Optimization of flotation processes by bubble size selection

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Abstract. It is known that the size of the bubbles plays a decisive role in the flotation of particles. The paper presents the calculation of the optimal sizes of floating bubbles depending on the size of the particles of pollution. The latter allows you to adjust (select) the dispersion of bubbles, which increases the efficiency of the equipment: an increase in hydraulic loads, a decrease in capital and metal consumption.

1 Introduction

The choice of this size is mainly determined by the probabilities of collision and fixation of particles on the bubble. Moreover, the first is determined by the hydrodynamics of fluid flows around the pop-up bubble, that is, the Reynolds number Re (the so-called Stokes number, with Reynolds number less than one, and potential, with Reynolds number greater than one, modes) closes, and hence the ratio of the sizes of bubbles and particles. The aim of the work is to find an optimizing ratio between the dispersion of bubbles and the particle sizes of contaminants during flotation [1-6].

2 Methods and Materials

An elementary calculation shows that the minimum surface energy of the bubble-particle system in a liquid is not a function of the angle alone, but is a complex function of the ratio Ro/r (Ro, r - the radii of the bubble and the particle, respectively). Moreover, with some values of this ratio:

$$\tilde{R}_0 = R_0/r \geq \tilde{R}_{0\text{крит}} \quad (1)$$

Where $\tilde{R}_{0\text{крит}}$ there is a function of specific surface energies at the liquid-particle-gas boundaries, and there is no minimum at all.

This will necessarily lead to the absence of a condition for fixing the particle on the bubble and, as a result, to a deterioration of flotation purification. This provision follows from the following considerations. Consider the bubble-particle system in a liquid before

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(Figure 1,a) and after (Figure 1,b) collision Then the surface energy of the bubble-particle aggregate according to Figure 1, a will be equal to [7-13]:

$$W^0 = S_{12}^0 \cdot \sigma_{12} + S_{23}^0 \cdot \sigma_{23} \tag{2}$$

And the energy according to Figure1,b is equal to:

$$W = S_{12} \cdot \sigma_{12} + S_{23} \cdot \sigma_{23} + S_{13} \cdot \sigma_{13} \tag{3}$$

Where S- the area of the interfacial surface; σ- the interfacial energy (tension) between the corresponding phases, the indices mean: lower 1, 2, 3- respectively, gas, liquid, particle, upper; "o"- parameters before collision and formation of a three-phase wetting perimeter.

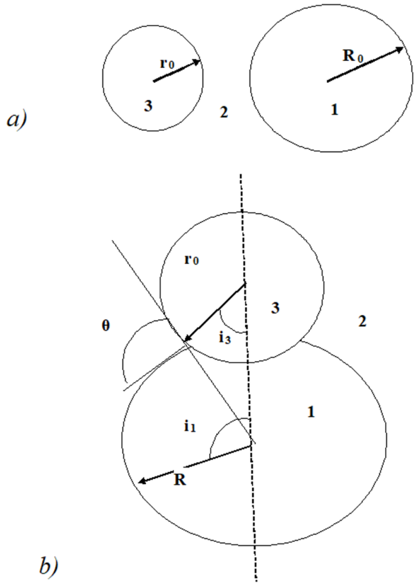

Fig. 1. The "gas bubble-particle" unit in the liquid "before" (a) and "after" (b) the formation of a three-phase wetting perimeter.

3 Results and Discussion

The values of the values included in (1,2) are equal to:

$$S_{12}^0 = 4 \cdot \pi \cdot R_0^2, S_{23}^0 = 4 \cdot \pi \cdot r^2, S_{12} = 4 \cdot \pi \cdot R^2 \cdot \sin^2(i_1/2) \tag{4}$$

$$S_{23} = 4 \cdot \pi \cdot r^2 \cdot \cos^2(i_3/2), S_{13} = 4 \cdot \pi \cdot r^2 \cdot \sin^2(i_3/2) \tag{5}$$

Where R- the radius of curvature of the bubble surface.

