Experimental Studies Conducted To Determine Gas Flow Rates Distributed To The Internal And External Mixing Zones Of A Bubble Column Extractor

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Abstract

In the article, the hydrodynamic processes of the gas distribution elements in the experimental installation of the newly created bubble extractor were investigated, and the distribution of gas flow depending on the size of the gas supply opening to the inner and outer mixing zones of the experimental installation in liquid and gas flow regimes was determined. For the operation of the internal and external mixing zones of the device in a hydrodynamic process of equal intensity, these distributed gas flow rates are of great importance. As a result of the conducted experimental studies, it became possible to correctly select the dimensions of the hole when designing the industrial version of the device.

Keywords: Extractor, gas flow rate, holes, distance, mixing, hole size, internal, external, gas cushion, gas consumption.

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1. Introduction

Liquid extraction accounts for 20% of the total production in the chemical, oil refining, hydrometallurgical, and pharmaceutical industries. The designs of the extractors used are diverse, and based on the analysis of their advantages and disadvantages, the use of bubble extractors is considered promising. The advantages of these extractors are the simplicity of their design, low hydraulic resistance, the absence of moving mechanical parts, and high extraction efficiency. We are conducting theoretical and experimental studies to study the hydrodynamic processes of bubble extractors created in recent years [1].

2. Research Object

The object of the research is the experimental setup of the bubble extractor created by us (Fig. 1 and 2) and equation 1 for calculating the gas cushion recommended as a result of theoretical studies.

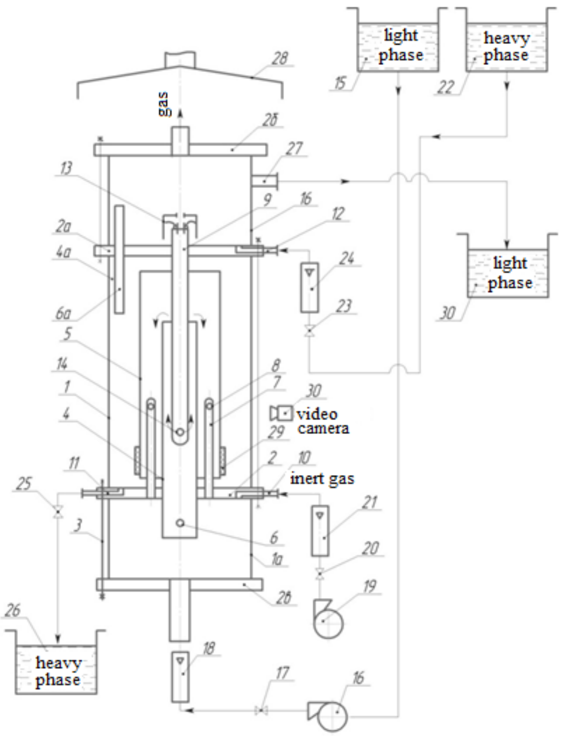

Fig 1. Diagram of the experimental setup

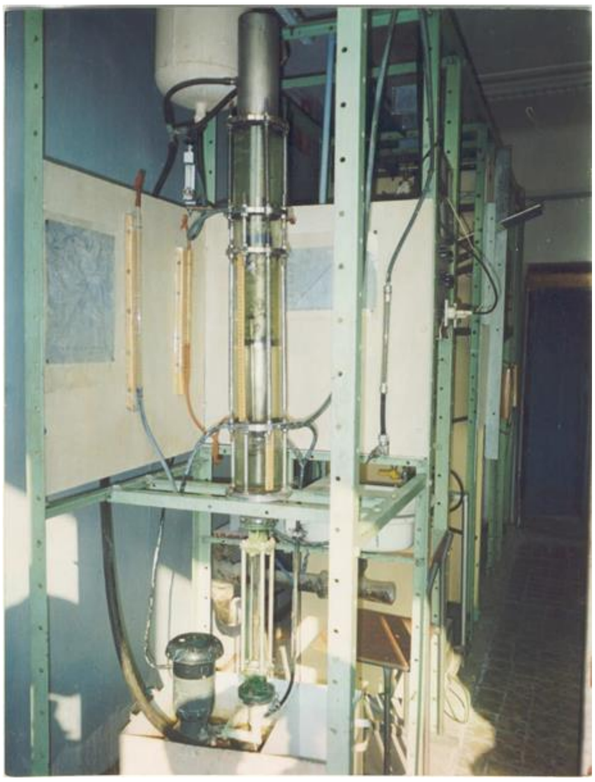

Fig. 2. General view of the experimental setup.

