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CONSIDERATION OF INFLUENCE OF THE THICKNESS OF THE HYDRATION SHELL OF SOLID PARTICLES IN THE GRAVITATIONAL ENRICHMENT METHODS

The results of the influence of the hydration shell thickness at an average density of the particle – shell complex and a decrease of the difference between the average density of the complexes with decreasing particle size of minerals are shown in the article.

When a solid particle is immersed in water, a hydrate shell is formed on its surface, moving with the particle. The mechanism of shell formation has not been elucidated in details yet because of the many factors influencing this process. On the surface of the solids there are uncompensated ionic and covalent bonds, by which it selectively acquires a charge of either sign relative to the water. Most minerals bear a negative charge in water. When interacting with these charges, polar water molecules form the adhesion layer, which is most strongly held by surface. The second row of molecules is attached to the first, following rows – to the second, and so on. It is known, that over a hundred of such layers may be formed [1]. In these layers there are hydrated ions, whose charge is opposite to the charge of the solid surface, the so-called counter ions. An electric double layer is formed, the value of which is characterized by a zeta-potential. Furthermore, water molecules can interact against each other through hydrogen bonds and form long chains analogous to polymeric.

During the study of water filtration through the precipitations of fine suspensions it was found that the thickness of the hydrated film on the surface of minerals may exceed 11 microns [3]. Apparently, the mechanism of the investigated phenomena is similar to the mechanism of formation of known in hydrodynamics boundary layer, whose thickness can attain tens of micrometers [2]. When calculating the velocity of movement of particles of size less than 100 microns in water Stokes formula without regard to grain shape is applied. This can be explained by the fact that the hydrate shell, moving with the particle, smoothes the surface roughness and particle shape approaches spherical. Of course, the shell thickness should depend on the speed and nature of the water flow around it, the physicochemical properties of the surface and ionic composition of the solution, temperature, etc. Although in any case it is necessary to consider the presence of such a shell in the calculation of gravitational mineral dressing processes.

To simplify the calculations, consider a spherical particle with diameter of d , coated with hydrated shell with thickness of δ . The average density of such a complex is defined from expression:

$$\gamma_{cp} = \left(\frac{d}{d + 2\delta}\right)^3 \cdot (\gamma_m - \gamma_{\text{жс}}) + \gamma_{\text{жс}}$$

Gravity separation

where γ_{cp} , γ_m , $\gamma_{ж}$ – the densities: average, of the solid and liquid phases respectively, kg/m^3 .

Taking hydration shell thickness equal to 5 microns, the water density of 1000 kg/m^3 , calculate the average density of the complexes for the minerals of quartz, rhodochrosite and magnetite, the density of which is equal to 2700, 3700 and 5400 kg/m^3 respectively.

The results of calculations are presented graphically in Fig. 1 as a function of particle – hydrate shell complexes density on the particle diameter. As can be seen from the figure, when the particle size reaches 50 microns the density of the complexes is much less than the density of the solid phase. When the particle size decreases, the average density tends to density of water. Thus, an average density of particles with the size of 5 microns, which corresponds to the taken hydration shell thickness, is slightly different from the density of water. Therefore, such particles will move along with the flow of water irrespective of the impact of gravitational or inertial forces.

