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HYDRODYNAMICS OF FLUID TRANSMISSION CAPACITY OF BUBBLE EXTRACTOR FILTER

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Abstract
In the article, a new construction of filter bubble extractor is recommended, its construction structure and working principles are presented. As a result of theoretical studies, empirical equations for calculating the resistance coefficients of the filter and the equation for calculating the liquid permeability, i.e., the liquid speed, depending on these resistance coefficients and the density of liquid mixtures, were recommended. By determining this speed, it is possible to select and design the main parameters of the filter to ensure a stable, non-condensing flow of liquid phases in the mixing zones of the apparatus, and to determine the consumption of light and heavy phases supplied to the apparatus.

Keywords: bubbler, extractor, filter, contact surface, fiber material, base mesh, external mixing zone speed.

Introduction

In the worldscientific research is being carried out to create new designs of highly efficient extractors for liquid extraction processes, to increase the contact surface of liquid phases and to accelerate the mixing process. In this regard, the use of compressed gas energy, which is chemically inert to liquids, the improvement of drop crushing and mass exchange models according to the physico-chemical properties of liquid phases, the reduction of extractant consumption and stability in the stages of the device, the reduction of the number of stages , special attention is being paid to the creation of a new series of extractors capable of extracting high-performance metal and energy-saving, compact, various liquids [1,2].

Research Object

The main characteristic of bubble extractors is that the dispersed phase droplets formed in each mixing zone of the device are multi-dispersed, and small droplets that do not settle are combined with a light phase stream and move to the upper stages. This, in turn, affects the efficiency of the device steps. To overcome these shortcomings, we created a new construction of a bubble extractor with a multi-stage filter [4].
Figure 1 below shows the structural and calculation scheme of this device.
The structure of the extractor is as follows
The extractor body 1 is divided into separate mixing and sieving stages by means of barriers 2. Barrier 2 is equipped with internal 3 and external 4 mixing concentric nozzles and a gap with

upper barrier 2 is formed. Additional inner 5 (odd) and outer 6 (even) concentric nozzles are inserted between these nozzles. The internal pipe 5 is fixed to the upper barrier 2 by welding and a gap is formed with the lower barrier. The external mixing nozzle 6 is fixed to the lower block 2 by welding and a gap is formed with the upper block. The lower part of the internal nozzle 3 is inserted from under the barrier 2, and holes 8 are opened in its side walls and serve as nozzles 7 for distributing gas to the mixing zones of the apparatus.

