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Determination of factors effecting the properties of water-air micro dispersion

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ABSTRACT

The article presents the results of laboratory studies on the effect of the liquid-gas ratio and the foaming agent type on the average water-air micro dispersion size obtained from the foaming agent solution. The size of microbubbles significantly effects the efficiency of flotation and depends on the type and concentration of foaming agent used for their production. A generator was used to obtain water-air micro dispersion. The works were performed to work out the water-air micro dispersion parameters of at different liquid-gas ratio and different performance of the generator. The following foaming agents were used as objects of research: sodium butyl aero flot (BTF), flotanol C-7, butyl triethylenetetramine (B-TETA) at a concentration of 0.5 g/dm^3. It has been established, that the optimal phase liquid-gas ratio was 1:1, the optimal capacity of the generator was 6-7.2 dm^3/h with an average particle size of air-water micro dispersion- 33-41 μm for BTF solution, 103-107 μm for C-7 solution, 90-93 μm for B-TETA solution. The type of foaming agent used in flotation effects the size and stability of microbubbles. It is established that the flotation agents can be arranged in the following line with respect to their ability to create micro dispersion: IIBK→Senfroth 580→B-TETA→OPSB→Flotanol C-7→T-92→BTF. The best results are shown by BTF that creates micro dispersion of 43-58 μm (t 20-40 °C) and stability of 80 sec with concentration of 0.5 g/dm^3.

Keywords*:* flotation, combined micro flotation, flotation reagent, water-air micro dispersion, microbubbles.

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Introduction

Low efficiency of flotation recovery of micron-sized particles from ores is one of the important reasons for large losses of valuable components at beneficiation plants [[1], [2]]. Beneficiation plants in all countries are engaged in solvation of this problem [[3], [4], [5], [6], [7], [8], [9], [10]]. One of the solutions to this problem is the use of combined microflotation with water-air micro-dispersion obtaining enabling to extract additional micro-dispersed valuable oreminerals, optimize the flotation process and obtain higher technological parameters [11], [12], [13]].

The problem is reduced to finding a microbubble production method [[14], [15], [16], 17]]. Spatial separation of the processes of microbubble formation and flotation is also important that willeliminate the pulp heating process in the flotation chamber and coalescence of bubbles, stabilizing formation process of micro dispersions homogeneous in size. All this in aggregate provides improved flotation performance of deeply milled ores to the micro-dispersed state, more complete recovery of finely dispersed valuable minerals

It is well known that classical flotation also uses different types of bubbles: macro-, medium- and micro-bubbles. Macro-bubbles that are transportable bubbles have a size of 300-500 μm, medium - 70-300 μmand micro - less than 70 μm. But, in conventional flotation, the amount of macro-bubbles (>90%) significantly exceeds the amount of medium and micro-bubbles. When stable micro dispersion sizes with the correct ratio of bubbles of different sizes is used, the flotation recoveryprocessformicroparticles is accelerated, the flotation time is reduced.

Scientists conduct researches to study sizes and stability of water-air microemulsion [[18], [19], [20]] obtained from the foaming agent solution. The effect of the water-air microemulsion (WAMD) nature on the flotability of sulfide minerals of non-ferrous metals and the properties of water-air microemulsion was studied in [21].

The purpose of this study is to study the effect of the liquid-gas ratio and the foaming agenttype on the average water-air micro dispersion size.

Thus, the problem to find more effective ways intended to obtain microbubbles for flotation of fine particles of minerals of non-ferrous and rare metals from minerals still remains relevant.

Experimental part

A generator was used to obtain water-air micro dispersion. The laboratory generator principle is that air and foaming solution is transferred through the inlet pipe of the dispersant head into the mixing chamberwith the help of metering pumps.

Additional mixing of the mixture is performed in the mixing chamber by means of the rotor part of the dispersator head. The mixture is thrown to the periphery and goes through the slot between the rotor and the stator due to the high circumferential speed. Its size is determined by the composition of raw materials and the required degree of dispersion. The rotating rotor crushes air bubbles with its teeth. The crushing degree of the final product depends on the viscosity of the medium, the foaming agenttype, the peripheral speed.

The properties of water-air micro dispersion are effectd by the ratio of air and foaming agent solution whose flow rate is regulated by dosing pumps with maximum capacity of 3.3 cm^3/s (12 dm^3/h).

