AZƏRBAYCAN RESPUBLİKASI ELM VƏ TƏHSİL NAZİRLİYİ

AZƏRBAYCAN DÖVLƏT NEFT VƏ SƏNAYE UNİVERSİTETİ

MINISTRY OF SCIENCE AND EDUCATION

REPUBLIC OF AZERBAIJAN

AZERBAIJAN STATE UNIVERSITY OF OIL AND INDUSTRY

“NEFTİN, QAZIN GEOTEXNOLOJİ PROBLEMLƏRİ VƏ KİMYA”

ELMİ-TƏDQİQAT İNSTİTUTUNUN

ELMİ ƏSƏRLƏRİ

SCIENTIFIC PROCEEDINGS

SCIENTIFIC RESEARCH INSTITUTE

“GEOTECHNOLOGICAL PROBLEMS OF OIL, GAS AND CHEMISTRY”

VOLUME 23 Number1

BAKU-2023

ISSN 2218-5054

Scı. Proc. SRI GPOGC. 2023. Volume 23, Number 1

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Study of the designs of devices for centrifugal extraction

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Abstract

This article provides an overview of centrifugal extractors of various configurations, their advantages are noted advantages and disadvantages. It is noted that, despite the variety of types of

extractors, there are few generalized studies on optimization presented in the scientific literature. Methods for increasing the efficiency and productivity of existing structures are proposed.
***Keywords**:* centrifugal extraction, devices optimization, sectional rotor, annular chamber.
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1. Introduction

The development of methods of separation and purification of substances is motivated by the needs of the petroleum, chemical and pharmaceutical industries. One of the promising methods of separation of mixtures is extraction.

Currently, many extractor designs have been developed that are used in various industries, which is explained by the variety of types of raw materials used and various technological requirements for extraction process. The choice of the optimal design of the apparatus for certain processes of the chemical, petrochemical industry should be based on a comparison of the technical and economic indicators of extractors with its performance, degree of separation, as well as various kinds of costs for its manufacture, operation and maintenance.

2. Methodological part

Extraction devices used in the chemical industry can be divided into several groups: differential contact, stepped and structures occupying an intermediate position. The first group includes, as a rule, column apparatuses, which are distinguished by a constant contact of phases and a smooth change in the concentration of the extracted component along the height of the apparatus. Their compactness, due to their vertical location, allows them to be used in conditions of limited production space, but as a result of longitudinal mixing caused by axial convective flows, turbulent pulsations and stagnant zones, it is possible to reduce the average driving force.

Multistage extractors are usually vertical columns divided by various contact devices into sections or so-called theoretical stages, at each of which the initial solution and extractant are repeatedly mixed and delaminated. The efficiency of these devices is estimated by the efficiency of individual stages or the height of the device equivalent to one equilibrium stage — the theoretical plate.

According to the type of process, extractors can be divided into periodic and continuous devices. In batch extractors, the process is usually carried out in a stationary layer, in which the filtration rate of the extractant, porosity and pressure drop, which creates a driving force, change over time. Often, to increase the filtration rate of the extract, the pressure drop in the apparatus is increased, which, in turn, leads to compression of the material layer in the apparatus and deterioration filtering. An excessive increase in the pressure drop can lead to the termination of the filtration of the extract in the layer. The same phenomenon is observed in continuous vertical type devices without the use of special transporting devices.

To devices occupying the intermediate position between step devices and devices of differential contact type include centrifugal extractors in which stirring followed by phase separation, occurs under the influence of centrifugal forces. How typically, the extractor rotor is set of perforated cylinders, spiral tapes, etc. Through contact devices that increase the phase contact surface to the periphery from the center moves the heavier phase, and more light phase - in the opposite direction, thus the extractant and the original solution move towards each other. Phase dispersion (and redispersion subject to recycling) - when passing through contact devices.

Among the devices for performing centrifugal extractions are distinguished in discrete-step (or chamber) and differential contact. Discrete-stage ones consist of individual workers volumes, in each of which phases moving countercurrent, first mixed, then are separated. In this case, the mass transfer process occurs under conditions close to constant contact moving towards one another phase flows; direction of movement is determined channels formed by internal devices rotor.

