INVESTIGATION AND CALCULATION OF THERMOPHYSICAL PROCESSES

CALCULATION OF THE OPTIMAL FILTRATION PRESSURE AND SOME DESIGN PARAMETERS OF FILTER PRESSES

O. L. Bruk, I. D. Peichev, and V. L. Radushkevich

The design of filter presses is mainly determined by such parameters as the working pressure in the filter chambers and the geometric dimensions of the elements comprising the chambers. To evaluate the effect of pressure on the specific resistance of the solids, we have proposed several simple empirical equations, in accordance with which the velocity increases without limit with increasing pressure, and, therefore, the efficiency of the filtration process increases. However, the efficiency of the filtration process for suspensions of highly compressible solids increases as the pressure is increased to some optimal value, above which the filtration process becomes less efficient.

Problems in selecting the optimal working pressure for filtration of organic-synthesis products and suspensions of some inorganic compounds have been considered in [1, 2].

To evaluate the resistance of the solids, the following equation is used most often:

\[ \alpha = \alpha_0 p^s, \]  

where \( \alpha \) is the volumetric specific resistance of the solids at a given pressure, \( 1/m^2 \); \( \alpha_0 \), volumetric specific resistance of the solids at a pressure equal to 1 N/m²; \( \rho \), working pressure, N/m²; and \( s \), compressibility coefficient of the solids.

Equation (1) is also used to calculate the resistance of iron hydroxide, aluminum, and copper solids [4].

Let us introduce an auxiliary quantity, viz., the dimensionless number for the efficiency of filtration under pressure:

\[ \eta = \tau_1/\tau_T, \]

where \( \tau_1 \) and \( \tau_T \) are the filtration times at a pressure of 1 N/m² and in an intensified regime (at increased pressure), respectively.

It is known [4] that when the resistance of the filter baffle is insignificant (for \( \beta \approx 0 \)), the filtration time is

\[ \tau = \frac{\mu s h^3}{2 p u}, \]  

where \( \mu \) is the viscosity of the liquid phase of the suspension, N·sec/m²; \( h \), thickness of the solids layer, m; and \( u \), ratio of the solids volume to the filtrate volume.

On the basis of Eqs. (1) and (2), we obtain

\[ \eta = \frac{\mu s h^3}{2 \cdot 1a} \frac{2 p u}{\mu s p h^2} = \rho^{1-s}, \]

i.e., the dimensionless number for the efficiency for \( s < 1 \) increases monotonically with increasing pressure.

To evaluate the resistance of the solids, the following more reliable equation [1, 3] is also often used:

\[ \alpha = \alpha_0 + a p^s, \]

(here \( \alpha_0 \) is the hypothetical specific volumetric resistance of the solids at pressure \( p = 0 \), and \( a = \alpha_1 - \alpha_0 \) is the experimental coefficient), which, unlike Eq. (1), does not require the necessary condition that the curve \( \alpha = f(p) \) pass through the origin of the coordinates.
Fig. 1. Relation of the filtration parameters to pressure: —— for power relation (1) \( s = 0.67 \); — for exponential relation (6) \( \alpha_0 = 2800 \times 10^{12} \text{ l/m}^2; s = 0.105 \); 1) \( \alpha = f(p) \); 2) \( \varphi = f(p) \); 3) \( \tau = f(p) \).

Fig. 2. Relation of the specific volumetric resistance of the solids \( \alpha \) to the pressure \( p \) for filtration of wastes from flotation of coal slurries of coal-upgrading plants: 1) Dzerzhinsk Central Upgrading Plant \( \alpha_0 = 2800 \times 10^{12} \text{ l/m}^2; s = 0.105 \); 2) Nikitovsk Central Upgrading Plant \( \alpha_0 = 650 \times 10^{12} \text{ l/m}^2; s = 0.08 \); 3) Taibin Dressing and Upgrading Plant \( \alpha_0 = 440 \times 10^{12} \text{ l/m}^2; s = 0.108 \); 4) Upgrading Plant No. 2 of the Makeevsk By-Product Coking Works \( \alpha_0 = 270 \times 10^{12} \text{ l/m}^2; s = 0.08 \).

When Eq. (3) is used, the dimensionless number for the efficiency is

\[
\varphi = \frac{(\alpha_0 + s) p}{\alpha_0 + \alpha p^s}.
\]

Let us analyze Eq. (4) for the maximum of the value of \( \varphi \):

\[
\frac{d \varphi}{dp} = \frac{(\alpha_0 + s) \left[ \alpha_0 + (1 - s) \alpha p^s \right]}{\left( \alpha_0 + \alpha p^s \right)^2} = 0.
\]

Since the denominator of the obtained expression is not equal to zero, we can write

\[
\alpha_0 + (1 - s) \alpha p^s = 0,
\]

whence the optimal pressure is

\[
P_{\text{opt}} = \frac{s}{\alpha (s - 1)}.
\]

A similar equation, but one which is less convenient to use, was obtained in [2, 4] in determining \( P_{\text{opt}} \) for suspensions of calcium sulfate \( (s = 2.54; P_{\text{opt}} = 0.25 \text{ MN/m}^2) \), calcium chloride \( (s = 1.5; P_{\text{opt}} = 0.44 \text{ MN/m}^2) \), and potassium-ore flotation wastes \( (s = 1.92; P_{\text{opt}} = 0.276 \text{ MN/m}^2) \).

Experiments carried out at the Institute for Upgrading of Solid Fossil Fuels have shown that the specific resistance of some highly compressible solids (e.g., in the filtration of wastes from flotation of polydisperse coal slurries containing over 70% argillaceous matter) is not in a power relation, but in an exponential relation to the pressure (see Fig. 1):

\[
s = \alpha_0 \varphi^p.
\]