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Improvement of Devices in the Development of Catalytic Cracking Process in Azerbaijan

Abstract

The catalytic cracking process was first applied on an industrial scale in 1936 and has been an important process in the oil refining industry of many countries since then.

Among the catalytic processes proposed for the processing of oil fractions in Azerbaijan, the catalytic cracking process occupies one of the first places due to its importance.

The achievements achieved in the catalytic cracking process in the late 20th and early 21st centuries are determined by 88 years of development experience, technical and economic indicators of the market economy and oil refining enterprises. This fact requires constant improvement of the technology of the process and catalysts in order for it to take a comprehensive place among the oil refining processes and become multi-directional.

The development of the catalytic cracking process in industry is based, first of all, on the fundamental work of the Russian scientists in the field of catalytic conversion of hydrocarbons, which belongs to the school of academician N.D.Zelinsky and academician S.V.Lebedev. These works include the work of S.V. Lebedev and his students in the field of contact-catalytic polymerization and depolymerization of olefins on active aluminosilicates, the work of N.D.Zelinsky and other leading scientists of his school on the development of theoretical problems of catalysis .

L.G.Gurvich, S.V.Lebedev N.D.Zelinsky's research gave rise to the practical application of aluminosilicate catalysts in the conversion of hydrocarbons. These works were carried out before the first works on the catalytic cracking process on natural and synthetic aluminosilicates were published abroad.

The rapid development of the catalytic cracking process has created conditions for the successful combination of a wide range of processing capabilities for a wide range of raw materials, from light distillate fractions in the process to heavy vacuum gas oils and even residual fractions of oil. The results of research on the development of catalytic cracking systems with rising catalyst flow at the Institute of Petrochemical Processes named after academician Y.H. Mammadaliyev of ANAS (NKPI) were first presented at the Ufa All-Union meeting in July 1963.

The first monograph devoted to this issue was published in 1966 (Aliyev, Rustamov, Pryanikov, 1966). This monograph describes the scientific foundations of catalytic cracking in direct and partially counterflow systems, the indicators of the catalytic cracking process in various modified systems with rising flow.

Based on the research conducted by scientists of the National Research Institute of Chemical and Petroleum Engineering of the Azerbaijan Academy of Sciences, information is provided on the reconstruction of catalytic cracking units with finely dispersed catalysts at the refinery using direct and partially counterflow reactors.

In 1982, academicians Aliyev V.S., Rustamov M.I. Pryanikov E.I. received the Azerbaijan State Prize for the application of the two-stage catalytic cracking process of oil raw materials to industry (Aliyev, Rustamov, Pryanikov, 1966: 5-15).

Keywords: *Catalytic cracking process, oil wells, fluidized bed, small-dispersed catalyst, catalytic cracking units, improvement of catalytic cracking units*

Introduction

The catalytic cracking process was first applied on an industrial scale in 1936 and has been an important process in the oil refining industry of many countries since then.

Among the catalytic processes proposed for the processing of oil fractions in Azerbaijan, the catalytic cracking process occupies one of the first places due to its importance.

The achievements achieved in the catalytic cracking process in the late 20th and early 21st centuries are determined by 88 years of development experience, technical and economic indicators of the market economy and oil refining enterprises. This fact requires constant improvement of the technology of the process and catalysts in order for it to take a comprehensive place among the oil refining processes and become multi-directional (Problemi, 2000).

The main stages of development of the catalytic cracking process are as follows:

- transition from stationary catalyst layer catalytic cracking to cracking with a false layer of microspherical catalyst;
- development of a zeolite catalyst;
- hydrotreating of raw materials;
- cracking in a high-flow microspherical catalyst lift reactor;
- catalyst regeneration in a regenerator with complete combustion of CO to CO_2.

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The catalytic cracking process of petroleum raw materials has undergone major changes in terms of equipment and technology up to the present time.

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Research

In the development of the catalytic cracking process in Azerbaijan, catalytic cracking units, which play a key role in this process, play an important role. These units have been improved over time. Let's look at how these units have improved below (Kon, Zelkind, Shershun, 1968: 100-111).

The first industrial catalytic cracking unit with a circulating dust catalyst of the "model 1" type, the diagram of which is shown in Fig. 1, was put into operation in 1942.

