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EXPERIMENTAL STUDIES IN DETERMINATION OF BUBBLE EXTRACTOR FILTER'S FLUID CONDUCTIVITY

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ABSTRACT--*In the article, fluid conductivity of bubble extractor's glass fiber filter and it is operation to save the from mixing of nonsinking fluid droplets to the continuous fluid in the mixing zone of extractor are determined. Bubble extractor operates in liquid-liquid-gas system. In the results of theoretical researches formula for defining velocity of fluid outflow from the filter is recommended. By using that formula, fluid velocity that depends on coefficient resistance and flows through the filter surface and fluid displacement can be found. As the result, steady hydrodynamics of fluids movement in extractor's mixing zone is provided. In order to determine the gas velocity by using the 1-formula several experimentations had been carried out. In continuous gas velocity heavy and light liquids which have different densities are selected and light liquid's outflow velocity is determined experimentally. By using the recommended formula fluid outflow velocity is theoretically defined and compared with the experimental dates. With the help of computer processing of experimental dates had been made and values of correlation to the recommended formula had been entered. As the result of carried out experiments for determining fluid outflow velocity, 10-formula had been recommended. For selecting filter that value has the significant role in designing of apparatus.*

Key word--*bubble extractor, light phase, disperse phase, filter, contact surface, glass fiber, abutting net, external mixing zone, drop, resistance coefficient, gas velocity.*

I. INTRODUCTION

In manufacturing, usage of bubble extractors has its own benefits than several other types in dividing the liquid-liquid systems. In this type of extractors, mixing the liquid phases is carried out with help of inert gas. In science, inert gas passage is through the fluid layer named bubble, so extractors which operates in this method are called bubble extractors. Intensifying the extraction process and enhancing mass transfer are main purpose for researchers who are studying of that sphere of science. Therefore new design of extractor had been developed [1].

Dispersion of weight liquid through the continuous liquid phase is operated by using inert gas, with increasing gas flowrate in apparatus size of drops cab be reduced. By using increase of gas flowrate gives not only reduction of drops size but also light and weight phases can be mixed. In mixing the inert gases with liquids, weight phase drops are formed, than there are non sinking drops among that weight phase drops. In order to overcome this problem, a fiberglass filter is installed on the sealant that forms the outer mixing zone of the bubble extractor [1] to investigate the hydrodynamic processes of the filter (figures 1,2).

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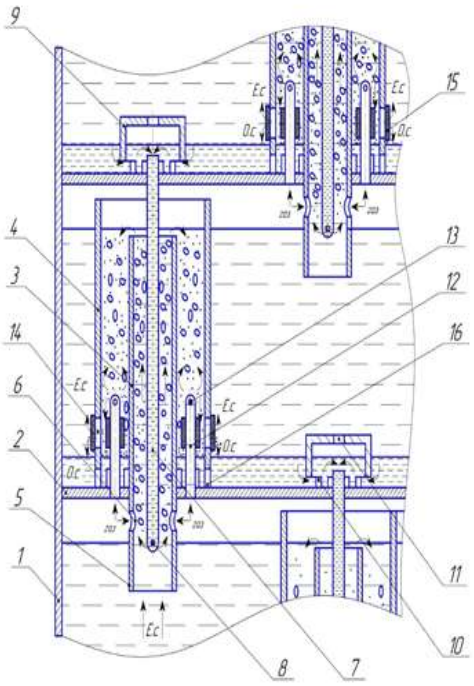

Figure 1: Scheme of bubble extractor

Figure 2: Total view of experimental equipment

1-body, 2-baffle, 3-internal nipple, 4-external nipple, 5- gas distribution nozzles, 6- hole for gas passage to the internal nipple, 7-weight liquid tube, 8-hole for flow weight liquid, 9- bubble-cap, 10- hole under the bubble-cap, 11- hole on the bubble-cap, 12- tube for liquid flow to external nipple, 13- hole for passage of gas to the external nipple, 14- hole, 15- glass fiber filter, 16- hole for flow weight phase.

II. OBJECT AND METHODS OF RESEARCH

The designed structure of the apparatus allows to mix liquid phases with inert gas in the interior and exterior mixing zones. The fluid phases flow from the internal mixing zone to the inert gas flow into the external mixing zone. In the external mixing zone, fluid phases flow in the opposite direction to the inert gas flow. The heavy phase droplets in the light phase form a submerged layer under gravitational and inertial forces. The light fluid extracted from the contact element of the apparatus only leaks through the filter, and the droplets of small particles of heavy particles that do not collapse are added to the filter and become large droplets. The rate of fluid leaking from the filter and the addition of small droplets depends on the filter resistance coefficient. Theoretical and experimental studies were carried out to determine these sizes.