The workswereperformedto work out the parameters of water-air micro dispersion at different liquid-gas (L:G)ratio, to study the effect of this ratio on the water-air micro dispersion size. Different L:G ratios were studied;theywere varied - L:G=1:0.75; L:G=1:1; L:G=1:1.25; L:G=1:1.5. The foaming agents used were sodium butyl aeroflot (BTF), flotanol C-7, butyltriethylenetetramine (B-TETA) at a concentration of 0.5 g/dm^3. Besides, tests were conducted at different dosing pump capacities.

The water-air mixture size obtained in the generator was analyzed using a Photocor Compact particle size analyzer. The operation principle of the analyzer was based on the method of static and dynamic light scattering (photon correlation spectroscopy). The size of the particles dispersed in the liquid was determined by measuring the correlation function of the fluctuations of the scattered light intensity and the integral scattering intensity. The analyzer laser power ranges from 2 to 35 mW.

Figures 1-3 show the dependencies of the average water-air micro dispersion size obtained from solutions of BTF, C-7, B-TETAfoamingagentson the liquid-gas ratio.

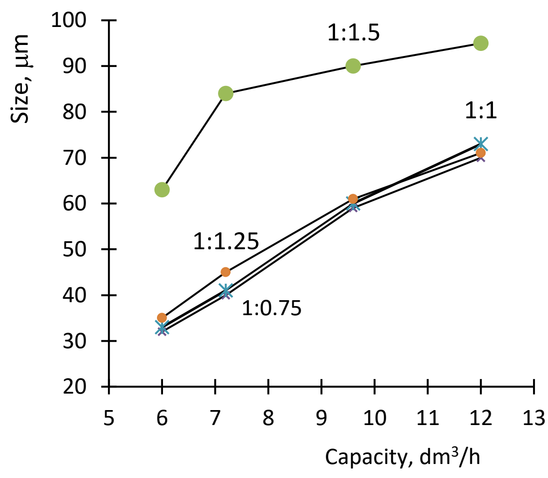

Figure 1 - Dependence of the average particle size of WWMD obtained from BTF solution on the L:G ratio at different pump capacities

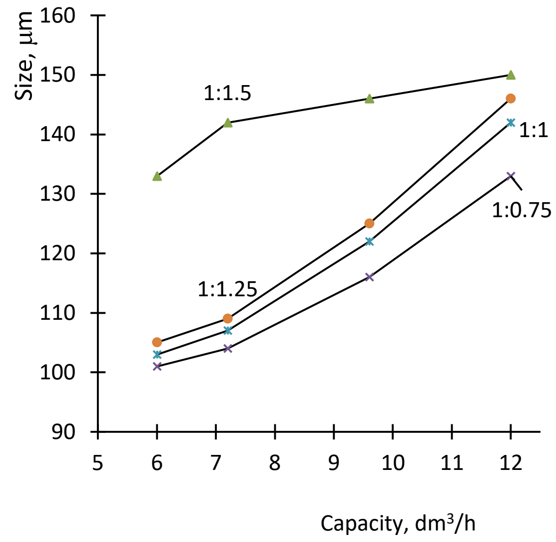

Figure 2 - Dependence of the average particle size of WWMD obtained from the C-7 solution on the L:G ratio at different pump capacities

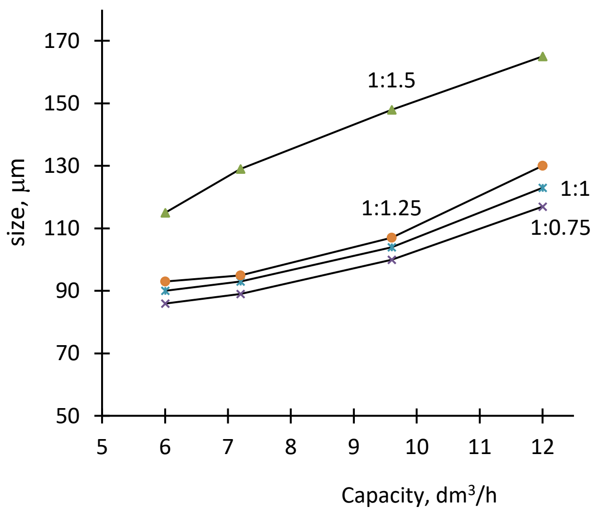

Figure 3 - Dependence of the average particle size of WWMD produced from B-TETA solution on the L:G ratio at different pump capacities

The result of the analyses shows that changes in the liquid-gas ratioeffects the final size of the water-air micro dispersion. The average water-air micro dispersion size increases for all solutions of foaming agents compared with other liquid-gas ratios at the liquid-gas ratio of 1:1.5. It indicates that thegas phase supply more than the liquid phase worsens the water-air micro dispersionproperties.