1-glass pipe, 2, 2a, 2b, 2c flanges, 3-tension stud, 4-internal bubbling pipe, 5-external bubbling pipe, 6-gas outlet, 7-gas outlet pipe, 8-gas outlet, 9-heavy fluid pipe, 10-gas inlet channel, 11-heavy fluid outlet channel, 12-heavy fluid inlet channel, 13-cap, 14-heavy fluid outlet, 15-light fluid tank, 16-pump, 17-valve, 18-rotameter, 19-compressor, 20-gas valve, 21-rotameter, 22-heavy fluid tank, 23-cock, 24-rotameter, 25-cock, 26-heavy fluid tank, 27-light fluid outlet channel, 28-sound, 29-filter, 30-video camera.

As a result of theoretical research, the form of the proposed formula for calculating the value of the gas cushion in the gas distribution elements of the proposed device is as follows:

$$h=\left(\xi_0\frac{\left[kw_0\right]^2\rho_г}{2g\Delta\rho}-\xi_{вх}\frac{w_c^2\cdot\rho_c}{2g\Delta\rho}\right)\cdot\frac{2\left(1-\varphi_1\right)H}{\left(1-\varphi_0\right)H_0} \quad (1)$$

Here ξ_0 - hole resistance coefficient in a bubbling pipe; w_0- gas flow rate through a hole, m/sec; $\rho_Г$ - gas density kg/m^3; K - pulsation coefficient, ρ_c - liquid density, kg/m^3; g - gravitational acceleration, (9.8 m/s^2); $\Delta\rho$ - mixture density, kg/m^3.

As a result of experimental studies conducted on an experimental barbotage extractor unit, it was established that separate gas flow rates are applied to the inner and outer mixing zones, and a change in the gas cushion is observed. The next task was aimed at determining the experimental values of the gas cushion by opening the gas delivery holes to the internal and external mixing zones and, depending on this, determining the gas flow rates distributed to these zones. Because the gas distribution is important for the internal and external mixing zones of the extractor to operate in an equally intensive hydrodynamic regime.

3. Results

Four holes with dimensions d_0=1mm are opened for gas supply to the internal mixing zone of the device, and in a constant state, there are pipes supplying gas to the external mixing zone with dimensions at heights of H_1=315; 240; 165 mm, respectively, Holes measuring d_1=0.6; 0.8; 1.0 mm were drilled sequentially, and separate experiments were conducted for each.

The results obtained during the experiments were as follows when opening 4 holes with a height of H_1=315mm and a size of d_1=0.6mm. The above procedure was maintained when supplying liquid to the mixing zones of the extractor. Liquid flow rate Q_C =0.07; 0.15; 0.23; 0.31; For each of the values of 0.39 m^3/hour, 8 different gas flow rates $Q_{Гум}$ =0.15; 025; 0.35; 0.45; 0.55; 0.65; 0.75; 0.85 m^3/hour. Given the gas flow rate $Q_{Гум}$ =0.15-0.45 m^3/hour, the gas cushion value was not sufficient. $Q_{Гум}$ =0.55; 0.65; 0.75; 0.85 m^3/hour, respectively, the gas cushion value is up to h=63; 80; 110; 130 mm. In the same mode, experiments were conducted by drilling 4 holes with a diameter of d_1=0.8 mm at a height of H_1=240mm. During these experiments, the gas cushion values were recorded as h=48, 55, 66, and 82 mm. When opening a hole d_1=1 mm at a height of H_1=165mm, the values of the gas cushion are h=23;30; 39; 49 mm.

The hole d_0=1mm for supplying gas to the internal mixing zone of the apparatus is closed, opened, and in a constant position, at a height between the holes H_1=315mm, through the holes d_1=0.6 mm, in a sequential position $Q_{Гум}$ =0.55; 0.65; 0.75; At a gas flow rate of 0.85 m^3/hour, the gas cushion values correspond to the gas flow rates h=47;65; 82; 101 mm.