Theoretical studies have developed a formula for determining the rate of fluid leakage [2,3].

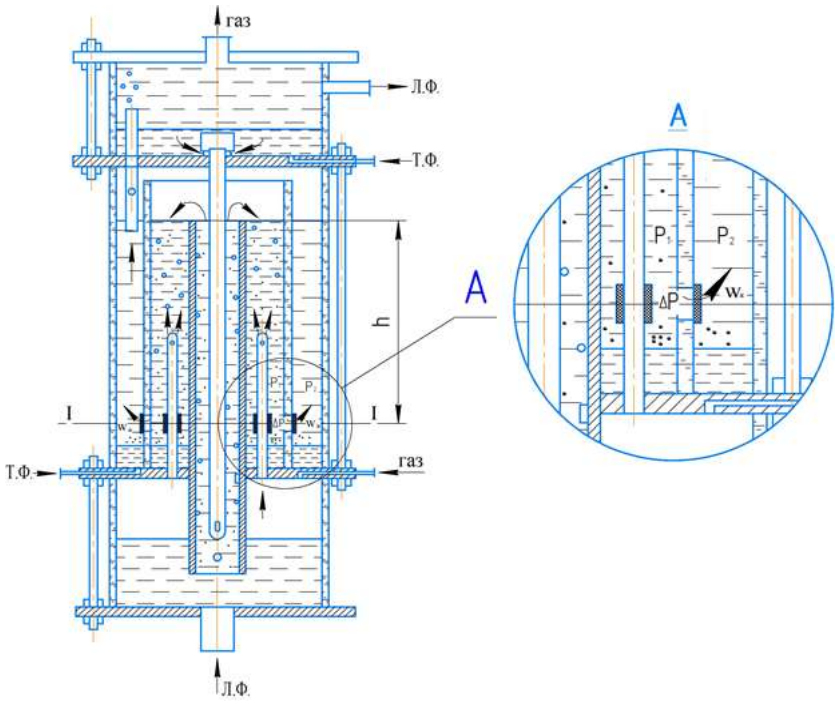

Figure 3. Calculation scheme of filter

Figure 3 : shows the filtering scheme.

The recommended equation for the rate of fluid leakage from the filter is as follows.

$$w_c = \sqrt{\frac{2gh(\rho_{ap}-\rho)(1-\varphi)}{\xi_\phi \rho_{ap}}} \quad , \text{м/с;} \qquad (1)$$

The size of the interior and exterior mixing zones of the apparatus depends on the amount of fluid extracted [2,3]. Determine the rate of fluid leakage using formula 1 to determine the difference between the amount of fluid flow and the amount of fluid flowing through the filter. This requires the proper selection of the filter resistance coefficient so that fluids can flow steadily without mixing in the mixing zones during the design of the apparatus.

Experimental research was carried out using the experimental device of bubble extractor installed in the shop for regenerating of acetic acid of JSC "Fargonaazot" (Figure 2).

Studies have revealed the coefficients of resistance, depending on the different surfaces of glass fibers at different values, the size of the base sets of 3 types, and the fluids with different surface tensions flowing through the filter surface [2,3]. An empirical formula for determining the resistance coefficients depending on the size of the base sets and the surface tension of the fluid, and the correction coefficients are calculated [4,5,7]. The results of the pilot studies are presented in tables 1,2,3.

table 1: Analyze experimental results in determination of filter resistance coefficients

water, σ = 0,073 N/m ;