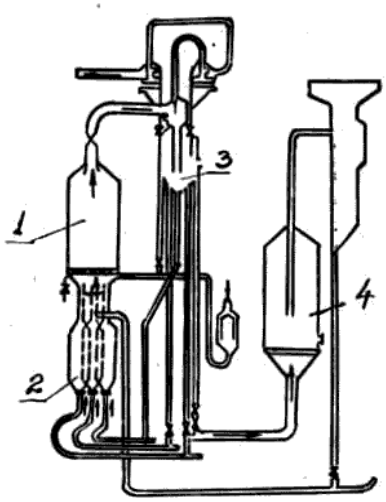

Fig.1. Schematic diagram of the installations.
Model 1. 1-Regenerator, 2-cooler for the regenerator, 3-bunker, 4-reactor

In this installation, the entire mass of circulating powdered catalyst passed through the reactor and regenerator from the bottom up and was discharged entirely from the top of these devices in a mixture with gaseous reaction products. The most characteristic feature of model 1 installations is the upper discharge of circulating catalyst from the reaction devices. The flow of air or oil vapors is separated from the catalyst in cyclone separators. These units are interesting not only as the first industrial units with a finely dispersed catalyst, but mainly because the reaction and regeneration here are carried out under flow transport conditions at relatively high densities of the gas catalyst flow. Consequently, the principles of catalytic cracking in this unit are substantially the same as those of contacting and reactions in a fluidized bed.

In 1951, after the reconstruction of one of the units of the model, its capacity was increased to 7,000 tons of raw materials per day. Judging by the literature, model 1 units were not widely used and were replaced due to the following main disadvantages inherent in them:

• Significant length of catalyst wires and high hydraulic resistance of the catalyst circulation system.

• The need to use large cyclone separators designed to capture the entire amount of circulating catalyst.

• Increased catalyst wear and, consequently, its high consumption.

• The bulkiness of the installation and its insufficient operational flexibility. The height of this installation reached 70 meters. The next step in the development of catalytic cracking technology was the appearance of installations of the model 11 type, the diagram of which is shown in Fig. 2.

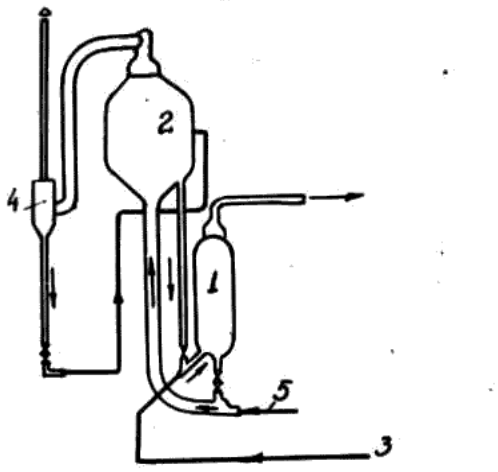

Fig. 2. Schematic diagram of the installations
Model 2. 1- Reactor, 2- Regenerator, 3- Raw material, 4- Electrostatic precipitator, 5- Air

A characteristic feature of these units was the introduction of the hydrodynamic regime of a boiling bed of finely dispersed catalyst with a downward catalyst flow into the practice of catalytic cracking. In other words, in these units the gas velocity in the reactor decreased, as a result of which the solid phase was concentrated in the gas flow, forming a dense turbulent layer with a sharply expressed upper level. Thus, here only an insignificant part (approximately 5%) of the total amount of circulating catalyst enters the cyclones for dust collection and the main part of the catalyst is in the devices.

As a result of the transfer from top to bottom of the place of catalyst output from the reactor and regenerator and the simultaneous reduction of speeds in these devices, the catalyst circulation scheme was simplified, and the hydraulic resistance of the system was reduced.

Both this made it possible to reduce the overall height of the unit to 50-55 meters, reduce metal consumption, and reduce the size of capital costs and operating costs. However, the height of the unit still remained large. The improvement of catalytic cracking units with the aim of reducing their initial cost and operating costs by reducing the height led to the development of the Model III unit, the schematic of which is shown in Fig. 3.