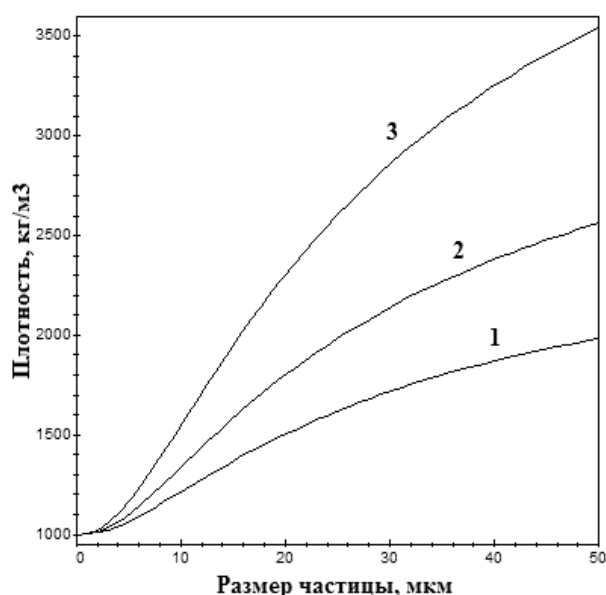


Fig. 1. Dependence of particle – hydrate shell complex average density on the particle diameter:
1 – quartz, 2 – rhodochrosite 3 – magnetite

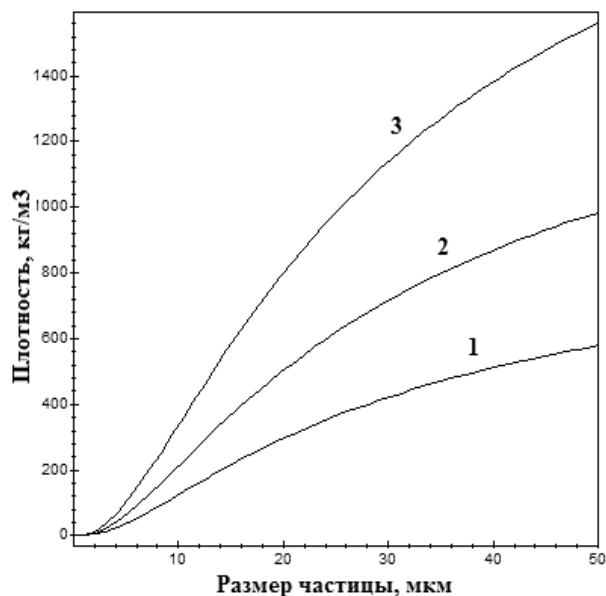


Fig. 2. Dependence of density difference of minerals in water on their size:
1 – rhodochrosite – quartz; 2 – magnetite - rhodochrosite; 3 – magnetite – quartz

However, even for relatively large magnetite particles of 0.5 mm the decrease in the average density is 4.7 % at the taken thickness of the shell. This fact must be considered in the technological calculations.

For enrichment of minerals by gravitational methods difference in their densities is required. Its minimum value depends on the specific method and the apparatus design. For example, in case of jigging enrichment the density difference should be more than 200 kg/m^3 . For heavy media separation, this value should be at least 120 kg/m^3 . Even for separation in heavy liquids density difference should exceed 60 kg/m^3 . The difference in the densities of minerals in the aqueous medium, based on

the availability of hydrated film, can be determined from the expression:

$$\Delta\gamma_{cp} = \left(\frac{d}{d+2\delta}\right)^3 \cdot (\gamma_{m1} - \gamma_{m2})$$

where $\Delta\gamma_{cp}$, γ_{m1} , γ_{m2} – the density difference of minerals, density of the first and second minerals respectively, kg/m^3 .

Dependence of the density difference of minerals with due regard to thickness of the hydration film on their size is shown in Fig. 2. As can be seen, the density difference of mineral –shell complexes decreases with decreasing particle size and for particle size less than 5 microns becomes lower than 100 kg/m^3 , which makes it almost impossible for them to be enriched with gravity methods. Exceptions are minerals with a very high density, such as native gold. But even in this case the separation of particles of size less than 1 micron is possible.

It was previously noted that the thickness of the hydration shell is influenced by the presence of the electric double layer. Therefore, the average density of particle – shell complex can be controlled by changing the value of zeta potential. If this change is implemented selectively, it is possible to enhance the contrast of the separation characteristic for minerals in the size range from 10 to 200 microns.

In addition it should be noted that the presence of the hydrated film on fine particles increases their motion resistance force in the medium, which reduces the velocity of their movement. Ultimately, this leads to decline in performance of processing equipment.

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