N	Filter elements	Surface of filter element S m^2	Time of flow Δt sec	Fluid conductivity Q m^3/h	Resistance coefficient ξ	Correlation coefficient ΔK	Average value of Correlation coefficient ΔK
1.	Hole	0,00066	0,7	-	1		
2.	Net a=0,25mm, δ=0,08 mm	0,000305	1,3	-	1,86		12,5
3.	Glass fiber m = 0,15 gram	0,0339	2,94	0,47	4,2	12,2	
4.	Glass fiber m = 0,25 gram	0,0565	4,69	0,31	6,7	12,7	
5.	Glass fiber m = 0,35 gram	0,0791	6,79	0,22	9,7	12,3	
6.	Glass fiber m = 0,45 gram	0,1	8,4	0,17	12	12,8	
7.	Net a=0,8 mm, δ=0,2 mm	0,000228	2,43		1,26		18
8.	Glass fiber m = 0,15 gram	0,0339	1,96	0,72	2,8	18,3	
9.	Glass fiber m = 0,25 gram	0,0565	3,36	0,43	4,8	17,8	
10.	Glass fiber m = 0,35 gram	0,0791	4,41	0,33	6,3	18,8	
11.	Glass fiber m = 0,45 gram	0,1	6,6	0,23	8,8	17,5	
12.	Net d=1,2 mm, δ=0,25mm	0,00016	0,8		1,1		19,8
13.	Glass fiber m = 0,15	0,0339	1,82	0,79	2,6	19,8	

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14.	Glass fiber m = 0,25	0,0565	3,22	0,45	4,6	18,6	
15.	Glass fiber m = 0,35	0,0791	3,85	0,38	5,5	21,5	
16.	Glass fiber m = 0,45	0,1	5,6	0,26	8	19.2	

Table 2: Ant acid, σ = 0,038 N / m

N	Filter elements	Surface of filter element S m^2	Time of flow Δt sec	Fluid conductivity Q m^3/h	Resistance coefficient ξ	Correlation coefficient ΔK	Average value of Correlation coefficient ΔK
1.	Hole	0,00066	0,9	-	1		
2.	Net a=0,25mm, δ=0,08mm	0,000305	2,43	-	2,7		8,55
3.	Glass fiber m = 0,15 gram	0,0339	5,49	0,27	6,1	8,4	
4.	Glass fiber m = 0,25 gram	0,0565	8,82	0,16	9,8	8,7	
5.	Glass fiber m = 0,35 gram	0,0791	12,78	0,12	14,2	8,4	
6.	Glass fiber m = 0,45 gram	0,1	15,75	0,1	17,5	8,7	
7.	Net a=0,8мм, δ=0,2мм	0,000228	1,66		1,85		12,1
8.	Glass fiber m = 0,15 gram	0,0339	3,69	0,39	4,1	12,5	
9.	Glass fiber m = 0,25 gram	0,0565	6,39	0,22	7,1	12	
10.	Glass fiber m = 0,35 гр	0,0791	8,37	0,17	9,3	12,8	
11.	Glass fiber m = 0,45 gram	0,1	12,5	0,12	13,5	11,2	
12.	Net d=1,2мм, δ=0,25мм	0,00016	1,44		1,6		13,2

13.	Glass fiber m = 0,15	0,0339	3,5	0,4	3,88	13,2	
14.	Glass fiber m = 0,25	0,0565	6,16	0,22	6,85	12,5	
15.	Glass fiber m = 0,35	0,0791	7,38	0,19	8,2	14,6	
16.	Glass fiber m = 0,45	0,1	10,62	0,14	11,8	12,8	

Table 3: Butyl acetate, σ = 0,0248 N/m ;

N	Filter elements	Surface of filter element S m^2	Time of flow Δt sec	Fluid conductivity Q m^3/h	Resistance coefficient ξ	Correlation coefficient ΔK	Average value of Correlation coefficient ΔK
1.	Hole	0,00066	0,95	-	1		
2.	Net a=0,25мм, δ=0,08мм	0,000305	2,75	-	2,9		7,65
3.	Glass fiber m = 0,15 gram	0,0339	6,46	0,22	6,8	7,5	
4.	Glass fiber m = 0,25 gram	0,0565	10,33	0,11	10,8	7,9	
5.	Glass fiber m = 0,35 gram	0,0791	14,9	0,1	15,7	7,6	
6.	Glass fiber m = 0,45 gram	0,1	18,9	0,08	19,92	7,6	
7.	Net a=0,8мм, δ=0,2мм	0,000228	1,85		1,95		11
8.	Glass fiber m = 0,15 gram	0,0339	4,2	0,34	4,5	11,4	
9.	Glass fiber m = 0,25 gram	0,0565	7,41	0,19	7,8	11	
10.	Glass fiber m = 0,35 gram	0,0791	9,6	0,15	10,2	11,7	
11.	Glass fiber m = 0,45 gram	0,1	13,87	0,1	14,6	10,4	

12.	Net d=1,2мм, δ=0,25мм	0,00016	1,6		1,7		12,2
13.	Glass fiber m = 0,15 gram	0,0339	3,99	0,36	4,2	12,2	
14.	Glass fiber m = 0,25 gram	0,0565	7,1	0,2	7,56	11,3	
15.	Glass fiber m = 0,35 gram	0,0791	8,55	0,17	9	13,3	
16.	Glass fiber m = 0,45 gram	0,1	12,35	0,12	13	12	

$$\xi = \frac{S_{\phi}}{\Delta K S_{т}} \qquad (2)$$

Where S_{ϕ}- specific contact surface of glass fiber filter m^2;

Sт- filter installed hole's surface, m^2; ΔK-correlation coefficient [4,5].

