A Method of Designing the Mixing Zones of a Bubble Extractor

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ABSTRACT

In the article, theoretical studies were carried out to determine the dimensions of the newly created bubble extractor that ensure the operation of the internal and external mixing zones in the hydrodynamic mode of equal speed, and an equation was derived that determines the diameter of the external mixing zone depending on the gas velocity and gas amount. As a result, an opportunity was created to determine the number of contact elements and overall dimensions in creating an industrial version of the device, depending on the performance of the device

Keywords: bubble extractor, inner zone, outer zone, mixing, gas cushion, liquid velocity, gas content, coefficient, gas transfer holes

Introduction

In order to increase the efficiency of the process by increasing the time of mixing of liquids by barbotizing inert gas, we have developed the design of a multistage bubble extractor [1], which according to our data is one of the promising for use in liquid extraction processes.

The main part

Devices and the principle of operation of the extractor are presented in Fig. 1.

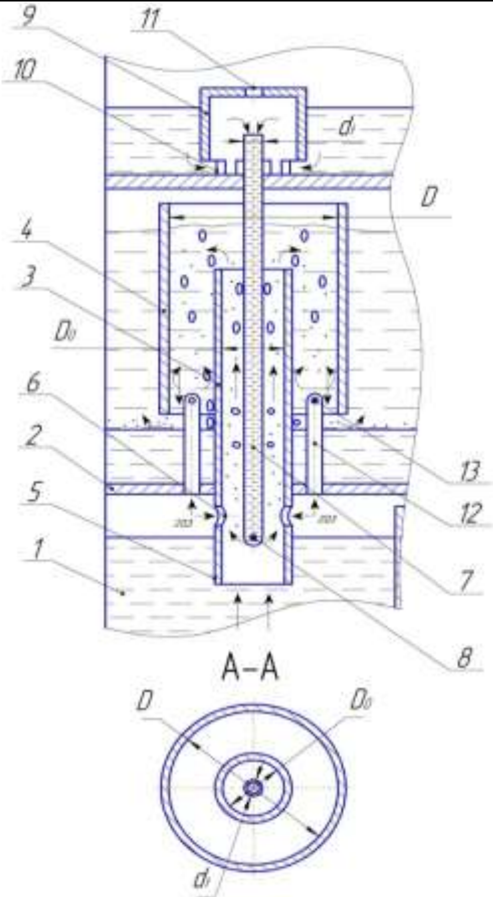

Figure 1. Intensified bubbling extractor

When the joint movement from the bottom up inside the pipe 3, the liquids are intensively mixed with a bubbling inert gas that flows from the "gas cushion" under the partition 2 through the holes 6. Then the mixture of liquids moves from top to bottom in the annular channel between pipes 3 and 4, and go into the settling section where drops of heavy liquid are deposited in a continuous layer; at the same time, the interface between light and heavy liquids determines the position of the upper edge of the overflow pipes 7 for heavy liquids.

During the movement from top to bottom in the annular channel between the pipes 3 and 4, the liquids are mixed with an additional portion of inert gas, which is supplied from the "gas cushion" through holes 13 of the tubes 12.

The stable operation of such an extractor depends on the uniform distribution of the inert gas into the internal nozzle 3 and into the annular channel between the nozzles 3 and 4 in order to create there equal hydrodynamic regimes determined by the equality of the volumetric gas contents. But this is due to the overcoming of certain features of the apparatus, the scraping inside the nozzle 3 is a mixture of liquids and the inert gas is in direct flow mode, and in the annular channel between the nozzles 3 and 4 there is a mixture of liquids and inert gas moving in countercurrent mode. With a direct flow of liquid and inert gas, the volumetric gas content is determined by the dependence [2,5]:

$$\phi_0 = \left(1 - 0,04w'_c\right)\phi' \qquad (1)$$

In the case of countercurrent motion of a liquid and an inert gas, the volumetric gas content can be determined by the dependence;

$$\phi_1 = \left(1 + 0,04w_c''\right)\phi' \qquad (2)$$

Where: w's is the reduced fluid velocity of the internal mixing zones of the apparatus; w'_c – is the reduced fluid velocity of the external mixing zones of the apparatus; w''_c is the gas content in the stationary liquid. An empirical equation has been proposed for calculating φ' [3]

$$\varphi' = 2,47 \cdot w_г^{0,97} \qquad (3)$$

$W_г$ –reduced gas velocity in the mixing zone, m/s;

In order to test the possibility of using dependencies (1 ÷ 3) for calculating the volumetric gas content of the mixing zones of a bubble extractor, we carried out experimental studies in the laboratory apparatus of the apparatus and the obtained results were publicized [4].