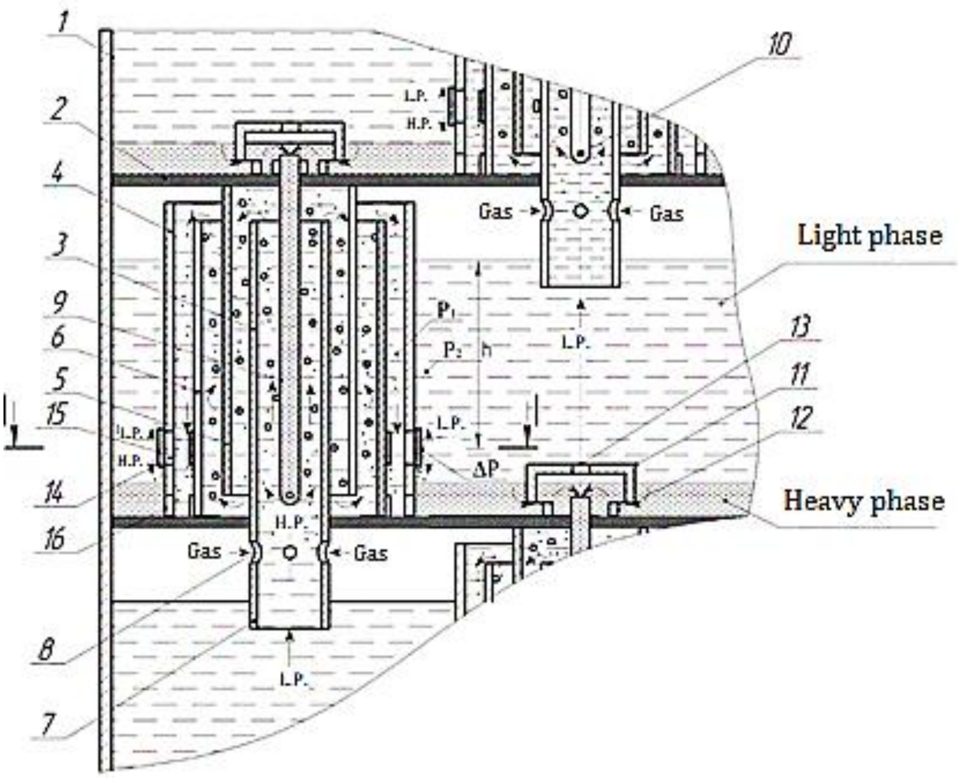

Figure 1. Constructive and calculation scheme of filter bubble extractor

In the lower parts of these pipes, holes 10 are opened for the flow of heavy phase. The upper part of the pipe 9 is closed with a cap 11. Caps have bottom 12 and top hole 13. Square holes 14 are formed from the upper part of the heavy phase level along the diameter of the nozzle 4 installed on the barrier 2, and fibrous material 15 (filter) is laid in these holes. The heavy phase level is understood as the upper part of the cap placed on top of the discharge pipe. In order to ensure the flow of the heavy phase, which has been quenched during the installation of the nozzle 4 on the barriers 2, to the next stage, the slits 16 are formed in the lower part.

The extractor works as intended

Light phase (L.P.) enters the manifold 3 through the gas distribution nozzle 7. Heavy phase (H.P.) flows through the opening 10 of the pipe 9, which discharges heavy phase into the pipe 3, from the opening of the upper step. In the process of movement of liquid mixture from bottom to top in nozzle 3, from top to bottom in the grooved channel between nozzles 3 and 5, and from bottom to top in the grooved channel between nozzles 5 and 6, the liquid phases are intensively mixed with inert gases entering through the holes 8 of the gas distribution nozzle 7 in nozzle 3. From the upper part of nozzles 5 and 6, the gas is separated from the phases, collects in the gas cushion under the barrier 2, and passes to the gas distribution nozzle installed on the next stage. The mixed liquid phases move from the top down through the ring channel between nozzles 4 and 6. The heavy phase sinks under the influence of gravitational and inertial forces and rests on the barrier 2 and flows out through the slits 16 in the lower part of the nozzle 4 and forms a homogeneous layer on the barrier 2. The light phase is trapped in the rectangular hole 14 formed at the bottom of the nozzle 4 and the fibrous material (filter) 15 laid on it, and they merge into large drops and under the influence of gravitational and inertial forces sinks. The light phase, which is purified from the heavy phase, continues to move to the top. Such installation condition of pipe 4 on the barriers 2 allows maximum use of the volume of the ring channel,

In order to ensure the operation of the extractor in the standard hydrodynamic mode, the cross-sectional size of the channel between nozzles 3 and 5 is determined by the condition that the velocity of liquid phases in this channel is greater than the velocity of gas bubbles.

The sizes of the holes 14 formed along the diameter of the pipe 4 and the fiber material 15 covered with it are determined by the condition of ensuring a uniform flow rate of the light phase, depending on the resistance coefficients. The dimensions of the slits 16, which ensure the outflow of heavy phase from the annular channel formed in the lower part of the pipe 4, are also determined depending on the consumption of heavy phase.

The industrial application of this multi-stage bubble extractor increases the efficiency of the extraction process. There is no need to increase the number of mixing and grinding steps to achieve the goal. The installation of the filter in the mixing zones of the apparatus ensures the stability of the consumption of heavy phases in the stages, the normal mass exchange process and the clean separation of the extracted phases from the apparatus.

Results

The task of the scientific research work is to investigate the phase transmission capabilities of this filter. The external mixing zone of the device and the settling zone are in the form of a contiguous container, and the phase flow passes through the filter. The resistance coefficient of the filter should be selected in such a way that phases leaking from the external mixing zone through the filter flow smoothly without condensation. Otherwise, the hydrodynamic mode of the device will be broken. This in turn depends on the surface of the slots in which the filter is installed and the relative contact surfaces of the filter.

The rate at which fluid leaks through the filter depends on the overall resistance coefficient of the filter. Theoretical research aimed at determining these quantities was carried out [5,6,7].

The calculation scheme of the filter installed in the external mixing zone of the device is shown in Fig. 1.

From Figure 1, according to section 1-1, the center of the filter is affected by the static pressure P_1 of the fluids in the annular channel of the device, the pressure P_2 in the deposition zone on the outside, and the hydrodynamic pressure ΔP of the fluid flowing through the filter. Then the sum of the total pressures will be in the following form, Pa;

$$\Delta P + P_1 + P_2 \qquad (1)$$

We know that hydrodynamic pressure is determined as follows, Pa;

$$\Delta P = \xi_f \frac{\rho_{ara} \cdot \omega^2_{ara}}{2} \qquad (2)$$

where ξ_f is the resistance coefficient of the filter, and the resistance coefficient of the filter support grid is equal to the sum of ξ_1 and fiber material resistance coefficients ξ_2. That is:

$$\xi_f = \xi_1 + \xi_2 \qquad (3)$$

and determined through experiments.