III. OBTAINED RESULTS

The next task is checking formula 1, so experiments will be hold in following sequences. Liquids which are formed different densities phases of compound are selected.

1.In the capacity of light phase water is selected, carbon chlorine with benzol is weight phase, ρ=1200kg/m^3.

2. In the capacity of light phase water is selected, carbon chlorine with benzol is weight phase, ρ=1100kg/m^3.

3.In the capacity of light phase ethyl acetate is selected ρ=900 kg/m^3, water is weight phase, ρ=1000kg/m^3.

Densities of weight and light liquid compounds are determined in the following formula[6].

Densities of liquids are measured with aerometer. Light and weight phases are passed to the extractor in relation 1/3.

Formula for determination of light and weight phases [6].

$$\rho_{ар} = \rho_0 \cdot a + \rho_{сув} (1 - a), \qquad kg/m^3 (3)$$

бу ерда: $\rho_{ар}$ – аралашма зичлиги, kg/m^3; ρ_0 – оғир суюқлик зичлиги, kg/m^3 ;

$\rho_{сув}$ – water density, kg/m^3 ;

a – density portion of liquid, %;

Portion of weight liquid is 33%, and light liquid portion is 67% are obtained. As the result compound density is determined.

1. $\rho_{ар} = 1200 \cdot 0,33 + 1000 (1 – 0,33) = 1066, kg/m^3$;
2. $\rho_{ар} = 1100 \cdot 0,33 + 1000 (1 – 0,33) = 1033, kg/m^3$;
3 $\rho_{ар} = 1000 \cdot 0,33 + 900 (1 – 0,33) = 933, kg/m^3$;

To the external nipple's nozzle supporting nets which have a=0,25мм, δ=0,08mm; a=0,8mm,δ=0,2mm; d=1,2mm,δ=0,25mm d=1,2mm,δ=0,25mm sizes,

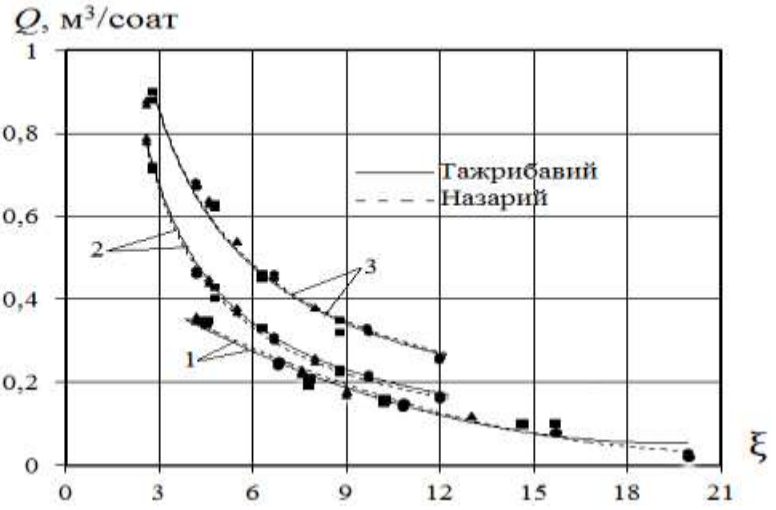
Glass fibers have $S_ф$= 0,034 ; 00565 ; 00791 ; 01 m^2 sizes are installed. Flowrate of light and weight liquids are measured with rotameter. To mixing zone of extractor gas is passed in $Q_{ум}$=0,85m^3/h flowrate. Q_0=0,385m^3/h is proportion of total gas flowrate, flowrate is to the external mixing zone is Q_1=0,465 m^3/h.

With a glance of appropriate flowrates volumes, gas velocity is $w_{1г}$=0,08 m/sec.