In the above liquid and gas flow regimes, when the distance between the holes is H_1= 240 mm, when opening 4 holes with a size of d_1= 0.8 mm and supplying gas, the values of the gas cushion are h=32;37; 48; At heights up to 67 mm, H_1=165 mm, holes d_1= 1.0 mm were also drilled, and during the experiments, the gas cushion value was changed to h=5;12; 19; 37 mm.

A hole d_0=2mm is opened for supplying gas to the internal mixing zone, and the height between the holes is H_1=315; 240; 165 mm; d_1=0.6; 0.8; When conducting experiments according to the above modes, the value of the gas cushion turned out to be insufficient with holes of 1.0 mm. We will not use this mode in the next stages of the experiments.

The results of the conducted experiments were processed based on a computer program, regression equations were obtained, and correlation graphs were obtained. (fig.3 and fig.3).

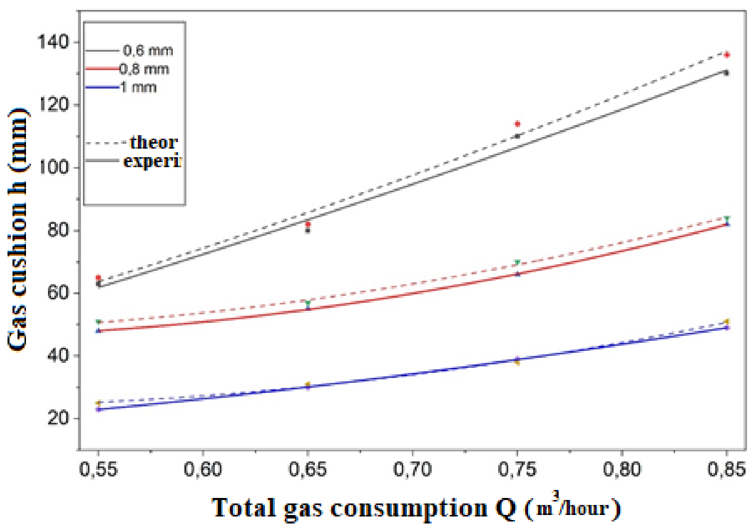

Fig. 3. Graph of the gas cushion change depending on the gas flow rate supplied to the internal and external mixing zones of the apparatus.

d_0=1 mm=const

The obtained regression equations have the following form:

$$1.y = 231x - 65,95 \qquad R^2 = 0,9894 \qquad (2)$$

$$2.y = 113x - 16,35 \qquad R^2 = 0,9692 \qquad (3)$$

$$3.y = 87x - 25,65 \qquad R^2 = 0,994 \qquad (4)$$

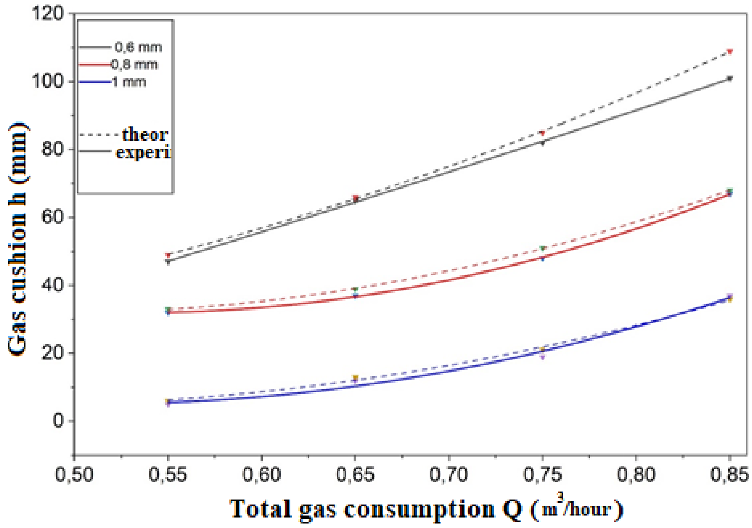

Fig. 4. Graph of the gas cushion change depending on the gas flow rate supplied to the internal and external mixing zones of the apparatus.

d_0=1,5 mm=const

The obtained regression equations have the following form:

$$1.y = 179x - 51,55 \qquad R^2 = 0,9996 \qquad (5)$$

$$2.y = 116x - 35,2 \qquad R^2 = 0,9319 \qquad (6)$$

$$3.y = 103x - 53,85 \qquad R^2 = 0,936 \qquad (7)$$

The theoretical values of the gas cushion were found using the gas cushion calculation equation (1).