Centrifugal extractors are distinguished by significant productivity (flow rates can be several hundred m^3/h) and high efficiency (small number of theoretical stages), as well as short duration of phase contact, as a result of which mass transfer processes in the apparatus occur very intensively. The listed advantages make it possible to use these devices in the production of unstable compounds, when working with radioactive solutions and stable emulsions, and when separating systems whose components have similar densities. Centrifugal extractors are advisable use for systems that require little time phase contact or having a small difference specific gravity. When comparing performance column countercurrent extraction devices with centrifugal extractors, then in the first case the intensity is limited mainly by the rate of deposition or rise of droplets of the dispersed phase, and in the second, it is limited by the speed of movement of the droplets in the direction of the radius. Ponikarov I.I. and Bochchachev V.G. in their study [1] provide a comparative analysis of the rate of sedimentation of droplets in a liquid in a gravitational field, calculated approximately using the Stokes equation, and the speed of movement of droplets in a liquid in a field of centrifugal forces. From the analysis of the results obtained and comparison of these speeds, it follows that the speed of drops moving under the influence of centrifugal forces will be greater than their speed in the gravitational field. Thus, the centrifugal field has a number of important advantages compared to gravity, which represents present ample opportunities for intensification extraction process in the apparatus. A more detailed development of this advantage will make it possible to develop centrifugal extractors that can be successfully used for other extraction systems that occur without chemical reactions, and be competitive in comparison with gravity-type devices.

Currently, there are a large number of different designs of centrifugal equipment, most of which have found widespread application in various technological processes in the chemical, food and oil refining industries industries. However, the variety of types and types of existing contact devices centrifugal extractors complicates them somewhat correct choice and rational use. In view of this, work is required not only to categorize and classify devices, but also to generalize methods for optimizing the structure of radial flows inside the rotor, to correctly solve the problem of increasing the efficiency of devices and optimizing structural and technological parameters.

Quite often, researchers achieve increasing the efficiency of centrifugal extractors by changing the design of the nozzles used, installing additional internal devices in them that intensify the mass transfer process. However, such modifications, as a rule, complicate the design of the apparatus and are based on the “design considerations” of the designer without taking into account the influence of hydrodynamic parameters; they do not have universal application, but are suitable only for solving a particular problem of optimizing an apparatus of a certain design. When solving the problem of increasing efficiency, it is necessary to take into account that the angular velocity changes along the radius of the apparatus and the free cross-section of the nozzle increases, which leads to a decrease in holding capacity and affects the mass transfer coefficient. To reduce the influence of these effects, recirculation, countercurrent movement and multiple phase dispersion.

Continuous is considered the most effective extraction carried out in multi-stage extractors with countercurrent of the initial solution and extractant. In this case, the specified degree of extraction is achieved with the lowest extractant consumption. If it is necessary to recirculate the extractant with a rotating rotor or increase the phase contact time in centrifugal extractors, an input and output unit is provided phases implemented in the form of suction tubes or disks (Fig.1). Disadvantages include longitudinal mixing, which has not yet been sufficiently studied. Currently, methods for studying this phenomenon are being considered and evaluation for different extractor designs.

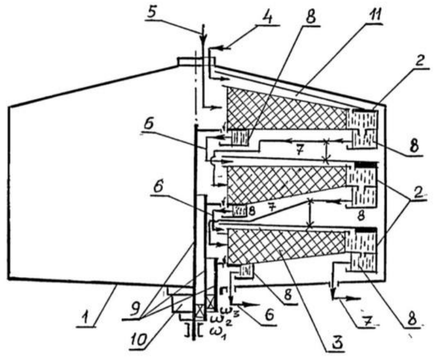

Fig. 1 – Schematic diagram of cascade extractor

The apparatus shown in Figure 1 consists of non-rotating housing 1; sectioned rotor 2 with nozzles 3; liquid input and output devices made in the form of tubes: for supplying light 4 and heavy phase 5 and sampling tubes, 6 and 7, respectively; overflow ring chambers 8; coaxial shafts 9 and bearing unit 10; circular slot for supplying the light phase to the periphery 11.

To create favorable conditions for phase selection from sections and improve separation, it is proposed to vary the speed of rotation of the sections and their sizes. Sections are provided with individual drives, the number of revolutions of which is determined from the condition of optimization of individual processes: extraction carried out at 1500-2000 rpm, separation – at 3000-5000 rpm, etc.

This design solution (cascade extractor) allows you to expand the range of processed liquid mixtures and implement a more efficient mode of movement of liquids in sections, resulting in increased productivity and efficiency of the apparatus.

