SOME FEATURES OF THE ENTRAINMENT OF FINE POLYDISPERSE PARTICLES FROM A FLUIDIZED BED

O. B. Tsitovich

Inzhenerno-Fizicheskii Zhurnal, Vol. 9, No. 6, pp. 806–809, 1965

UDC 541.182

An investigation has been made into the entrainment of shale flotation concentrate and polyvinyl chloride under fluidization conditions. The kinetics of entrainment are described by an equation given in [5].

Investigations have been made into the fluidization of shale flotation concentrate (SFC) and polyvinylchloride (PVC) of various grades in connection with the development of new technological processes in the production of plastics. SFC is a product of high concentration of kuckersite shales, i.e., a natural high-molecular organic compound, and PVC is a synthetic high-polymer, obtained by emulsion polymerization by the aqueous suspension or latex method; SFC particles are irregular flakes, while the PVC particles are spherical, often with internal voids.

Upon heating (SFC to 200°–300° C, PVC to 85° C), the particles soften and change shape, whereupon "fusion" of the particles into a single monolith may easily occur.

The investigations were carried out both in the laboratory and under industrial conditions, in cylindrical and conical-cylindrical equipment of diameter 25–1000 mm. The distributors employed were wire mesh, a DK miplastic separator, and porous glass and ceramic plates with clear cross sections from 0.5 to 40% and aperature size from 1 to $3 \cdot 10^3$ μ.

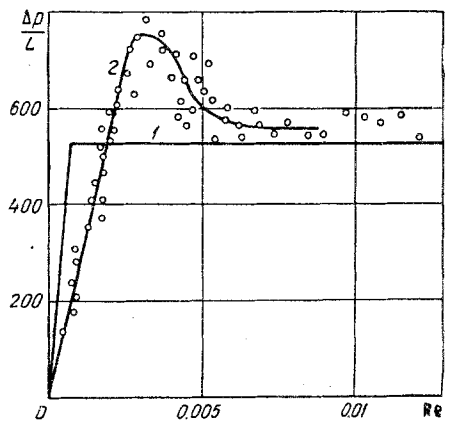

Fig. 1. Theoretical (1) and experimental (2) curves of fluidization of polyvinyl chloride with particle size 5–60 μ.

Tests without a distributor were run on the cylindrical-conical equipment. The fluidizing agent was air, but in some tests with SFC, nitrogen and carbon dioxide were also used. The average particle diameter was calculated from the formula recommended by Reboux [2]

$$1/d_m = \sum_i (x_i/d_i).$$

In all cases the largest particles of the product did not exceed 100 μ.

Judging from the data on granulometric composition, we see that a bed consisting of only fine particles must possess very great resistance and be fluidized even at negligible air flow velocities $w_K < 1$ cm/sec.

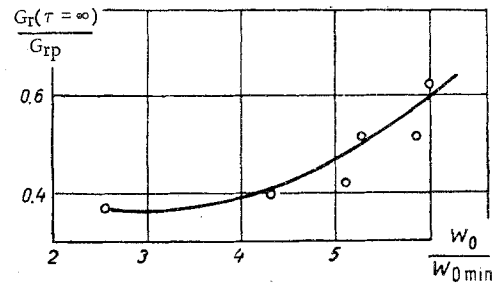

Fig. 2. Dependence of the ratio of the maximum amount of material removed $G_Г(\tau = \infty)$ to the fines fraction at $\omega_c \leq \omega$ on gas flow velocity ω in periodic fluidization of shale flotation concentrate with particle sizes 5–100 μ in a laboratory column of diameter 142 mm, bed height 50 mm, and with a porous glass distributor.

According to the usual formulas, the finest particles with $d \leq 5$ μ should be completely removed from the bed even at a velocity $\omega_c = 1.5 \cdot 10^{-3}$ cm/sec.

This picture is not confirmed by experiment. For gas flow through a stationary bed of SFC or PVC, the resistance of the bed is considerably lower than the theoretical value, and noticeable rearrangement of the bed begins only at velocities greater by approximately an order of magnitude than the theoretical fluidization velocities [3, 4]. Stable channels of odd configuration begin to form in the bed—craters along which the main gas flow is directed. When a porous glass and ceramic distributor or a miplastic separator is used, further increase of velocity causes the crater walls to begin to break down, while the craters themselves wander over the bed, creating around them regions of fluidization which gradually encompass the whole bed.

Upon fluidization of certain grades of PVC, particularly those that have undergone heat treatment, and SFC of increased humidity, and also when distributors with a large clear cross section are used, the craters prove to be stable even for a considerable increase of gas velocity. In this case even an artificial stimulus, e.g., tapping along the column or an abrupt

change in gas velocity, does not lead to uniform fluidization—following breakdown of the channels and temporary "boiling up" of the entire bed, new craters are formed with stagnant zones between them.

The behavior of the materials is considerably affected by the ratio of the height of the bed H to the apparatus diameter D. At small H/D values there is an increased tendency for the material to form stable craters, while at high H/D a piston regime is easily established. Figure 1 shows the variation of pressure loss in fluidizing PVC.

