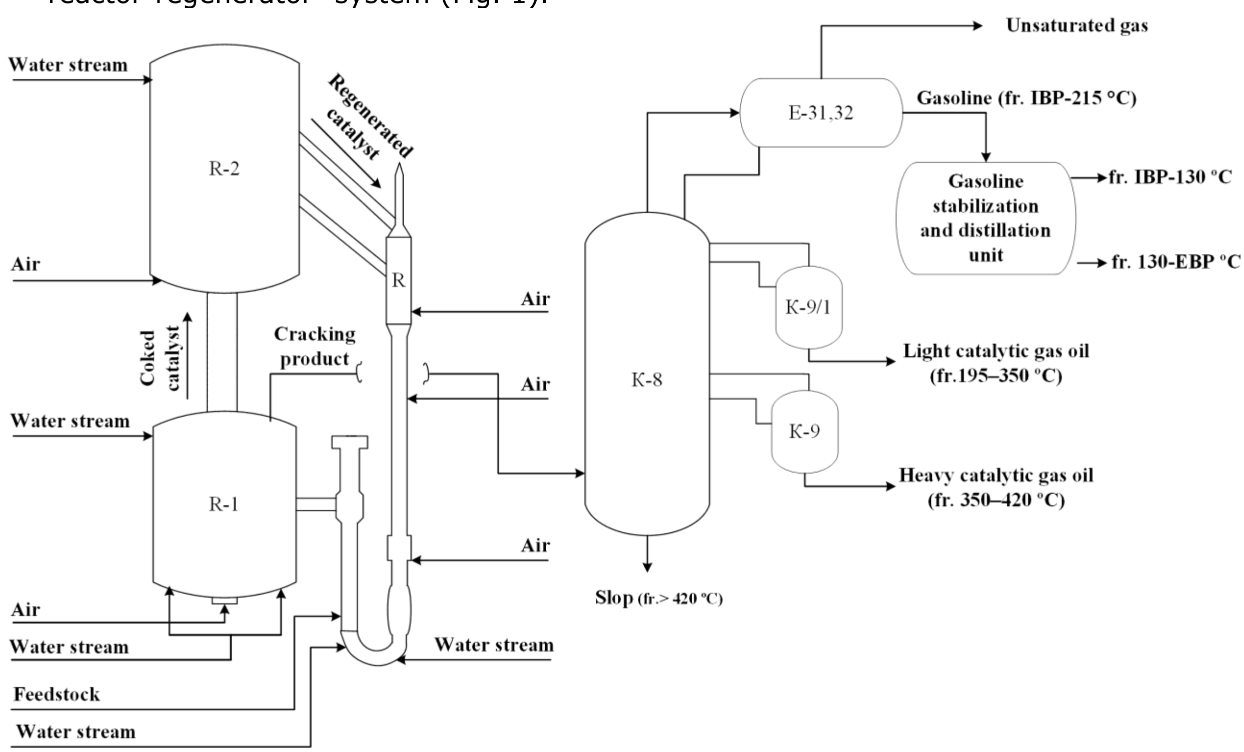

Fig. 1. Process flow diagram of a catalytic cracking unit

System of technological modelling of oil processing includes mathematical model of the of processing of hydrocarbon raw materials is building on the basis of physical and chemical laws of transformation of individual components, as well as taking into account the unsteadiness of industrial processes caused by the dynamic change in the hydrocarbon composition of the processed raw materials, as well as the deactivation of the catalytic systems used [15].

Subject area – a set of processes and devices of chemical technologies, information about which is accumulated in the intellectual system. The computer modelling system has an accessible and user-friendly interface (Fig. 2).