The theoretically found values were compared with experimental values. The error between the theoretical and experimental values is Δ=2÷7%. (Fig. 3 and 4). The conducted experiments fully confirmed equation (1).

Based on the above experiments, it was possible to determine the gas flow rates distributed to the internal and external mixing zones of the apparatus.

Based on the conducted experiments, when gas is supplied only to the external mixing zone of the device through a hole d_1=0.6 mm with a height of H_1=315 mm, the maximum gas flow rate of this hole was Q_1=0.135m3/hour, and when opening holes d_1=1.0 mm with a height of H_1=240 and conducting experiments, Q_1=0.280m^3/hour, the maximum gas flow rate of holes d_1=1.0 mm, corresponding to the distance between holes H_1=165 mm, was Q_1=0.465m^3/hour. A graph was constructed so that the dynamics of gas flow rate reception in these openings is clearly visible (Fig. 5).

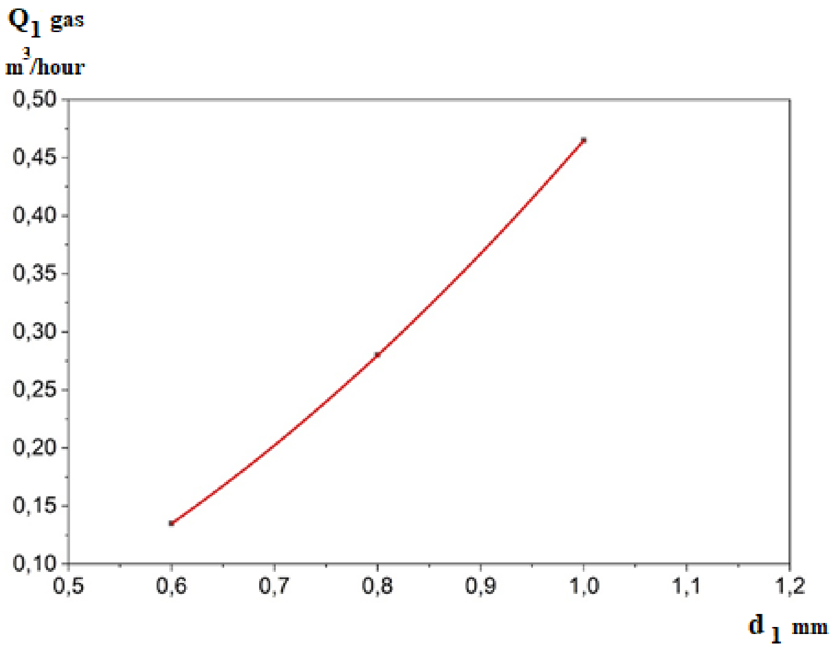

Fig.5. Graph of gas flow rate change depending on the size of the openings supplying gas to the external mixing zone

The obtained regression equations have the following form:

$$y = 0,825x - 0,3667 \qquad R^2 = 0,9951 \tag{8}$$

This calculated value is the gas flow rate distributed to the external mixing zone. The gas flow rate entering the internal mixing zone is determined by the following equation, m^3/hour;

$$Q_0 = Q_{УМ} - Q_1 \tag{9}$$

For each case of experiments conducted using the same method, the values of gas flow rates distributed to the mixing zones of the device were determined based on the total gas flow rate. Tables 1 and 2. Depending on the determined gas flow rates, it was possible to determine the values of the flow rates of gas passing through the gas delivery holes in the mixing zones.

1-table. Gas flow rates distributed to the internal and external mixing

zones of the extractor. d₀=1 mm-const

№	$Q_Г$ ум, m^3/hour	Q_0, m^3/hour	Q_1, m^3/hour	h, mm	d_0, mm	d_1, mm	Q_c m^3/hour
Distance between holes H_1=315 mm							
1	0,55	0,415	0,135	63	1	0,6	up to 0.07÷0.39, with 0.08 steps
2	0,65	0,515	0,135	80			
3	0,75	0,615	0,135	110			
4	0,85	0,715	0,135	130			
Distance between holes H_1=240 mm							
1	0,55	0,27	0,280	48	1	0,8	up to 0.07÷0.39, with 0.08 steps
2	0,65	0,37	0,280	55			
3	0,75	0,47	0,280	66			