In studied external mixing zone quantity of gas has $φ_1$=0,1 and in that gas velocity

With usage of tube light phase was exit to the V = 0,001m^3 tank and filling time was determined. Liquids velocities and conductivity which outflowed through filter has specific surface had been determined in depending on times.

Each of the experiments was filmed using a Canon EOS 700 D camcorder. The experiments were performed separately and repeatedly for each of the concentrations of fluid mixtures supplied to the apparatus. The results of the experimental studies were processed using the computer, the regression equations were obtained and the graphs were constructed (Figure 4).



●-$S_ф$=0,1m^2; ■- $S_ф$=0,0791m^2; ▲- $S_ф$=0,0565m^2; ◆- $S_ф$=0,0339m^2

1.ρ=933kg/m^3; 2.ρ=1033 kg/m^3; 3.ρ=1066 kg/m^3;

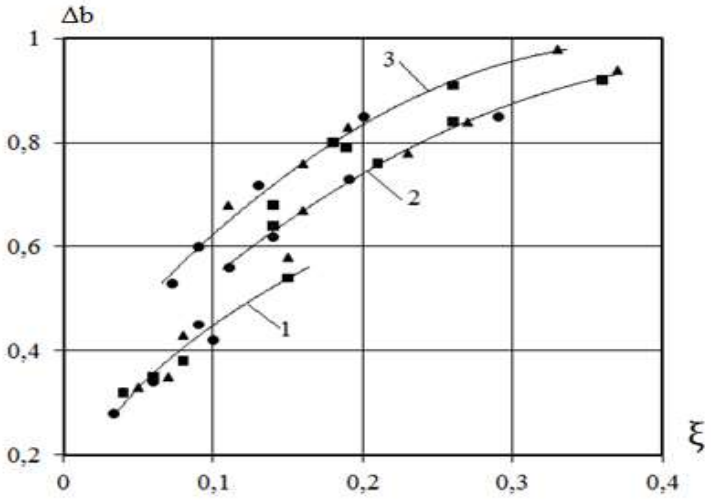
Figure 4: Fluid conductivity changes in depending on filter's resistance coefficient

1. $y = 0,0012x^2 - 0,0479x + 0,518$ $R^2 = 0,9617$

2. $y = 0,0093x^2 - 0,1916x + 1,1678$ $R^2 = 0,9667$

3. $y = 0,0074x^2 - 0,1741x + 1,2837$ $R^2 = 0,9922$

The theoretical values of the filter flow rate using formula 1 were determined and compared with their experimental values. According to the theoretical and experimental studies, the differences between theoretical and experimental values of fluid velocity leakage from the filter were determined. According to these differences, the correction factor Δb values were determined depending on the change in fluid velocity. The regression equations were obtained using the computer and graphs were constructed (Figure 5).



●-$S_ф$=0,1m^2; ■- $S_ф$=0,0791m^2; ▲- $S_ф$=0,0565 m^2; ◆- $S_ф$=0,0339 m^2

1.ρ=933kg/ m^3; 2.ρ=1033 kg/ m^3; 3.ρ=1066 kg/ m^3;

Figure 5: Correlation coefficient changes graph in depending on liquid velocity

1.ρ=933 kg/m^3; 2.ρ=1033 kg/ m^3; 3.ρ=1066 kg/ m^3;

1. $y = -0{,}0704x^2 + 2{,}3423x + 0{,}2099$ $R^2 = 0{,}9785$
2. $y = -3{,}1723x^2 + 2{,}9318x + 0{,}2809$ $R^2 = 0{,}9952$
3. $y = -4{,}4358x^2 + 3{,}4412x + 0{,}3236$ $R^2 = 0{,}9747$

The following is the recommended formula for correction of formula 1, which determines the fluid velocity leakage from the filter for use in the design of the industrial device.

$$w_c = \Delta b \sqrt{\frac{2gh(\rho_{ap}-\rho)(1-\varphi)}{\xi_ф \rho_{ap}}} \quad , \text{ m/sec;} \qquad (10)$$

IV. CONCLUSION

As a result of experimental studies it was found out that the fiberglass filtering capability of small particle droplets that do not collapse at constant and constant gas velocities, in light and heavy liquids of different densities. Using the formula 1, theoretical values were calculated and compared with their experimental values. Differences between theoretical and experimental values of fluid leakage rates were determined and values of correction coefficients were determined. When designing a device for the industrial device, it is recommended to use the formula 10 to calculate the fluid velocity flowing through the filter.

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