The device shown in Figure 2 contains fixed housing 1 with cover 2; rotor 3 with cover 4; extraction container 5 with collar 6 and sleeve 7; a conical glass 8 and an extract collector 9, installed coaxially with the rotor 3. A gap is formed between the extraction container 5 and the conical glass 8 to drain the extract. On the outer surface of the sleeve 7 there are grooves 10 for draining the extract into the extract collector 9. The rotor cover 4 is made in the form of an annular chamber in which a suction tube 11 is located, connected to a fitting 12, movably fixed in the housing cover. Rotor 3 is equipped with a drive 13.

The technical solution to the problem posed to the authors is that the centrifugal extractor, in addition to a vibration-driven mixer, was additionally equipped with a conical glass installed with a gap between the extract collector and the extraction container, which made with a sleeve with grooves for draining the extract. In turn, the rotor cover was made in the form of an annular chamber equipped with a suction tube connected to the fitting, movably fixed to the housing cover. The extraction container is made with a collar, the annular channels of which form a labyrinthine device with a rotor lid, which further reduces the loss of extract during extraction with a suction tube.

It is worth noting that the intensification of the process extraction can be achieved by discrete-pulse energy input methods. Physical the essence of these methods is that the supplied energy is dissipated mainly near the surface of solid particles, and unproductive energy consumption outside these zones is minimal. Thus, mechanical vibrations provide continuous flow of liquid around solid particles with variable direction and magnitude of speed.

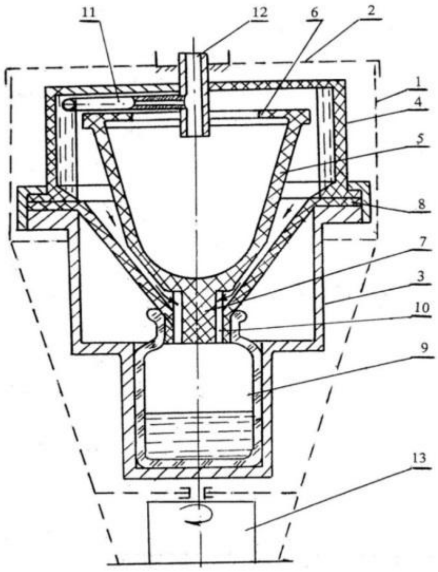

Fig. 2 - Schematic diagram of the extractor centrifuge

For creating vibrations, extractors with vibrating bodies and special vibrating devices installed in the apparatus itself are used. Latest they are used mainly in column or container type extractors. Experimentally it has been proven that the application of vibration fields of different frequencies and amplitudes significantly accelerates mass transfer and increases the productivity and efficiency of the apparatus.

2. Conclusions

1. Currently researched and developed a large number of various equipment using centrifugal forces to intensify various mass transfer processes, ranging from the simplest mixing devices to the most complex multi-module designs of centrifugal extractors.
2. The theory and practice of various mixers, separators and centrifuges are widely covered in the existing scientific and technical literature, however there are scattered data on centrifugal extractors, both on designs and on the results of theoretical and experimental studies, and they are presented mainly in individual dissertations and scientific articles.
3. Particular attention in the works of researchers is paid to the most promising designs of centrifugal devices, ways to increase the efficiency of existing devices by profiling rotors, sectioning packed devices and the use of packed elements that ensure the creation of an optimal flow structure and increasing the productivity of the device, as well as various ways of supplying energy.

Conflict of interest
The authors declare that they have no conflict of interest in relation to this research

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Hydrocarbon losses arising from phase transformations in field collection pipelines

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Abstract

In offshore fields, the quality indicators of the well product are subjected to change when it passes the initial preparation stage at the collection points and is transported to the shore. Researches show that most of the problems that arise in the collection points of fields operated in marine conditions are related to multi-component and multiphase flows. Contamination from the inner surface of the pipeline due to the internal phase transformations of the pipeline causes an increase in the operation and energy costs of the collection transport system. Blockages are formed in underwater pipelines when the liquid and mechanical particles in the transported gas are separated and settle inside the pipe.

Keywords: Carbohydrogen mixtures, multiphase, phase transformations, condensation, carbohydorgen losses, inner pipe separation.

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1. Introduction

The movement of gas and liquid phases that is a stratified flow form actually takes place in the gas pipeline. Separation of the liquid phase of hydrocarbon mixtures also causes certain errors in the measurement of the consumption of the transported gas. Thus, the existing international standards for measuring gas consumption are based on its monophase principles [1,2,3,4]. On the other hand, the presence of a liquid phase in gas flows causes pressure and consumption pulses. These harmful pulses cause pipelines to deform and fail prematurely [5,6].