In the bubbly type apparatus, the velocity of the gas phase motion has the main influence on the hydrodynamic regime and gas content. The mode of movement of the gas phase inside the liquid is conventionally divided into 2 main groups; 1) bubbling mode, which exists at the given gas speeds

$w_g \le 0{,}05$ м/ сек. 2) the mode of coalescing bubbles, which exists at reduced gas velocities $w_g > 0{,}05$ м/ сек. The transition from the first mode to the second occurs at a gas velocity of 0.05 m/s. Bubble mode gas content $\varphi_0, \varphi_1 \le 0{,}3$ [3-11]. Therefore, for uniform and stable operation of the mixing zones of the apparatus, φ0 = φ1, conditions must be met. To meet these conditions, it is necessary to choose the right cross-section of the pipe inside and outside mixing zones of the apparatus.

The diameter of the internal bubbling pipe is determined depending on the flow rate of the extracted liquid by the following equation.

$$D_0 = \sqrt{\frac{4Q}{\omega_c' \cdot 3600}} + d_t m \qquad (4)$$

Q-extractable fluid consumption, m³/h; ω_c'-the speed of the extracted fluid during movement in the internal bubbling nozzles, m/s; d_t- the outer diameter of the flow pipes of heavy liquid, is selected from the condition. ($d_t = d_0(3 \div 5)$), d_0 -the diameter of the hole for the supply of heavy fluid in the overflow pipes, are selected depending on the performance of the heavy phase [12-14].

The inner diameter of the annular channel is determined by such conditions that the velocity of the fluid is less than the velocity of the gas, since in this zone the movement of liquids and gases is countercurrent.

$$w_г > \omega_c'' \qquad (5)$$

Otherwise, if the velocity of the fluid is high, gas bubbles enter the lower part of the annular channel through the settling zones of the apparatus. As a result, the intensity of mixing of liquids in the annular channel decreases.

Or it is necessary to take into account and multiply by the gas velocity the dimensionality coefficient K, which takes into account the velocity of the fluid, then 5 inequalities have the form

$$K w_г = \omega_c'' \qquad (6)$$

K - dimensionality coefficient is determined experimentally. The velocity of the gas passing along the surface of the cross section of the annular channel is determined depending on the gas content according to the following equation [3].

$$\omega_г = a\ \varphi_1 (1 - \varphi_1);\ м/\sec \qquad (7)$$

Where a is the coefficient corresponding to the speed of a single bubble (a = 30 ÷ 32 cm/ s), φ_1 is the volumetric gas content of the external bubbled pipes. The cross-sectional area of the annular channel is defined as follows.

by equation.

$$S_к = S_{вн} - S_0 = \frac{\pi D^2}{4} - \frac{\pi D_0^2}{4} m^2 \qquad (8)$$

$S_{ВН}$ -total cross-sectional area of external bubbling nozzles, m², S_0-cross-sectional area of internal bubbling nozzle, m², D is the inner diameter of the outer bubbling nozzle, D_0 is the outer diameter of the inner bubbling nozzle. (pic-1). The flow rate of fluid flowing through the cross-sectional area of the annular channel is determined by the following equation.

$$Q = \omega_c'' \left(\frac{\pi D^2}{4} - \frac{\pi D_0^2}{4}\right) \times 3600\ ,\ m^3/h; \qquad (9)$$

Where ω''_c is the flow rate of the fluid in the annular channel, m/s;

From equation 9, we get

$$\omega''_c = \frac{4Q}{\left(\pi D^2 - \pi D_0^2\right) \cdot 3600} \cdot m/\sec; \qquad (10)$$

Substituting the value of equation 7 and 10 into equation 6, we get

$$K a \varphi_1 (1 - \varphi_1) = \frac{4Q}{\pi \left(D^2 - D_0^2\right) \cdot 3600} \cdot m/\sec; \qquad (11)$$

From equation 11, we get

$$D^2 - D_0^2 = \frac{4Q}{K\pi a\varphi_1(1-\varphi_1)\cdot 3600}\cdot m \qquad (12)$$

From equation 12 we find the internal daimeter of the external bubbling pipe

$$D = \sqrt{\frac{4Q}{K\pi a\varphi_1(1-\varphi_1)\cdot 3600} + D_0^2}\cdot m \qquad (13)$$

Using equation 13, the diameter of the external bubbling nozzle is determined depending on the velocity of the gas and the liquid. This makes it possible to intensively and uniformly mix the extractable liquids in the internal and external mixing zones of the bubbling extractor.

Conclusion

In the article, theoretical studies were conducted to determine the dimensions of the internal and external mixing zones, which are important for ensuring the operation of the internal and external mixing zones of the bubble extractor created by us in the hydrodynamic mode of equal speed. An equation was derived that determines the diameter of the outer mixing zone depending on the gas velocity and gas volume. Based on the results of the research, an opportunity was created to determine the number of contact elements and overall dimensions when creating an industrial version of the device, depending on the performance of the device.

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