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Control of the process of vacuum gasoil catalytic cracking in terms of aerosol nanocatalysis technology

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Summary. The article considers control of the process of catalytic cracking of vacuum gasoil. Authors suggest a block diagram of automatic control system of catalytic cracking reactor by aerosol nanocatalysis to stabilize oscillation frequency and temperature in the reactor.

Key words: catalytic cracking, aerosol nanocatalysis, scheme, control.

INTRODUCTION

Currently, catalytic cracking is the most promising and important process of oil refining. Catalytic cracking in terms of nanocatalysis aerosol technology (AnC) with vibration liquefied layer is a promising area of oil production. One of the major challenges faced by every production is steadily improvement of product quality, increasing efficiency and reducing costs. This can be solved by improving existing and developing new control systems, establishment of adequate mathematical models, application of modern methods of optimal control [1-5].

Thus, the purpose of this article is to develop an automatic control system of catalytic cracking process using aerosol nanocatalysis technology.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Cracking reactor of AnC technology, considered in this article, can be attributed to devices with vibration liquefied layer. The feature of such devices, as of reactors with mechanical stirring, bubbling devices and pseudofluidized-bed reactors, is the stochastic motion of discrete phase in volume of apparatus and intensive fluctuations of different types [6-9].

Vacuum gasoil and catalyst are supplied to catalytic cracking reactor by aerosol nanocatalysis technology. The catalyst undergoes continuous techno chemical activation in situ by forced mechanical vibrations of inert dispersing material. There occurs constant grinding of coagulated catalyst particles to the nanoscale and maintenance of high activity for an unlimited time [10]. Formed catalyst particle acts as an acid catalyst for cracking of vacuum gasoil, as a result high-octane gasoline fraction and diesel, gas fraction and coke are being obtained. Reaction’s products and catalyst are derived from techno chemical activation zone, the catalyst is separated and sent for recycling and regeneration, and the products of reaction are sent to the rectification.

Numerous studies have found that varying of techno chemical activation frequency can change characteristics of process of catalytic cracking, including speed of the process and mechanism of chemical reactions, which in principle can increase selectivity of targeted responses by changing processes of energy metabolism and force interactions at micro level [11]. In fact, hydro mechanic processes in vibration liquefied layer determine the effectiveness of chemical-technological process in general to some extent. Mathematical modeling of such processes are carried out with a view to optimizing and using it to build an automatic control system [12-15].

The difference of nanocatalysis aerosol technology is the lack of a carrier for catalytically active substance [10]. The catalytic system includes dispersing material - glass beads - acting as techno chemical activation of catalyst particles located in reactor, and mixing reagents. Original size of catalyst particles is 200 microns. Working size in continuous techno chemical activation is 8-100 nm. Lack of carrier and high activity of a large number of nanoparticles of catalytically active component cause lack of diffusion braking and increase of speed in cracking reactions in 10^4- 10^6 times (for different catalysts and modes) per weight of catalyst. Thus, in terms of AnC technology, there are additional factors of catalyst activity control (original catalyst concentration, size of dispersing material, intensity of techno chemical activation, etc.) that in the processes of heterogeneous catalysis are included in speed constant due to impossibility of their rapid change, or because of the absence of this factor in the process.

Research of vacuum gasoil catalytic cracking [16] in terms of AnC technology showed the possibility of increasing reaction rate up to 10 times per reaction volume, causing a corresponding decrease in equipment size. Required amount of catalyst in terms of 2 g/m^3 reactor to 300-700 kg/m^3 in heterogeneous catalysis causes decrease in the required volume for regeneration of catalyst in almost 2000 times. Thus, if in industrial heterogeneous processes of catalytic cracking the ratio reactor: regenerator is 1:1.2-1.5, in AnC technology it changes to 1:0,001. In addition, deposition of coke on the catalyst surface that deactivates it in industrial processes for 1-2 seconds of work, in AnC technology it does not happen due to constant techno chemical activation. Coke moves parallel to catalyst nanoparticles by cycle "reactor-regenerator". But on leaving the reactor, there is still a need for oxidation of coke in order to separate it from catalyst and get heat, necessary for cracking reactions flow in reactor. All these factors require an original approach to organization of automatic control of catalytic cracking process using aerosol nanocatalysis technology.

