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SIZE OF MINERAL PARTICLE

IN RELATION TO

FLOTATION CONCENTRATION

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By A. W. Fahrenwald

Introduction

The size of the mineral particle is a factor of flotation that has been given little more than a passing thought by flotation engineers. Every one familiar with the older gravity methods of concentration well understands the advantages accruing through close classification of the feed to the concentrators. However, it is not logical to assume that classification of feed for flotation will be equally profitable. It is hoped the following analysis of this subject will be of value.

The factors controlling the size of a mineral particle that can be floated are: (1) The degrees of oil-mineral, oil-water, and air-water adsorption which determine the force with which the particle is held to the bubble; (2) the shape of the particle; (3) its specific gravity; (4) the cleanness of its surface, which influences the degrees of adsorption (1); and (5) the swirl of the pulp.

Of course maximum flotation efficiency is to be obtained by treating the largest particle that can be floated by its first attachment to a bubble or a number of bubbles; when the mineral particle is of such size, however, that it is dropped and caught many times by the rising bubbles before it is entangled in the froth and finally removed from the machine, finer grinding would result in greater recovery and higher efficiency. The agitation and swirl of pulp, particularly near the surface, will influence greatly the size of particle floatable under given conditions. A machine giving a concurrent motion to the pulp will allow the maximum size of mineral particle to be floated. The size of bubble is important; the more numerous and the finer the bubbles, the more efficient will be the flotation. There is no doubt that a good many bubbles actually engage each particle before it is finally floated.

Size of Particle and Flotative Intensity

The following analysis will illustrate the relations existing between the floatability of minerals and the sizes and weights of mineral particles.

In the discussion to follow the following symbols will be used: SpS, W, UFI, and TFI.

By SpS (specific surface) is meant the ratio of surface of a mineral particle to its volume. In other words, the total surface of a mineral particle with respect to its volume increases as the size of the particle decreases.

By W is meant the weight of the particle.

By UFI (unit flotative intensity) is meant the forces of flotation acting on a unit surface (1 sq. cm.) of the mineral particle. There is probably a close relation between this force and the unit adsorptive capacity of the mineral for oil, and as pointed out by the writer in another paper* it is different for different minerals, and it may even be different for two minerals of apparently the same composition and molecular structure.

By TFI (total flotative intensity) is meant the total force acting to bring about the flotation of a mineral particle, and it is equal to the specific surface (SpS) of the particle times its unit flotative intensity (UFI), divided by the density of the mineral referred to, considering that of galena as unity.

The formulae PbS and ZnS are used to represent respectively the minerals galena and sphalerite.

Case I

Two Particles of the Same Size and of the Same Mineral.

PbS

PbS

If	SpS is to	SpS′ as 1 is to 1
	W is to	W′ as 1 is to 1
	UFI is to	UFI′ as 1 is to 1
Then	TFI is to	TFI′ as 1 is to 1

Case II

Particles of the same Mineral but of Different Sizes.

PbS

PbS

If	SpS is to	SpS′ as 1 is to 1.3
	W is to	W′ as 2 is to 1.0
	UFI is to	UFI′ as 1 is to 1.0
Then	TFI is to	TFI′ as 1 is to 1.3

* "Surface Energy and Adsorption in Flotation." Min. and Sci. Press Vol. 123 pp. 227-234, (August 13, 1921.)

Case III

Particles of Different Minerals of the Same size

PbS ZnS

(A)	If	SpS is to	SpS′ as 1 is to 1.0
		W is to	W′ as 1 is to 0.5
and	if	UFI is to	UFI′ as 1 is to 1.0
	Then	TFI is to	TFI′ as 1 is to 2.0

(B) If UFI is greater than UFI′ (exact ratio not known),
Then TFI is equal to, greater than,
or less than* TFI′

(C) If UFI is less than UFI′ (Usually not the case),
Then TFI will be less than TFI′

Case IV

Particles of the Different Minerals of Different Sizes, the Lighter Mineral Being the Smaller.

PbS ZnS

(A)	If	SpS is to	SpS′ as 1 is to 1.3
		W is to	W′ as 4 is to 1.0
		UFI is to	UFI′ as 1 is to 1.0
	Then	TFI is to	TFI′ as 1 is to 2.6
(B)	If	UFI is greater than	UFI′
	Then	TFI is equal to, greater than, or less than	TFI′
(C)	If	UFI is less than	UFI′
	Then	TFI is much less than	TFI′

Case V

Particles of Different Minerals of Different Sizes, the Heavier Mineral being the Smaller.

PbS ZnS

(A)	If	SpS is to	SpS′ as 1.3 is to 1.0
		W is to	W′ as 1.0 is to 1.0
		UFI is to	UFI′ as 1.0 is to 1.0
	Then	TFI is to	TFI′ as 1.0 is to 1.5

* Depending upon the actual UFI of the PbS mineral.