4	0,85	0,57	0,280	82			
Distance between holes H_1=165 mm							
1	0,55	0,085	0,465	23	1	1	up to 0.07÷0.39, with 0.08 steps
2	0,65	0,185	0,465	30			
3	0,75	0,285	0,465	39			
4	0,85	0,385	0,465	49			

2-table. Gas flow rates distributed to the internal and external mixing zones of the extractor. d_0=1,5 mm-const

№	$Q_{Г\ ум}$, m^3/hour	Q_0, m^3/hour	Q_1, m^3/hour	h, mm	d_0, mm	d_1, mm	Q_c m^3/hour
Distance between holes H_1=315 mm							
1	0,55	0,415	0,135	47	1,5	0,6	up to 0.07÷0.39, with 0.08 steps
2	0,65	0,515	0,135	65			
3	0,75	0,615	0,135	82			
4	0,85	0,715	0,135	101			
Distance between holes H_1=240 mm							
1	0,55	0,27	0,280	32	1,5	0,8	up to 0.07÷0.39, with 0.08 steps
2	0,65	0,37	0,280	37			
3	0,75	0,47	0,280	48			
4	0,85	0,57	0,280	67			
Distance between holes H_1=165 mm							
1	0,55	0,085	0,465	5	1,5	1	up to 0.07÷0.39, with 0.08 steps
2	0,65	0,185	0,465	12			
3	0,75	0,285	0,465	19			
4	0,85	0,385	0,465	37			

Note

H_1- Distance between holes mm; $Q_{0\ ум}$- Total gas consumption, m^3/hour; Q_0- gas flow rate entering the internal mixing zone m^3/hour; Q_1- Gas flow rate entering the external mixing zone m^3/hour; h- Gas cushion value; d_0- diameter of the gas outlet to the external mixing zone mm; d_1- diameter of the gas outlet to the external mixing zone mm;

Q_C -Liquid consumption m^3/hour;

As can be seen from tables 1 and 2 above, the holes with dimensions d_0= 1.0;1.5 mm for supplying gas to the internal mixing zone are opened sequentially in a constant position, for each of which the gas supply to the external mixing zone is d_1=0.6; 0.8; 1.0 mm When conducting experiments with sequential opening of holes, there was no change in the gas flow rates distributed to these two zones. But the value of the gas cushion decreased. This, in turn, is of great importance in the design of the industrial version of the device, when setting the value of the standard gas cushion, when choosing the correct size of the hole.

4. Conclusion

In the article, the hydrodynamic processes of the gas distribution elements in the experimental installation of the newly created bubble extractor were investigated, and the distribution of gas flow depending on the size of the gas supply opening to the inner and outer mixing zones of the experimental installation in liquid and gas flow regimes was determined. For the operation of the internal and external mixing zones of the device in a hydrodynamic process of equal intensity, these distributed gas flow rates are of great importance. As a result of the conducted experimental studies, it became possible to correctly select the dimensions of the hole when designing the industrial version of the apparatus.

References

1. Каримов И.Т. "Разработка и применение в химической промышленности аппаратов для переработки гетерогенных систем «жидкость-жидкость-газ»дисс.Д.т.н. Т.ТХТИ,2021.С-278.
2. И.Т.Каримов., Б.А.Алиматов., Х.М.Садуллаев Б.Ж. Хурсанов. Гетероген тизимларга ишлов берувчи барботажли экстракторларни саноатда қўлланишнинг илмий – техник асослари. ФарПИ. Илмий кенгаш баёни №2, 04.11.2021 йил, "Классик" наширёти, -228 бет.
3. Алиматов Б.А., Соколов В.Н., Саъдуллаев Х.М., Каримов И.Т. Многоступенчатый барботажный экстрактор. А.С. №1607859 (СССР) , БИ №43, 1990.
4. Каримов И.Т.,Алиматов Б.А.,Тожиев Р.Ж., Садуллаев Х.М Кўп поғонали барботажли экстрактор. Ўз. Рес. ПАТЕНТ № IAP 06714 ташкент 31.01.2022 йил
5. Соколов В.Н., Доманский И.В. Газожидкостные реакторы. – Л.:Машиностроение, 1976. – 216 с.

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