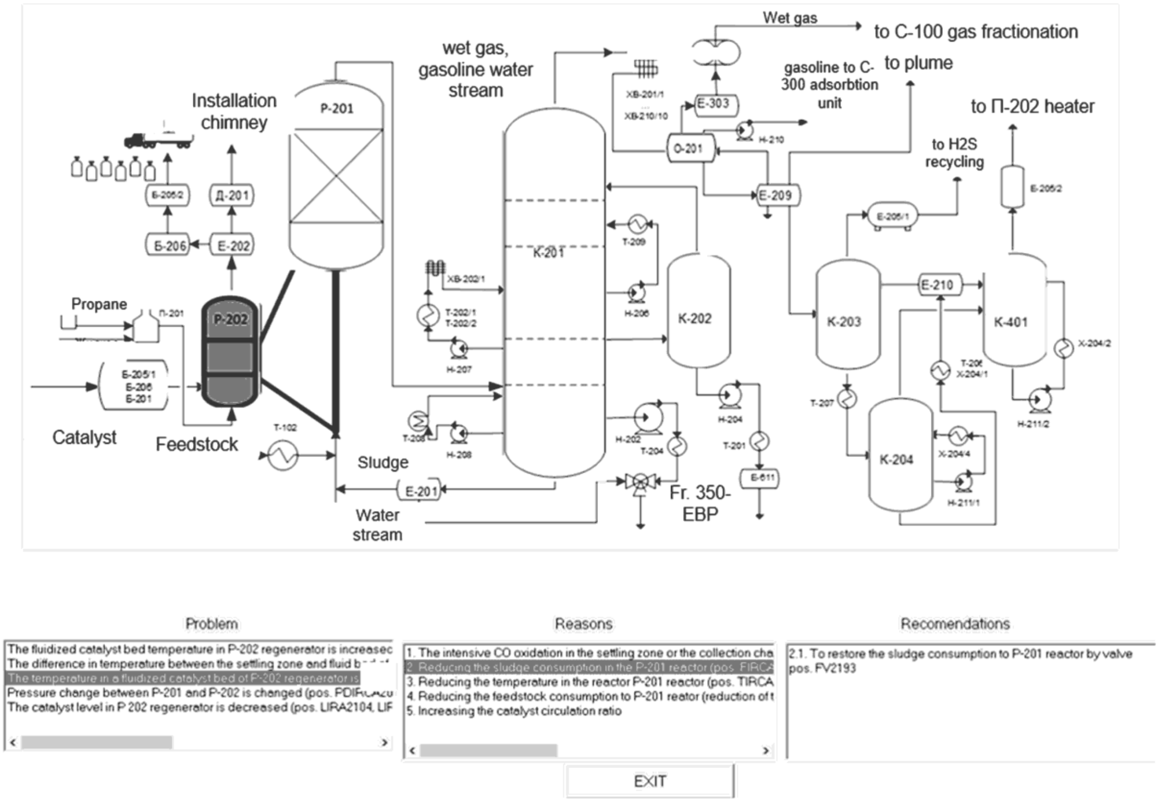

Fig. 2. The program working window

3. Cases for training of engineering personnel of the catalytic cracking industrial unit of oil raw materials

Case 1. The effect of temperature changes on the material balance of the process

It is necessary to determine how the yields of products (gasoline fraction, light catalytic gas oil, heavy catalytic gas oil, fatty gas (gas and reflux) and coke will change when the process temperature changes (operating temperature range for section C-200 of the industrial unit KT-1/1 – 475-535°C , for the industrial unit i 43-103 – 490-525°C, according to the technological regulations).

The studies were carried out using a computer training system "Catalytic cracking", which allows to calculate the group composition of the flow after the reactor unit, the individual composition of gasoline from different units, as well as the outputs of products from the catalytic cracking (Fig. 3).

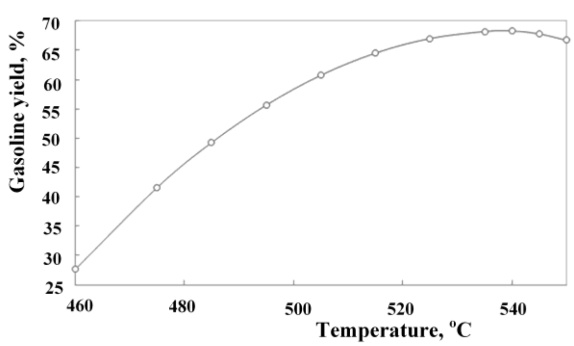

Fig. 3. The dependence of the gasoline and wet gas yields from the process temperature