The final average water-air micro dispersion size is close to each other at liquid-gas ratios equal to 1:0.75, 1:1 and 1:1.25. It is required to properly adjust the generator (pumps) capacity and the liquid-gas ratio phases to obtain the optimum water-air micro dispersion size. Proper feeding of the gas phase, the optimal liquid-gas ratiohave a huge impact on the water-air micro dispersion formation. Increased supply of the gas phase results in an increase in the number of micro-bubbles with a smaller flow of the liquid phase (reagent solution). Not only the final size of the air-water micro dispersion but also the amount of created micro dispersionisimportantto obtain high performance in the flotation process, i.e. it is required to create a certain amount of air-water micro dispersion. The final amount of air-water micro dispersion created by quantity should provide recovery of all useful particles of slurry class not adsorbed by standard bubbles in the standard mode.

Discussion of the results

Analysis of the results shows that the liquid-gas ratio, equal to 1:1isthe optimum of all types of foaming agents. Figure 4 shows the dependence of the average water-air micro dispersion size obtained from 0.5 g/l solutions of BTF, C-7, B-TETA foaming agents at a liquid-gas ratio of 1:1.

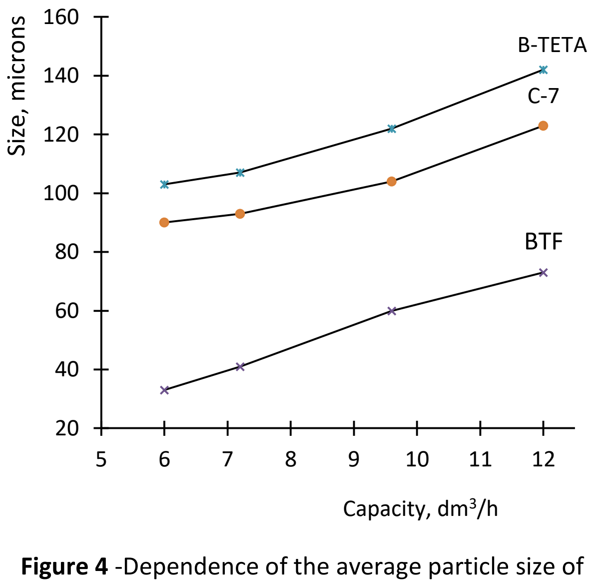

Figure 4 -Dependence of the average particle size of WWAMD obtained from BTF, C-7, B-TETAfoaming agent solutions at the ratio L:G = 1:1, on the generator capacity

The average size of the water-air micro dispersion obtained from 0.5 g/l BTP solution is 60-73 µm; from 0.5 g/l C-7 solution - 122-142 µm; from 0.5 g/l B-TETA solution - 104-123 µm at increased capacity of the liquid phase (9.6 l/h; 12 l/h). Analysis of the results shows that the water-air micro dispersion size for BTF solution increases by 100%; for C-7 solution by 20%; for B-TETA solution by 15%at capacities of 9.6 l/h; 12 l/h. Thus, the generator capacity should vary between 6-7.2 l/hto create the optimum water-air micro dispersion size.

Thus, the parameters to be used to obtain water-air micro dispersion have been worked out, the effect of the phase ratio: liquid-gas on the micro dispersion properties has been studied. It has been established that the optimal liquid-gas ratio is 1:1, the optimal generator capacity - 6-7.2 l/h, and the average particle size of air-water micro dispersion is 33-41 µm for BTP solution, 103-107 µm - for C-7 solution, 90-93 µm - for B-TETA solution.

The researches to study micro dispersion properties depending on the flotation foamingagent used and their concentration were performed at the established optimum L:G ratio and generator capacity. The following foaming agents were studied: BTF, oxal T-92, propylene oxide butyl alcohol (OPSB),C-7, B-TETA, methyl isobutyl carbinol (MIBC), Senfroth 580 foaming agent. Here are some characteristics of these foaming agents.

