CONSTRAINED SEDIMENTATION OF POLYDISPERSED PARTICLES IN A CENTRIFUGAL FIELD

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The article presents the results of a study concerning the constrained sedimentation of microparticles in a centrifugal field, treating the kinetics of this process as the kinetics of a random process described by methods analogous to the classical methods of describing the sedimentation of colloidal particles and the Brownian motion in a gravitational field [Smolukhovskii, Einstein, etc.].

Assuming that sedimentation takes place in a cylindrical vessel which revolves at an angular velocity ω and disregarding the relativistic as well as the Coriolis forces of inertia, one can describe the sedimentation of particles along the vessel by the following stochastic equation:

$$\frac{dr}{dt} = \frac{2R^2\left(\frac{\rho}{\rho_s} - 1\right)\omega^2 r}{9\nu} + \frac{1}{6\pi\rho_s \nu R}\xi(t),$$

where R is the equivalent radius of a particle; ρ and ρ_s are the density of particles and of the suspension respectively; ν is the kinematic viscosity; and $\xi(t)$ is a random perturbation which will further be treated as "white noise."

Corresponding to this equation one can set up a differential equation of the probability density distribution in a random process:

$$\frac{\partial w(t, r)}{\partial t} = \frac{b}{2} \cdot \frac{\partial^2 w(t, r)}{\partial r^2} - \beta\frac{\partial}{\partial r}[rw(t, r)],$$

where

$$b = \frac{b'}{36\pi^2\rho_s^2 \nu^2 R^2}; \quad \beta = \frac{2R^2\left(\frac{\rho}{\rho_s} - 1\right)\omega^2}{9\nu};$$

and b' is the intensity of random perturbations. The coefficient b is a measure of disorder in the motion of particles along the vessel under a random perturbation, while β determines the mean rate of particle sedimentation in a centrifugal field.

A solution to this equation for $w(t, r)$ has been obtained with the initial condition $w(0, r) = f(r)$ and with the boundary conditions:

$$\frac{b}{2} \cdot \frac{\partial w}{\partial r} - \beta r w = 0 \text{ for } r = r_0; \; w = 0 \text{ for } r = r_0 + h.$$

The first of these boundary conditions signifies that no particles flow across the wall $r = r_0$, while the second one indicates that particles which reached the region boundary $r_0 + h$ are removed and do not participate further in the sedimentation process.

As a process quality index we use the extracted quantity, i.e., the quantity

$$Q = \frac{1}{w_p}\int_{r_0}^{r} w\,dr,$$

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which defines the ratio of particles of a given class contained between sections r and r_0 at an instant of time t to the number of such particles in the original mixture uniformly distributed along the height of the vessel with the density $w_p = 1/h$, where h denotes the height of the vessel.

Curves representing the process kinetics have been calculated as functions of the parameters $\bar{h} = h(\beta/b)^{1/2}$ and r_0/h.

The agreement between calculated and tested data on the constrained sedimentation of abrasive micropowders in tumbler-type centrifuges has been found satisfactory.