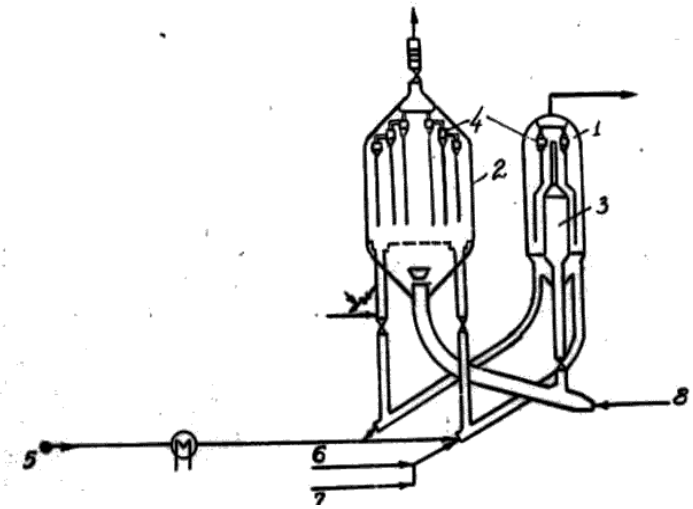

Fig. 3. Basic technical diagram of the installations.
Model 3 1- Reactor, 2- Regenerator, 3- Steam separator, 4- Cyclones, 5- Raw material, 6- Water vapor, 7- Risauk, 8- Air

The characteristic difference of this installation is the location of the reactor and regenerator on the same level, the reduced volume of the regenerator and the fact that it has a lower height - 37-40 m. All this was achieved due to a slight increase in pressure in the regenerator. In the series of model installations, the last are theinstallations of model IV, the basic diagram of which is shown in Fig. 4.

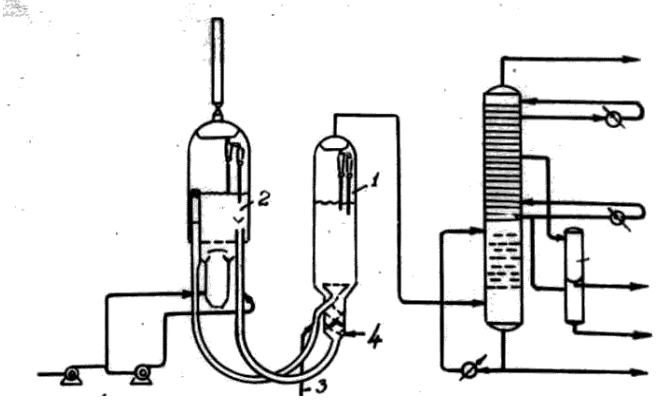

Fig.4. Schematic diagram of the installations.
Model 4. 1- Reactor, 2- Regenerator, 3- Raw material, 4- Air
Model IV resembles model III in its arrangement of equipment.

The implementation of catalyst transport in a dense layer along U-shaped catalyst pipes allowed the "model IV" type units to have all the advantages of "model III" type units without increasing the pressure of all the air supplied to the regenerator.

In model IV units, the intensity of catalyst circulation between the reactor and the regenerator is regulated mainly by changing the equality of flow densities by supplying a larger or smaller amount of air to the upper section of the spent catalyst pipeline.

The velocity of gas movement in the reactor and regenerator is approximately twice as high here as in model III units, and boiling layers in the units are formed at the maximum permissible velocities of gas-steam flows.

In addition to the above-considered cracking units of the model series, units of other types have also found industrial application. First of all, these include the Orthoflow type units and those of Union Oil Products (UOP) (Ismayilova, 2008, 126-127).

Both of the named types of installations are distinguished by the use of a combined apparatus, in which the reactor and regenerator are enclosed in a common housing, and the Orthoflow type installations have two models - "A" and "B", which are aligned in the mutual arrangement of the reactor and regenerator.

Fig. 5 shows the diagram of the Orthoflow installation of model "A", and Fig. 7 and model "B" .

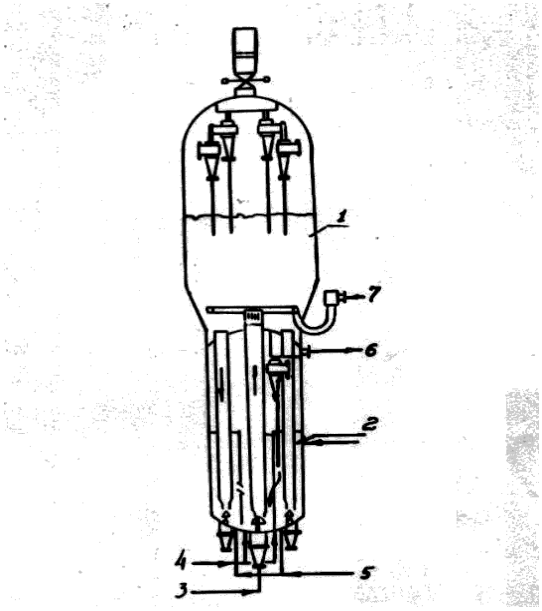

Fig. 5. Basic-technical installation of catalytic cracking orthoflow scheme "A" type
1-Reactor, 2-Regenerator, 3-air, 4-Steam, 5-Raw material, 6-catalyst, 7-air