BTF - sodium-butyl aeroflot ($(C_4H_9)_2S_2O_2PNa$, molar mass 264.3 g/mol) is an aqueous solution of sodium salt of dibutyl dithiophosphoric acid.

Oxal T-92 is a product of high boiling by-products of dimethyldioxane production. It contains more than 50 % of dioxane alcohols and esters and about 50 % of a mixture of 1, 2, 3 atom alcohols.

OPSB is a mixture of monobutyl esters of C_4H_9-O-$(C_3H_6O)_nH$ polypropylene glycols.

Flotanol C7 is an alkylpolyglycol based foaming agent. These foaming agents for sulfide ores were developed with optimal selectivity and are effective with ores containing nonferrous metals, platinum group minerals and precious metals.

B-TETA has four amino groups with four butyl radicals in its composition and is well soluble in water. It adsorbs on the surface of the bubbles, and changes their negative charges into positive ones, thus intensifying the flotation process.

MIBCwith the molecular formula $(CH_3)_2CHCH_2CHOCH_3$ is slightly soluble in water and can dissolve in most organic solvents.

Senfroth foaming agents consist of varying amounts of alcohol, polyethylene glycol and ethylene glycol. Senfroth 580 contains 37-50% alcohol, 38-51% glycol ether, ≥9% glycol with density of 0.903-0.96.

Such concept as water-air micro dispersionstability was introduced - it is time spent for destruction of emulsion. A flotation agent solution of 500 dm^3 is passed through the generator and water-air microemulsion is obtained for this purpose (Figure 5a). Then a stirrerand a stopwatch are turned on, and time spent for microemulsion destruction to a certain state is recorded (Figure 5b). The time taken tp break indicates the stability of the water-air micro dispersion.

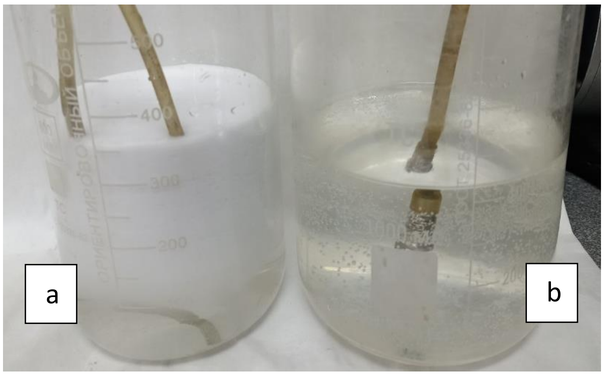

Figure 5 - View of water-air micro dispersion before (a) and after (b) destruction

Table 1 shows the dependence of water-air micro dispersion stability and size on the foaming agent type and concentration at the optimal speed of the generator of 6000 rpm.

The results of Table 1 show that:

- The optimal concentration for butyl aeroflot is 0.5 g/l, at which the particle size varies 43-58 µm (t 20-40 °C), the bubble stability is 80 sec;
- The optimal concentration for T-92 is 5 g/l, at which the particle size varies 41-43 µm (t 20-40°C), the bubble stability is 70-80 sec;
- The optimal concentration for OPSB is 5 g/l and more, at which the particle size varies 81-83 µm (t 20-40°C), the bubble stability is 60 sec;
- The optimal concentration for flotanol C-7 is 5 g/l, at which the particle size varies from 55 to 75 µm (t 20-40 °C), the bubble stability is 65-70 sec;
- The optimal concentration for B-TETA is 50 g/l, at which the particle size varies from 53-59 µm (t 20-40°C), the stability of the bubbles is 70-75 sec;
- Senfroth 580 foaming agent gives microbubbles with a stability of 60-65 seconds, the particle size from 73-85 µm (t 20-40°C)at a concentration of 5 g/l and more.