ω_{ara} - phase flow rate from the filter, m/s; is the density of ρ_{ar} - phase mixtures, defined as follows, kg/m^3;

$$\rho_{ar} = \rho_1 a + \rho_2 (1-a) \qquad (4)$$

where a is the percentage of heavy and light phases in the mixture, %; ρ_1-light phase density, kg/m^3; ρ_2-heavy phase density, kg/m^3.

ξ_1 - the resistance coefficient of the base grid on which the fiber filter is laid is determined as follows. [8];

$$\xi_1 = \Delta\Pi \frac{\sum S_c \cdot \delta}{\sum S_c \cdot a}, \qquad (5)$$

where $\Delta\Pi$ is the correction factor determined by experiments, ΣS_c is the total surface of the base mesh, m^2; δ-grid wire thickness, m; square hole dimensions of a mesh, m. The optimal values of the sizes of the holes of the base grid are determined by experiments. ξ_2-base is the resistance coefficient of the fiber filter laid between the poles and is determined as follows [6,7];

$$\xi_t = \frac{S_f}{\Delta K S_t} \qquad (6)$$

where ΔK is a correction factor determined by experiments.

S_f-specific surface of glass fiber filter by mass, m^2; S_t-filter mounting hole surface, m^2.
The relative contact surface of the fiber filter is reduced as follows.
The density equation was used to calculate the contact surface of the fiber filter, kg/m3 [8,9];

$$\rho = \frac{m}{V} \qquad (7)$$

where m - fiber filter mass, kg; v - is the volume of fiber material and is defined as follows. m^3;

$$V = \pi \cdot R^2 \cdot l \qquad (8)$$

where R is the fiber radius, m; l – fiber length, m;
Putting equation (7) into equation (6) and finding the fiber length l, the equation becomes as follows.

$$l_{um} = \frac{m}{\pi \cdot R^2 \cdot \rho} \qquad (9)$$

To find the relative contact surface of the filter fibers, the length of the circle depending on its diameter is found, m;

$$l_a = 2\pi \cdot R \qquad (10)$$

If the total length of the filter fiber is multiplied by the length of its circumference, the equivalent contact surface can be found. That is

$$S = l_{um} \cdot l_a \qquad (11)$$

If the values of equations (9.12) and (10. 13) are put into equation (11. 14), the equation for determining the relative contact surface of filter fibers is obtained m^2 [8,9];

$$S_f = \frac{m}{\pi R^2 \cdot \rho} \cdot 2\pi \cdot R = \frac{2m}{R \cdot \rho} \qquad (12)$$

where m is the mass of fibrous material, kg; R – fiber material radius; m; Density of r - fiber material, kg/m^3

The static pressure P_1 (see Figure 1) is determined by the following equation, Pa;

$$P_1 = \rho_{ar} \; gh(1-\varphi) \qquad (13)$$

where h is the height of the liquid level falling to the center of the filter, m; φ is the value of the amount of gas in the external mixing zone.

The pressure P_2 falling on the center of the filter from the outside is determined as follows, Pa;

$$P_2 = \rho gh \qquad (14)$$

where r is the density of the light phase, kg/m^3.

If we put the values of equations (2), (13) and (14) into equation (1), it will look like this, Pa;

$$\xi_f \frac{\omega_{ar}^2 \cdot \rho_{ar}}{2} + \rho_{ar} gh(1-\varphi) + \rho gh \qquad (15)$$

If necessary mathematical operations are performed in equation (15) and ω_{ar} is found, it will look like this, m/s;

$$\omega_{ar} = \sqrt{\frac{2gh(\rho_{ar}(1-\varphi) - \rho}{\xi_f \rho_{ar}}} \qquad (16)$$

Since the external mixing zone and the sedimentation zone of the device are in the form of a contiguous tank, the pressure generated due to the amount of gas φ_1 is equally affected by the inner and outer sides of the filter center. Then the equation 16 will look like this, m/s;

$$\omega_{ar} = \sqrt{\frac{2gh(\rho_{ar} - \rho)(1-\varphi)}{\xi_f \rho_{ar}}} \qquad (17)$$

The speed of light liquid flowing through the filter in the external mixing zone of the extractor can be determined using equation (17), and depending on this speed, it is possible to determine the difference between the liquid consumption supplied to the device for extraction and the liquid flow capacity of the liquid consumption flowing through the filter. This, in turn, requires the correct selection of the resistance coefficient of the filter for stable flow of fluids when designing the device.

Conclusion

As a result of theoretical studies, empirical equations for calculating the resistance coefficients of the recommended filter bubble extractor filter and an equation for calculating the liquid permeability, i.e. liquid speed, depending on these resistance coefficients and the densities of liquid mixtures were recommended. By determining this speed, it is possible to ensure the operation of the apparatus at a constant current and to select and design the main parameters of the filter.

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