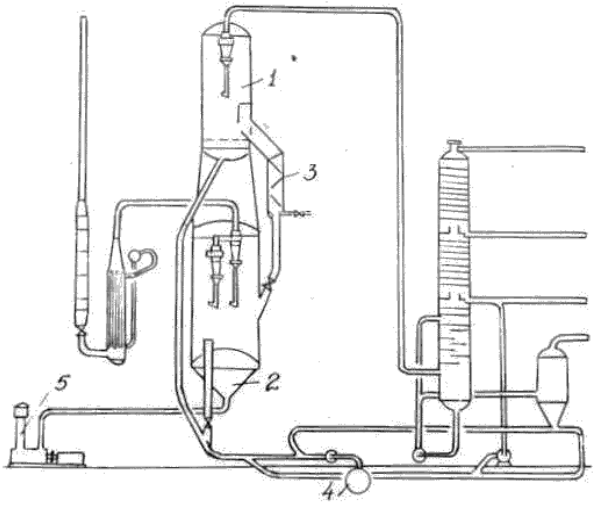

Fig. 6. Basic technical scheme of the UOP type installations.
1-Reactor, 2-Regenerator, 3-Stripping section, 4-Raw material, 5-air

When considering both schemes, it is necessary to note the original design layout and compactness of the design. The main advantage of this type of installations is the use of a vertical (without bends and turns) catalyst pipeline, which minimizes abrasive wear of the equipment.

In addition to the original design solution of the general layout of the system, Orthoflow installations differ from other installations by the presence of a direct catalyst flow without the use of a driving agent from the reactor to the regenerator for model "A" and from the regenerator to the reactor for model "B".

There is an indication in the literature that from a mechanical point of view it is easier to place the reactor under the regenerator, since the diameter of the regenerator is larger.

This principle is the basis for the modern version of the catalytic cracking process in a boiling bed of the company "UOP". A typical diagram of one of the installations of this company is shown in Fig. 6. In these installations, like Orthoflow installations, the principle of direct catalyst flow from one device to another is preserved. At the same time, the lifting catalyst pipeline in these installations is curved. In addition to the listed installations with a boiling bed of finely dispersed catalyst, a number of other installations are known abroad. For example, there is an installation in which the spent catalyst enters the regenerator not directly from the reactor but through a pressure bunker-separator and the coked catalyst is transported not by air but by water vapor. However, due to the fact that their total number is small and they represent only a modification of the installations described above, we will not dwell on them. At the same time, we note that we deliberately did not touch on industrial installations, although few, but described in the literature, in which a tendency to intensify the catalytic cracking process is outlined. These are installations for 2-stage cracking and with a sectioned boiling bed. These units will be discussed below (Ismaılova, 2024).

At the end of the 20th century, in the research conducted in the field of catalysis, a relationship was established between the surface properties of celite-containing catalysts, coking, and the influence of this factor on the activity and selectivity of the catalytic cracking process. A distinctive feature of the studies was the study of these patterns in the first seconds of contact of the feedstock with the catalyst.

The results obtained made it possible to model the catalyst by the height of the reactor and regulate the surface properties of the catalyst by its coking. This became the scientific basis for the creation of a technology for processing unstable gasolines and were confirmed during the processing of pyrocondensate at the G-43-107 catalytic cracking complex (Rustamov, 2006).