(B)	If	UFI is greater than	UFI′
	Then	TFI is equal to, greater than, or less than	TFI′
(C)	If	UFI is less than	UFI′
	Then	TFI is less than	TFI′

In case I let us consider two particles of the same mineral (PbS for example) and of the same shape and size. For convenience in calculations let the particles be one millimeter cubes. Then they will weigh the same and their specific surfaces, i.e., total surfaces divided by volumes, respectively, will be equal. If now, as will naturally be the case, they have equal unit flotative intensities, i.e., the same flotative intensity per unit of surface, the two particles will have equal total flotative intensities, i.e., they will be raised to the surface of the aerated pulp with the same amount of force. This is the simplest combination of particles for flotation.

In case II let us still consider two particles of the same mineral, but of different sizes, say for the sake of convenience in calculation that one particle is twice the volume of the other. Then if the edge dimension of the larger particle is 1 mm., the edge of the smaller will be 0.8 mm. approximately, their specific surfaces will be as 1 is to 1.3 (larger to smaller) their weights will be as 2 is to 1, and their UFI's will be equal as in case I. The relation of their TFI's will be as 1 is to 1.3, larger to smaller. The TFI is determined by dividing the specific surface by the density of the mineral particle, considering that of galena as 1, sphalerite as 0.5, etc.

It appears that this relation of particles of the same mineral is not the best for most advantageous flotation. Of course, as is the case in proper flotation practice, the largest particles resulting from the grinding process should be small enough to be readily floated under the conditions prevailing. When this is the case, the smaller particles are sure of being floated.

In case III let us consider two minerals, say galena and sphalerite, of the same size. The particles will then have equal specific surfaces and their weights will be in the ratio of 2 to 1 approximately. If we assume that their UFI's are equal, their TFI's will be as 1 is to 2 (PbS to ZnS). If, however, the UFI of the galena is greater than the UFI of the sphalerite, as is true, the TFI of the galena will be equal to, greater than, or less than TFI of the sphalerite, depending upon the actual difference in UFI of the two particles. If the UFI were twice as great for the PbS as for the ZnS, the TFI's would be equal.

In case IV we have a special case of case III. Considering particles of the same two minerals, where the volume of the ZnS particle is half that of the PbS particle, the specific surfaces of the particles are as 1 is to 1.3 (PbS to ZnS), and their weights are as 4 to 1 respectively. Now if the UFI's of the minerals are equal, case IV*a*, the total flotative intensities of the particles will be as 1 is to 2.6 (PbS to ZnS); if the UFI of the PbS is greater than the UFI of the ZnS, case IV*b*, then the TFI of the one may be equal to, greater than, or less than that of the other; and finally, if the UFI of the PbS is less than that of the ZnS, case IV*c*, the TFI of the ZnS will be greater than the TFI of the PbS. This latter relation would be the most advantageous condition for separation of two minerals by differential flotation. It, however, can not be realized by classification.

In case V consider the same two minerals, but in this case let the heavy mineral (galena) be the smaller. The specific surfaces will then be as 1.3 is to 1 (PbS to ZnS), and the weights will be equal. If the UFI'c are equal, case V*a*, the TFI'c will be as 1.0 is to 1.5. If the UFI of the PbS is greater than the UFI of the ZnS, case V*b*, then the TFI of the one mineral particle will be equal to, greater than, or less than that of the other; and if the UFI of the PbS is less than that of the ZnS, case V*c*, then the TFI of the PbS will be less than that of the TFI of the ZnS.

Conclusions

(1) For the flotation of a single sulphide mineral away from gangue, it appears that classification either as to size of particle (screening) or as to size and weight (hydraulic classification) would be of little value, excepting that it would give a more uniform condition of total mineral surface which could be more consistently met in practice.

(2) Of two particles of the same mineral, the smaller has the greater total flotative intensity.

(3) With two particles of different minerals the widest difference in total flotative intensity would result if the particle

of the lighter mineral were the smaller and had the higher unit flotative intensity, because the difference in the weights of the two particles is greatest, and the specific surface increases as the size of particle decreases. This association of particles can not be realized by classification.

(4) For two different minerals the conditions of cases V*a*, V*b*, and V*c* could be obtained by water classification. If the smaller mineral happened to have the higher unit flotative intensity, water classification would make the separation of the two minerals by flotation more readily accomplished.

For two floatable minerals of equal or nearly equal specific gravities, water classification would give a product more adaptable to differential flotation than if the two minerals were of widely different specific gravities. To elucidate: water classification of particles of unlike specific gravities would give products consisting of large-light and small-heavy particles. The small-heavy minerals would have greater specific surface, and consequently greater total flotative intensity, which would, however, be largely counterbalanced by the greater weight of the small particles. The same reasoning shows why a feed made up of small-light and large-heavy particles would give the greatest difference in total flotative intensity of particles and most advantageous relation of particles for differential flotation.