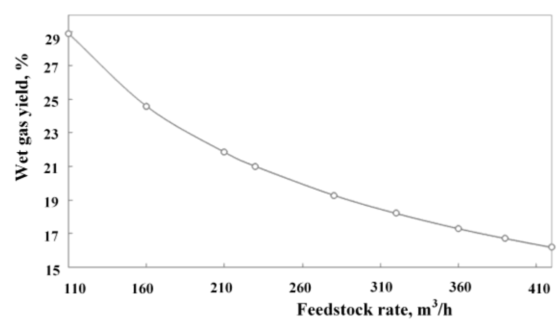

Fig. 3. The dependence of the wet gas yields from the feedstock rate

Case 2. The effect of raw material consumption on the material balance of the process

It is necessary to determine to determine how to change the yields of products (gasoline, light catalytic gas oil, heavy catalytic gas oil, wet gas (gas and reflux) and coke) for a change in the consumption of raw materials (working range of changes of consumption of raw materials 130-420 m^3/h, according to the technological regulations) (Fig. 4).

Case 3. The influence of raw material composition and temperature on the material balance of the process

It is necessary to determine the temperature of the process necessary to maintain the yield of gasoline fraction at the level of a 59.42% and the octane number 91.98, changes in the composition of the *raw material 1 in 2*. The compositions of raw materials are given and the parameters of the process mode are given in the tables. The parameters of the technological mode must be maintained at a constant level (Tab. 1).

Table 1. Initial data for model-based calculations

The parameters of the technological mode		
Raw material consumption, m^3/h		378.22
Slops consumption, m^3/h		9.23
Density g/cm^3		0.90
Total steam flow to the reaction zone, kg/h		7898.04
Temperature at the separator outlet, °C		521.40
Reactor inlet temperature, °C		303.70
Pressure, kg/cm^2		1.44
The compositions of raw materials for the calculation in case 3 and 4.		
Hydrocarbon group	Raw material 1, wt. %	Raw material 2, wt. %
Saturated hydrocarbons	69.32	58.00
Aromatic hydrocarbons	27.68	38.00
Resins	3.00	4.00

Case 4. Study of the influence of the composition and consumption of raw materials on the material balance of the process

The parameters of the technological mode are presented in Tab. 2.

Table 2. The parameters of the technological mode according to the case 4

	Raw material 1		Raw material 2	
Component	Flow rate, t/h	Yield, %	Flow rate, t/h	Yield, %
Unstable gasoline	163.74	59.42	155.68	56.50
Light catalytic gasoil	30.95	11.23	35.03	12.72
Heavy catalytic gasoil	22.96	8.33	26.81	9.73
Wet gas	47.70	17.31	44.03	15.98
Coke	10.20	3.70	13.98	5.07

Raw material 1 of catalytic cracking mainly consists of paraffin and naphthenic hydrocarbons (69.32 % by weight.), the content of resins and aromatics is lower (30.68 % by weight.). The yield of unstable gasoline on favorable raw materials is 59.42 % and its RON is 91.98. On unfavorable raw materials, which mainly consists of aromatic hydrocarbons and resins – 42 % by weight. (RON – 90.24).

If we go to the conventional units, which are defined as the product of the octane number of gasoline output, it is possible to conditionally assess the economic efficiency of forecasting the composition and quality of products. For favorable *raw materials 1*, this indicator 5465.45, and adverse raw material 5098.56.

4. Conclusions

The following results were obtained:

Reduction of capital and operating costs, due to forecasting and planning of the optimal operation mode of the industrial plant and formulations of mixing of commercial products, taking into account the basic physical and chemical properties, as well as research on the effect of technological parameters on the composition and quality of products using the simulator – 2-3%.

Improved knowledge, skills and competencies of staff, use of software to enhance the speed of response personnel of process plants with detection of faults and emergency situations (the use of the simulator as a data source) – 1 %; improved quality of personnel training technological peculiarities and regularities of the plant and as a consequence.

Increase in the depth of orientation and degree of readiness for emergency situations – 1 %; high degree of readiness for the implementation of the plan of localization and liquidation of emergency situations, based on knowledge of the sources and causes of emergency situations, a step-by-step analysis of their development and analysis of the actions of production personnel for localization and elimination of emergency situations, worked out with the use of computer simulators (reducing the risk of emergency situations and, respectively, reducing the cost of equipment restoration and downtime) – 5%.

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