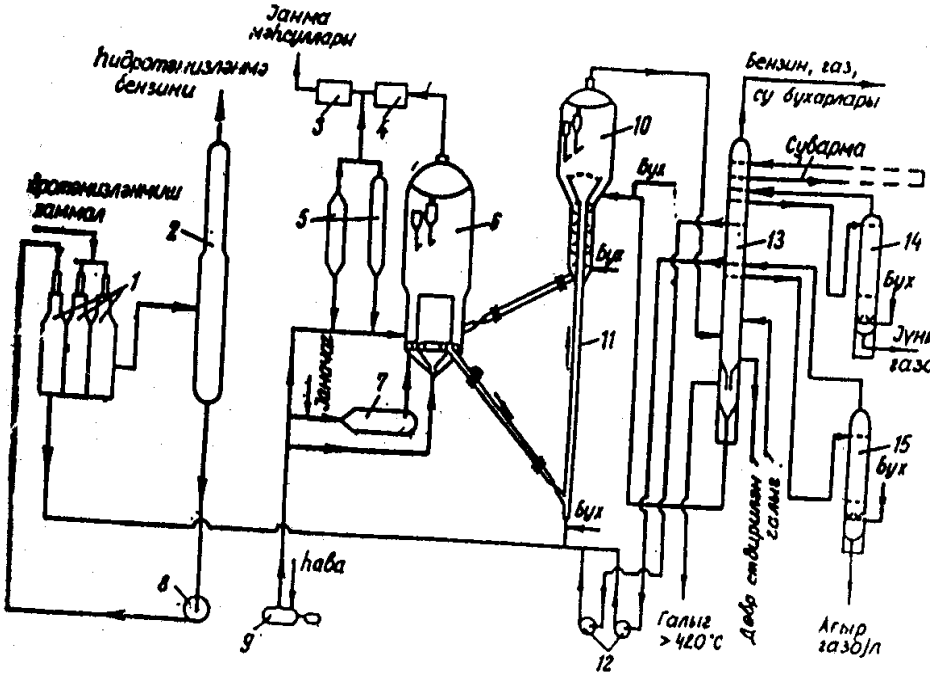

Fig. 7. G-43-107 catalytic cracking unit

The table presents data characterizing the distribution of some of the above-described units in the USA, their process parameters, characteristics of raw materials and products obtained.

To summarize the above, it becomes obvious that since the start-up of the first units, the design of the devices and units as a whole has been significantly improved. As a result of this improvement, the units have become much simpler and more compact.

Ultimately, the need for metal for the construction of units and their cost is currently approximately three times less than for the first catalytic cracking units.

The main improvement of the units was aimed primarily at reducing the cost of the process by reducing capital investments and consisted of the following:

- the catalyst capture system has been simplified;
- the dimensions of the units have been reduced and the overall height has been reduced;
- the catalyst circulation system has been simplified and made more compact;
- the layout of the units has been improved;
- the productivity of the units has been increased.

However, this improvement did not have any significant effect on the essence of the process itself and the yield of target products (as can be seen from the table), therefore, along with the above improvement of the units, a lot of work was done to further develop the catalytic cracking process. The most important moments in the development of the process were the work on deepening the process, involving high-boiling gas oil fractions for cracking, developing new types of catalysts, etc. At that time, as a result of generalizing a large number of research works and accumulated experience in the operation of units with a boiling catalyst bed, serious shortcomings inherent in this method of contacting were revealed. It was necessary to outline ways of further intensifying the process based on a deep study of the catalytic cracking process occurring in hollow contactors using a boiling bed of finely dispersed catalyst (Ismayilova, Gasimzade, Huseyinova, 2008: 52-56).

Academician M.I. Rustamov, together with GrozNI II and VNNII NP, developed a new catalytic cracking complex Q-43-107, which is distinguished by its higher productivity and metal capacity, using rising-flow reactors. The Q-43-107 unit is a combined unit that includes a vacuum gas oil hydrotreating unit, catalytic cracking of hydrotreated vacuum gas oil in a vertical lift reactor, and gas fractionation. This system is very effective, as it allows using all the advantages of zeolite-containing catalysts, providing high yields of gasoline, propane, propylene, butane and butylene fractions. Currently, the Q-43-107 unit has been successfully used at oil refineries in Moscow, Mozheyky, Burgas, Ufa, Pavlodar, Angarsk, Lisichansk. One of the technical specifications of the process has been sold abroad under license. Over the past 3 years, the use of the Q-43-107 complex in Baku has brought 750 billion manats to the state budget. According to European experts, at present this facility is on a par with its foreign counterparts and is the only facility in the former USSR oil refineries that does not need any serious modernization (Ismaılova, 2024).

Conclusion

The results of numerous scientific research works of Azerbaijani scientists were the first experimental-industrial catalytic cracking unit with a circulating finely dispersed catalyst, which was put into operation in Baku in the middle of the 20th century. Based on the experimental results obtained, it was recommended to design the first industrial catalytic cracking unit of oil raw materials with a powder catalyst. Here, the kerosene-gasoil fraction of Baku oils boiling at a temperature of 200-350 ^{0}C was used as raw material.

The technology of the catalytic cracking process developed by Azerbaijani scientists made it possible to solve the problem of high-quality gasoline production. This technology found wide application in the former USSR and abroad. The product of the catalytic cracking process was gas, which, along with high-octane gasoline, was a valuable raw material for petrochemical synthesis.

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