

EXPERIMENTAL INVESTIGATION OF THE FLOTATION OF
NONMAGNETIC SOLIDS IN A MAGNETIC LIQUID

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The use of magnetic liquids (ML) in concentration techniques is determined, besides various technological factors, primarily by the accuracy of distribution of the effective specific weight in the liquid and the minimum size of nonmagnetic particles for which a certain method of density determination is admissible. Fundamentally, there are no limitations on the accuracy of distribution of the effective specific weight, since it is determined by the ML characteristics and the magnetic field geometry in the gap of the apparatus, which can always be secured under the circumstances necessary for practical application. The problem of the minimum particle size is more complex. Beginning with a certain size, difficulties arise in separating the particles with respect to density because of, first, the low velocity of particles and, second, their aggregation and adhesion to the bottom as the surface forces come into play.

We provide here the results of an experimental investigation of fine particles in a ML. Glass powder, separated into seven size fractions in the range from +0.04 to -2.5, was used in the experiments. These were performed by using an MGS-1 device [1] with No. 2 poles and the MZh-1 magnetic liquid with saturation magnetization of 6 G, which is produced by the Khimreaktiv plant.

The experiments were started by calibrating the MGS-1 device with respect to the test material with subsequent control with respect to coarse glass powder. The density of the test material and glass was determined by hydrostatic weighting; it amounted to 2510 kg/m³.

A Plexiglas vial was filled with the ML and placed in the operating section of MGS-1. The previously weighed powder (the batch mass amounted to 80...100 g) was poured into the vial. The supply current of the device was somewhat lower than the current ensuring glass flotation on the liquid surface in the vial, but it guaranteed suspension of the powder within the liquid. This prevented powder adhesion to the bottom of the vial. After a short exposure to ensure wetting of the powder, the supply current corresponding to the density of glass was switched on. Powder that floated to the surface was removed. In the course of experiments, it was noted that the percentage of the powder that had floated to the surface diminished with a reduction in powder size, while, even for supply current values corresponding to a density of 2700 deg/m³, a deposit still remained in the vial.

The powder taken off the liquid surface was rinsed to remove remnants of the liquid and was then dried and weighed. The deposit in the vessel was treated similarly. Figure 1 shows the deposit mass, reduced to the entire batch, as a function of the particle size.

In order to establish a relationship between the effect observed and the surface phenomena, we determined the specific surface of powder in each size fraction. The specific surface was measured chromatographically, using thermal desorption and the device described in [2]. The measurement results are given in Fig. 2.

Using the experimental results provided in Figs. 1 and 2, we readily established a direct relationship between the percentage of the powder deposit and the specific surface of the powder (Fig. 3, curve 1). Consequently, we reached the conclusion that there is adsorption of the ML by glass particles, whereby the ML causes "weighting" of the glass powder in a magnetic field. In order to check this hypothesis, we determined by chemical analysis the concentration of iron in the powder after its exposure in the magnetic liquid. Figure 3 (curve 2) provides the iron concentration as a function of the specific surface of glass

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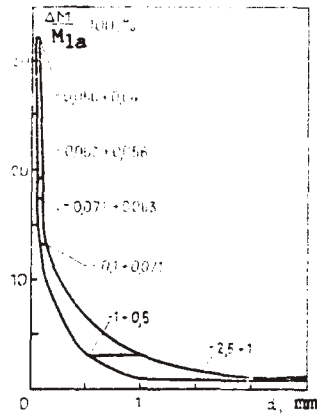


Fig. 1

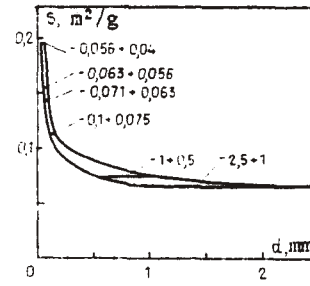


Fig. 2

Fig. 1. Relative percentage of the deposit as a function of the particle size (the figures characterizing the size fractions are given at the curves and, similarly, at the curves in Fig. 2; according to the commonly used rules, for instance, the size fraction $-0.056 + 0.04$ denotes a group of particles that have passed through a 0.056-mm mesh screen, but are retained in a 0.04-mm mesh screen).

Fig. 2. Specific surface of glass as a function of the particle size.

particles. It is evident that the percentage of magnetite bound to a particle increases with a reduction in particle size.