THE MAIN RESULTS OF THE RESEARCH

One of the areas of AnC technology development is aerosol nanocatalysis in vibration liquefied layer of AnCVB catalyst, for which there has been proposed the following industry scheme (Fig. 1) [17]. In the proposed scheme, vacuum gasoil heated in the oven O, falls into reactor R, which represents the vibration mill. From the reactor, reaction products come to the cyclone C, where they are separated from catalyst dust and coke. The catalyst enters the coke hopper, after which returns to the process. Besides, supply of fresh catalyst is provided. Reaction products enter the distillation column DC, from which part of the heavy distillate is recirculated.

Experimental studies have shown that the quality of initial products of catalytic cracking process of vacuum gasoil under AnC conditions is mainly influenced by both the catalyst type and reactor oscillation frequency, which affects the intensity of techno chemical activation, and by the temperature of catalytic system in the reactor.

Currently existing control systems of liquid reactors [18-21] do not allow implementing all the features and advantages of AnC catalytic cracking technology in full. In this regard, there has been proposed the following structure scheme of automatic control system of catalytic cracking reactor with aerosol nanocatalysis (Fig. 2). The main parameters subjected to stabilizing are reactor oscillation frequency S and reactor temperature T.

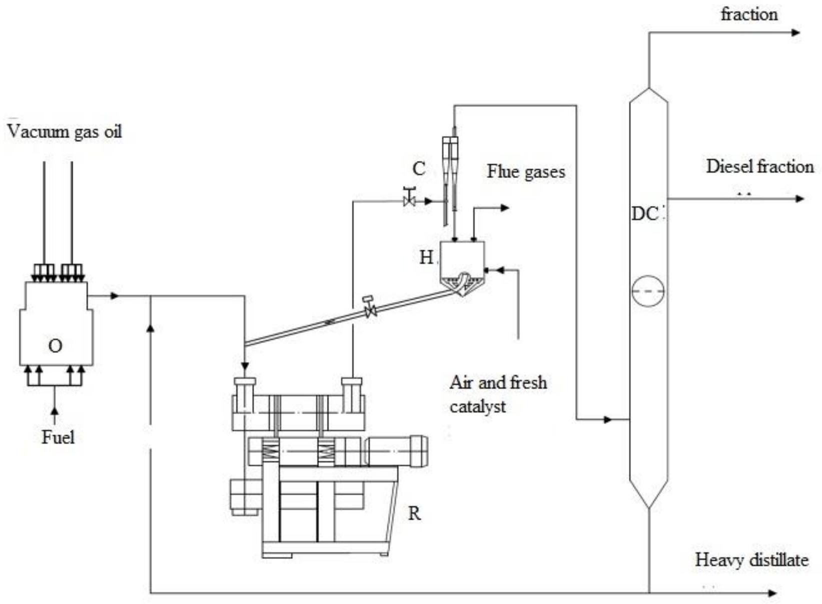

Fig. 1. Industrial scheme of process of catalyst cracking with aerosol nanocatalysis in vibration liquefied layer of catalyst.