The connection between the corners i3, i1, θ It is found from the geometry of the drawing and the conditions for maintaining the initial volume of gas:

$$(4/3) \cdot \pi \cdot R_0^3 = \pi \cdot R^3 \cdot C(i_1) - \pi \cdot r^3 \cdot C(i_3); \theta = 180 - i_1 + i_3 \tag{6}$$

Where $C(x) = 2/3 - \cos(x) + 1/3\cos^3(x); R = r\sin(i_3)/\sin(i_1)$.

The system of equations (5,6) has relatively unique solutions for each fixed value. Finding these values i_3, i_1, θ it is easy to calibrate (3), which means that the angle corresponding to the minimum value can be determined W, that is, to determine the equilibrium edge angle θ_p.

For the convenience of presentation and generality of the result, we will keep an account of the dimensionless energy W/W°:

$$\frac{W}{W^0} = \frac{\sigma_{23} \cdot \cos^2(i_2/2) + \tilde{R}^2 \cdot \sigma_{12} \cdot \sin^2(i_1/2) + \sigma_{13} \cdot \sin^2(i_3/2)}{\sigma_{23} + \tilde{R}^2 \cdot \sigma_{12}} \tag{7}$$

Where $\tilde{R} = R/r$.

The calculation using formula 7 shows (Figure 2) that the possibility of a minimum energy (corresponding to the equilibrium angle) strongly depends on the dimensionless radius of the bubble [14-16].

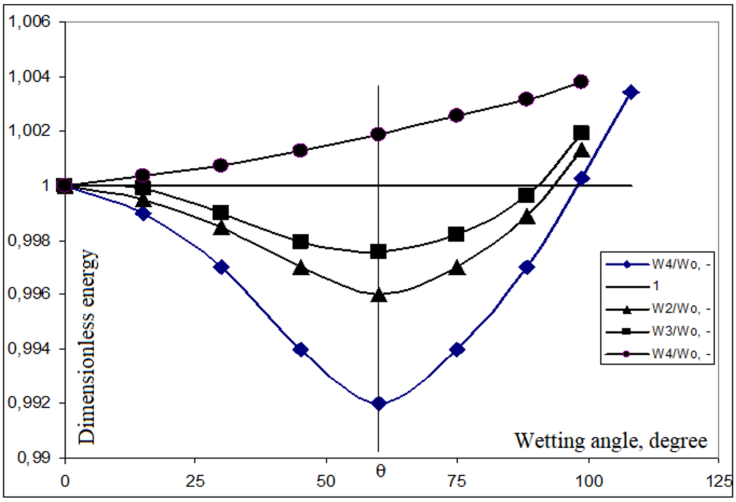

Fig. 2. Theoretical dependences (calculated) on the possibility of forming a three-phase wetting perimeter: $\tilde{R}o$ = 0.01, 0.1, 1.0, 10, respectively, for curves 1, 2, 3, 4.

4 Conclusion

It can be seen that the less $\tilde{R}_0$, thus, the depth of the potential pit (and hence the adhesion force) is greater, and at $\tilde{R}_0 = 10$ there is no minimum at all (curve 4). This indicates that it is impossible for a particle and a bubble to stick together at these values σ_{12}, σ_{13},σ_{23}. Obviously, there is a certain value $\tilde{R}_0$, in which such minimization of energy is possible, which means that the appearance of a flotation unit is possible. The considered dependencies make it possible to regulate flotation processes both by selecting appropriate collectors and suppressants (surfactants), so is the selection of bubble sizes (R_0) depending on the particle size (r).

The numerical values of the quantities included in (7) are taken as an example (which does not exclude the generality of the conclusion) equal to: σ_{13}=500, σ_{12}=70, σ_{23}=465 J/м^2. Moreover, it can be seen that the angles obtained from the well-known Young's equation

$$\sigma_{13} = \sigma_{12} \cdot \cos\theta_\text{p} + \sigma_{23} \tag{8}$$

$$\cos\theta_\text{p} = \frac{\sigma_{13} - \sigma_{23}}{\sigma_{12}} = \frac{500 - 465}{70} = \frac{35}{70} = 0.5 \tag{9}$$

And from the condition of the minimum surface energy (Figure 2), they are the same (600). This indicates the adequacy of the model (conditions for maintaining the spherical shape of the bubble in the aggregate) to nature. This is also indicated by the fact that, as is known, the equilibrium edge angle θ_p it does not depend on the size of the bubble or drop (R_O).

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