Estimates of the order of magnitude of the force acting on the adsorbed layer relative to the force acting on the nonmagnetic solid in a magnetic liquid yield the relationship

$$F_{1a}/F_m = \rho_{so} S d_{eq} I_{1a} / I,$$

where ρ_{so} is the density of the solid, S is the specific surface, d_{eq} is the equivalent layer thickness, and I_{1a} and I are the magnetization values for the layer and the liquid, respectively. Using the above results, we obtain for glass $F_{1a}/F_m \sim 0.1 \dots 1$ if $d_{eq} \sim 10^{-6} \dots 10^{-7}$ m and $I_{1a}/I \sim 2$. Thus, the forces acting on the adsorption layer can materially alter the flotation conditions, for nonmagnetic solids in a magnetic liquid.

If there is equilibrium, we can use the equation of motion of a solid in projection onto the vertical axis [3] with an allowance for the associated magnetic layer to derive an expression for the effective specific weight of the liquid,

$$\gamma_{so} = \frac{\gamma_l + \mu_0 I |dH/dz|}{1 + \rho_l S d_{eq} [(I_{1a}/I) - 1] (\mu_0 I / \gamma_l) |dH/dz| + (\rho_{so} / \rho_l) - 1},$$

whence it follows that the effects produced by the presence of an adsorption layer are observed only if $I_{1a} > I$ and $\rho_{1a} > \rho_l$. Physically, this corresponds to selective adsorption of the magnetic phase from the carrier liquid at the particle surface.

Furthermore, we have attempted to investigate experimentally the behavior of particles within the limits of one size fraction. For glass powder of size $-0.1 + 0.075$, sampling was performed with currents from 60 to 100 A at 10 A intervals, which corresponded roughly to a uniform subdivision of the 2510...2680 kg/m³ range of density values. Then, using selections of 50 and 100 particles from each sample, we measured the mean particle dimensions under a microscope and processed the data statistically [4]. Figure 4 shows the results of processing with respect to all the current values with a distribution histogram for the initial size fraction. The parameter $P_{dp} = n_i / (n \Delta d)$, where n_i is the number of particles in the size range $d_{i+1} - d_i = \Delta d$, while n is the total number of particles in a sample, is laid off along the vertical axis of the histogram. Unfortunately, it was not possible to establish a definite correlation between the MGS-1 supply current and the particle distribution characteristics.

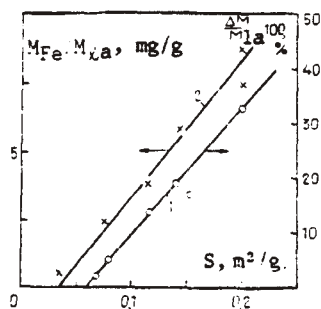


Fig. 3

Fig. 3. Relative deposit percentage and the iron percentage in glass powder as functions of the specific surface.

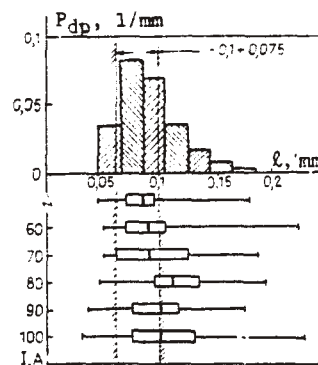


Fig. 4

Fig. 4. Diagram of the particle distribution within the $-1 + 0.075$ size fraction (initial powder) with respect to the values of the separator supply current; the form at the top of the lower part of the diagram also pertains to the initial powder.

Investigations of the flotation conditions for quartz, baryta, and fluorite powders yielded qualitatively similar results.

According to our experimental investigations, a correspondence between the effective specific weight and the density of a solid is still observed for size fractions of the order of $+ 0.25 + 0.3$ mm (with an accuracy sufficient for the separation of minerals).

Thus, as a result of our investigations, we have established limits from below with respect to sizes of particles in determining their density. Since there is a direct proportional dependence of particle "weighting" on the specific surface, this phenomenon is naturally explained as being caused by the adsorption layer of ML at the particle surface. According to estimates, the force acting on the adsorption layer amounts to more than 10% of the body force acting on the nonmagnetic solid in the ML. The expression for the effective specific weight indicates that the "weighting" effect occurs when the magnetization of the layer is different from the magnetization of the liquid. Attempts at a thorough analysis of particle behavior within one size fraction did not yield positive results.

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