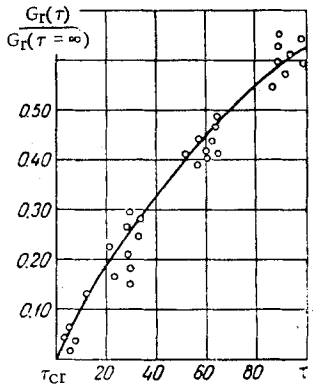

Fig. 3. Example of correlation of theoretical removal curve with experimental curves for $k_1 = 0.01$ l/min; $k_2 = 0.5$ l/min.

The peculiarities described point to the formation in the bed of aggregations of adjacent particles. The presence of such aggregations in beds of very fine particles, due to electrification and Van der Waals forces, was also pointed out earlier [6]. Aggregation leads to increased effective diameter, and therefore to lowered hydraulic resistance and increased critical velocity for the start of fluidization of the bed. Evidently the aggregations are friable and disintegrate in the course of measurement of granulometric composition.

The correctness of these ideas about the structure of a fluidized bed of SFC and PVC is confirmed in the study of entrainment for these systems. Bearing in mind the measured granulometric composition, we see that at operating velocities $\omega > \omega_c$ a considerable number of fine particles with critical velocity ω_c less than the flow velocity w must be entrained. Moreover, with increase of ω and τ, not only would there be an increase in the number N_r of particles removed from the fluidized bed, but also a smooth change in their granulometric composition.

The measured entrainment, both in laboratory and in industrial conditions, is paradoxically small. Comparison of the granulometric composition of PVC and SFC particles removed and caught by filters with the original composition indicates that particles of all sizes, except the largest, are removed from the fluidized bed in practically the same way. This phenomenon was notices both in laboratory conditions with the fluidization number varied from 2.5 to 6.0, and in an industrial cylindrical-conical equipment with a stirrer and fluidization number up to 10.

During an investigation of entrainment under periodic fluidization conditions, in a column with a porous glass distributor, the rate of removal $dG_r/d\tau$ (where G_r is the amount of material removed up to time τ) fell practically to zero over 2–5 hr. The limiting amount of material calculated in this way, G_r ($\tau = \infty$), that would be removed from the bed at the given flow velocity ω, proves to be considerably less than the possible value, G_{rp}, determined from the granulometric composition with the condition $\omega_c \leq \omega$. The ratio

$$\frac{G_r(\tau=\infty)}{G_{r.p}} = f(\omega)$$

increases with the flow velocity and tends to unity (Fig. 2). The data presented indicate that increase of flow velocity and intensity of fluidization in such systems leads to gradual breakdown of the aggregations and to the possibility of removal of more fine particles from the fluidized bed. To determine the kinetic constants of the removal process, we compared the experimental curves of G_r versus τ with the theoretical formulas given in the first part of [5]. With the help of simple algebraic transformations, formula (12) of [5] can be brought to the form

$$\varphi = \frac{G_r}{G_r(\tau=\infty)} = \frac{1-\exp(-k_2\tau)}{1-k_2/k_1} - \frac{1-\exp(-k_1\tau)}{k_1/k_2-1}$$

Coefficients k_1, k_2 of the removal curve may be determined by a grapho-analytical method on the basis of two experimental values of φ. An example of such a correlation is shown in Fig. 3.

In our tests the values of the kinetic constants k_1 and k_2 proved to be only very slightly dependent on the flow velocity. While the absolute amount of material removed increased rapidly with increase of gas flow velocity, the relative (dimensionless) rate of removal φ proved to be practically independent of gas velocity.

It should also be noted that the appearance of craters in the bed leads to a sharp increase in entrainment, since the gas velocities are large in the craters, the aggregations break down, and the intensity of entrainment approximates to that normal for the given granulometric composition. This phenomenon was observed, for example, when the porous glass distributor was replaced by wire mesh.

The specific properties described are evidently typical, not only of SFC and PVC, but in general of highly disperse, predominantly organic materials of low specific weight.

NOTATION

d_m—mean particle size; x_i—contribution by weight of narrow fraction; d_i—particle diameter of narrow fraction; H—height of stationary bed; D—diameter of

apparatus (diameter of cylindrical part of cylindrical-conical apparatus); ω—air flow velocity over whole section of apparatus; w_c—critical particle velocity; τ—duration of test; N_r—number of particles removed; k_1, k_2—kinetic constants defined in [5].

REFERENCES

1. A. F. Dobryanskii, Petroleum Geochemistry [in Russian], Leningrad, 1948.

2. P. Reboux, The fluidized Bed [Russian translation], TsNIITsVETMET, 1959.

3. V. D. Goroshko, R. B. Rozenbaum, and O. M. Todes, "Hydraulics of the fluidized bed," Proceedings of the 1st All-Union Conference on Heterogeneous Processes involving Solids in Fluidized Beds [in Russian], GNTK SSSR, 1957.

4. I. G. Lesokhin, O. B. Tsitovich, G. N. Balabanovich, and L. I. Vinnikov, Tr. Lensovet LTI, no. 9, Goskhimizdat, 1961.

5. O. M. Todes and O. B. Tsitovich, IFZh, 9, no. 5, 1965.

6. M. Leva, Fluidization [Russian translation], Gostopizdat, 1961.

12 January 1965

Higher Military School of Engineering and Technology, Leningrad