Table 1 - Dependence of -air micro dispersion stability and water size on the foaming agenttype and concentration at the optimal speed of the generator of 6000 rpm

Temperature, ^{0}C	Bubble size and bubble life at different concentrations (g/L)							
	0,05		0,5		5,0		50	
	Bubblestability, sec	Particlesize. µm	Bubblestability, sec	Particlesize. µm	Bubblestability, sec	Particle size,µm	Bubblestability, sec	Particlesize, µm
BTF								
20	55	90	80	42	70	65	70	65
30	45	100	80	43	65	73	70	69
40	40	110	80	41	65	76	70	67
50	35	120	70	65	65	75	70	66
60	35	123	70	68	65	72	65	73
70	30	142	60	81	60	83	65	75
80	25	150	50	85	50	93	55	86
T-92								
20	35	123	60	80	80	42	35	128
30	35	121	60	83	75	53	35	125
40	30	145	60	81	70	58	35	126
50	30	141	60	84	65	73	35	124
60	30	140	60	82	60	82	30	142
70	30	144	55	88	55	87	20	159
80	30	145	55	89	50	96	20	162
OPSB								
20	30	143	55	85	60	81	60	83
30	30	141	55	87	60	83	55	88
40	30	144	55	89	60	83	55	89
50	30	143	55	86	55	89	50	87
60	30	142	55	87	55	87	45	103
70	30	141	50	98	55	88	45	105
80	30	140	50	97	55	86	40	113
C-7								
20	30	143	40	112	70	55	75	55
30	30	142	40	116	70	57	75	54
40	25	153	40	114	65	75	70	58
50	25	156	40	113	65	74	70	59
60	25	151	30	145	60	82	65	72
70	25	154	30	147	55	88	65	71
80	25	152	30	143	55	87	65	71
B- TETA								
20	20	180	50	91	60	83	75	53
30	20	185	50	94	55	89	75	54
40	20	188	50	93	55	88	70	59
50	20	181	50	93	50	95	70	60
60	20	189	45	103	50	94	70	59
70	20	187	40	117	45	105	65	73
80	20	185	35	125	45	104	60	81
SENFROTH 580								
20					65	73	65	74
30					60	85	65	73
40					60	84	60	86
50					55	89	60	84
60					55	90	60	85
70					55	89	55	87
80					50	97	45	62

MIBC at a concentration of 50 g/l produces unstable microbubbles which quickly disintegrate within 10 seconds.

The flotation agents can be arranged in the following lineunder theor ability to create water-air micro dispersion: MIBC → SENFROTH 580→ B-TETA→OPSB→ Flotanol C-7→T-92→Butyl Aeroflot.

Attempts in the area of bubble formationare made to create more microbubbles. Reduction of the bubblesize increases the flotationefficiency. The asymmetric structure of foaming agent molecules and their low solubility in water contribute to their concentration on the interface L-G (or L-T), where they are oriented so that their hydrophilic group is directed to water, while the hydrophobic one (hydrocarbon radical) is directed to less polar phase (air, oil). Having a low surface tension, foaming agents reduce the surface tension of water and form a hydrate layer around the air bubble. It dramatically increases the stability of the air bubbles enabling to retain their original dispersibility [[22], [23], [24]]. The arrangement of the polar groups in the moleculeis essential for the surface activity of the substance. Foaming agent molecules adsorb more actively the more asymmetric the arrangement of hydrophilic and hydrophobic groups in the molecule is; the limiting location of the polar group is the end of the hydrocarbon radical. Bubbles should be elastic and elastic, i.e., deformable in addition to coalescence stability. Elasticity depends on the length of the hydrocarbon radicall middle homologues of the series of single-atom alcoholshaveespecially high elasticity.

Thus, the factors effecting the water-air micro dispersion properties are the temperature of the pulp, the speed of the generator, the concentration of foaming agent solution [19], as well as the L:G ratioregulated by the dosing pumps of the generator, as well as the foaming agenttype.

Conclusions

The effect of L:G phase ratio on the properties of water-air micro dispersion was studied. It was found that the optimum liquid-gas ratio is 1:1, the optimum capacity of the generator is 6-7.2 l/h, with the average size of the water-air micro dispersion is 33-41 μm for BTF solution, 103-107 μm - for C-7 solution, 90-93 μm - for B-TETA solution.

The type of foaming agent used in flotation effects the size and stability of microbubbles. It is established that the flotation agents can be arranged in the followinglinewith respect to ability to create micro dispersion: MIBC→Senfroth 580→B-TETA→OPSB→Flotanol C-7→T-92→BTF. The best results are shown by BTF that creates a micro dispersion of 43-58 μm size (t 20-40 °C) and stability of 80 sec.at concentration of 0.5 g/dm^3.

Conflict of interest

The correspondent author declares that there is no conflict of interest on behalf of all authors.