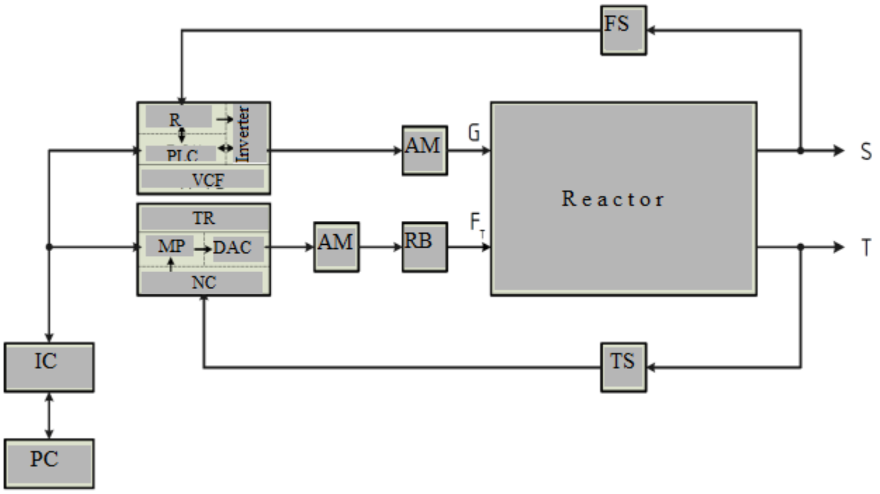

Fig. 2. Structure scheme of reactor automatic control system of catalytic cracking process with aerosol nanocatalysis

Stabilization of reactor oscillation frequency S is performed by circuit, which consists of frequency sensor FS, vector frequency converter VFC and asynchronous motor AM. Frequency sensor determines the frequency at which the reactor varies and transmits this value in the form of unified signal to vector convector of frequency VCF. Uniform signal from the sensor enters controller C of vector frequency converter VFC, where by the appropriate regulation law and current value of oscillation frequency S, happens control of VFC inverter. Inverter, depending on the chosen method of motor control (scalar or vector) and signal from regulator R, generates harmonic currents (voltage) of AM electric motor phases and controls its magnetic flux of rotor (only for vector control method). Asynchronous motor AM, depending on control action of VFC inverter, rotates with appropriate frequency G, which allows bringing to action the mechanism that shakes reactor with inflicted frequency. Programmable logic controller PLC VFC allows control of electric motor in different modes ("Automatic control", "Manual control", "Start", "Stop", "Pause", "Speed Up", "Speed Down", etc.), monitor the status of VFC nodes.

Stabilizing temperature in reactor T is performed by circuit, which consists of temperature sensor TS, temperature regulator TR, actuator mechanism AM and regulating body RB. Temperature sensor TS determines temperature in the reactor, whose value in the form of electrical signal is supplied to normalizing converter NC of temperature regulator TR. After conversion, the signal from normalizing converter NC comes to microprocessor MP, where it is filtered, corrected, and digital control signal is generated according to appropriate regulation law. This digital control signal comes to digital-analog converter DAC of TR, where it is converted into analog control signal, which is sent to actuator mechanism AM. Actuator mechanism AM changes position of regulating body RB, which results in a corresponding change in heat consumption F_T and maintaining desired temperature in the reactor

Each stabilizing system is connected to automatic control system of catalytic cracking process with aerosol nanocatalysis, implemented in SCADA-system based on industrial PC computer. Connection between PC and contours of stabilization is carried out by using interface converter IC (eg, RS485 / RS232).

CONCLUSION

1. The block diagram of automatic control system of catalytic cracking reactor with aerosol nanocatalysis to stabilize oscillation frequency and temperature in the reactor is developed.
2. The proposed automatic control system of catalytic cracking process with aerosol nanocatalysis will allow accurate maintaining of the required quality of initial products of catalytic cracking and reduce consumption of heat and electricity through the use of modern means of automation.

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УПРАВЛЕНИЕ ПРОЦЕССОМ КАТАЛИТИЧЕСКОГО КРЕКИНГА ВАКУУМНОГО ГАЗОЙЛЯ В УСЛОВИЯХ ТЕХНОЛОГИИ АЭРОЗОЛЬНОГО НАНОКАТАЛИЗА

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Аннотация. В статье рассматривается управление процессом каталитического крекинга вакуумного газойля. Предложена структурная схема автоматической системы управления реактором каталитического крекинга аэрозольным нанокатализом для стабилизации частоты колебаний и температуры в реакторе

Ключевые слова: каталитический крекинг, аэрозольный нанокатализ, катализатор, схема, управление.