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Су-ауалы микродисперсияның қасиеттеріне әсер ететін факторларды анықтау

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ТҮЙІНДЕМЕ

Мақалада сұйық-газ фазасының қатынасы және көбіктендіргіш реагентінің түрі көбіктендіргіш ерітіндіден алынған су-ауа микродисперсиясының орташа мөлшеріне әсері бойынша зертханалық зерттеулердің нәтижелері берілген. Микрокөпіршіктердің мөлшері

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Сараптамадан өтті: *24 ақпан 2022*
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оларды өндіру үшін қолданылатын көбіктендіргіш реагентінің түрі мен концентрациясына байланысты флотация тиімділігіне айтарлықтай әсер етеді. Су-ауа микродисперсиясын алу үшін генератор қолданылды. Сұйық-газ фазаларының әртүрлі қатынасында және генератордың әртүрлі өнімділігінде су-ауалы микродисперсиясын алу параметрлерін анықау жұмыстары жүргізілді. Зерттеу объектілері ретінде концентрациясы 0,5 г/дм^3 құрайтын келесі көбіктендіргіш реагенттері пайдаланылды: натрий бутил аэрофлоты (БТФ), флотанол С-7, бутилтриэтилентетрамин (В-ТЕТА). Сұйық-газ фазаларының оңтайлы қатынасы 1:1, генератордың оңтайлы өнімділігі 6-7,2 дм^3/сағ құрайды, ал БТФ ерітіндісінен алынған су-ауа микродисперсиясының орташа мөлшері 33-41 мкм, С-7 ерітіндісінен - 103-107 мкм, В-ТЕТА ерітіндісінен - 90-93 мкм құрайды. Флотацияда қолданылатын көбіктендіргіш реагентінің түрі микрокөпіршіктердің мөлшері мен тұрақтылығына әсер етеді. Микродисперсия жасау қабілетіне қарай флотациялық реагенттерді келесі қатарға орналастыруға болады: MIBK → Senfroth 580 → B-TETA → OPSB → флотанол S-7 → T-92 → BTF. Ең жақсы нәтижелерді БТФ реагенті көрсетті, ол 0,5 г/дм^3 концентрациясында микробөлшектердің мөлшері 43–58 мкм (t 20–40 °C) және тұрақтылығы 80 сек құрайтын микродисперсия өңдейді.

Түйін сөздер: флотация, комбинирленген микрофлотация, флотациялық реагент, су-ауа микродисперсиясы, микрокөпіршіктер.

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Определение факторов, влияющих на свойства водовоздушной микродисперсии

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АННОТАЦИЯ

В статье представлены результаты лабораторных исследований по изучению влияния соотношения фаз жидкое-газ и вида пенообразователя на среднюю крупность водо-воздушной микродисперсии, полученной из раствора пенообразователя. Размер микропузырьков существенно влияет на эффективность флотации, зависит от вида и концентрации вспенивателя, используемого для их производства. Для получения водо-воздушной микродисперсии использовали генератор. Проведены работы по отработке параметров получения водовоздушной микродисперсии при разном соотношении фаз жидкость-газ и разной производительности генератора. В качестве объектов исследований использованы вспениватели: бутиловый аэрофлот натрия (БТФ), флотанол С-7, бутилтриэтилентетрамин (Б-ТЭТА) при концентрации 0,5 г/дм^3. Установлено, что оптимальное соотношение фаз жидкость—газ составляет 1:1, оптимальная производительность генератора 6-7,2 дм^3/ч, при этом средняя крупность водовоздушной микродисперсии составляет 33-41 мкм для раствора БТФ, 103-107 мкм - для раствора С-7, 90-93 мкм - для раствора Б-ТЭТА. Вид вспенивателя, используемого при флотации, влияет на размер и устойчивость микропузырьков. Установлено, что по способности создавать микродисперсию флотореагенты можно расположить в следующий ряд: МИБК→ Senfroth 580→ Б-ТЭТА→ОПСБ→ флотанол С-7→Т-92→БТФ. Наилучшие результаты показывает БТФ, который при концентрации 0,5 г/дм^3 создает микроодисперсию крупностью 43-58 мкм (t 20-40 °С) и устойчивостью 80 сек.

Ключевые слова: флотация, комбинированная микрофлотация, флотореагент, водовоздушная микродисперсия, микропузырьки

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