УДК

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PROCEDURE TO RESEARCH CHARACTERISTICS OF FINELY DISPERSED COAL BEARING SLUDGE.

The lacks of existent methods ofquality of finely dispersed sediments, which influence on filtration process. There are investigations which took place in pores on micro level. By results of researchers the maximum time which is necessary of dewatering of slim-sediment with various permeability is defined. The time of dewatering, which depends on permeability of sediments, pressure difference and thickness of sediments , is defined.

Key words: coal, slime accumulation, filtration, speed, shear.

The problem and its connection with scientific and practical tasks. The current condition of coal mining equipment has resulted in the situation that run-of -mine coal delivered to preparation contains about one third of slurry fineness particles and its ash content is, as a rule, 25-30% . The solution to the problem how to improve the quality of commercial concentrates and at the same time increase the volume of coal preparation is indispensably connected with processing and dewatering of fine and thin size coals, the amount of which in run-of -mine coal is constantly increasing. Transportability and cost of such products depend on their humidity, high values of which make the utilization of these materials less efficient. Improvements in the technologies related to small particles and slurries are an important task of the production.

Dewatering of fine and small particles causes great difficulties as they form sludge with a highly- developed surface which is active with water. Porosity and permeability of these media are usually low.

Consequently, enterprises have to use several stages of dewatering to receive slurry products with required humidity level. The combination of mechanical and thermal dewatering is commonly used.

When comparing these types of dewatering with respect to their environmental assessment and cost estimate, the first method is, as a rule, preferable, especially when there are no strict requirements concerning the product humidity, and the product has to be processed until it becomes transportable.

Mechanical dewatering is the cheapest and commonly used method. Increase in the efficiency of fine sludge dewatering to reduce sludge humidity using the mechanical method permits to save the electrical energy consumed during thermal aftertreatment of the product until its commercial humidity. A great variety of equipment with different operating principles is used for this purpose and filtering prevails among them.

The analysis of the latest researches and publications. The analysis of the latest researches conducted recently has shown that finely-dispersed sludge actively reacts with water and traps a considerable amount of it due to a highly-developed surface of the particles and the capillary and electrostatic forces acting there. Since the particles are fine, the sludge has a high resistance to water flow in the pore space.

During filtering all three phases interact in the pore space of sludge. Numerous foreign and national researches have established the fundamental laws of these complex interactions. The main task is to increase the rate of dewatering the porous medium of the sludge which is often hindered by the microbubbles adsorbed on the surfaces of particles and this phenomenon results in blocking of fine pores.

Rather complex processes take place in the extensive network of pores in the sludge and this fact makes it necessary to explore the sludge properties on the microlevel. This will allow defining the ways how to make the process of filtering more effective.

The analysis of the researches permits to come to the conclusion that despite the fact that there are a lot of theoretical and experimental investigations, the problem how the sludge resulting from coal washing changes its properties when shearing deformations are applied simultaneously with movement of the fluid in porous medium has not been studied properly yet.

The analysis of the papers devoted to mechanical dewatering of the fine sludge difficult to filter and the analysis of theoretical and experimental investigations have shown that the processes of movement of the fluid in sludge pores are still underinvestigated. Opinions differ when studying how various parameters influence the changes in the porous structure of the sludge and gas and liquid phase flow through it.

In most cases there are no quantitative parameters and the assessment of the stresses and deformations taking place in sludge when various mechanical actions are applied. In doing so, many authors point out that it is possible to improve the filtration processes and increase its efficiency by acting namely mechanically on the sludge as it is more feasible and relatively cheap.

Task setting. The problem analysis has proved the necessity to develop the procedure how to research the sludge characteristics which are important for dewatering of finely dispersed coal bearing sludge using mechanical methods. The task set in this paper is solved with the help of the procedure containing the calculation formulae to define the limits of the movement of the wetting and nonwetting phases in the pores of coal bearing sludge, the calculation of the maximum filtration time and specification of the parameters allowing process intensification.

Material presentation and the research results. When studying the processes taking place in the sludge volume during dewatering it is difficult to take into account the properties of individual pores having variable diameters along the length, alternation of widening and contractions, dead sections. For practical purposes it is important to study the movement of the phase boundary front as a whole, that is to use an integral approach which involves analytical simulation of the front movement of the phase boundary between liquid and gas in the sludge pore medium which is one of the defining components of the mechanical dewatering during filtration.

Analytical investigation is undertaken for the conditions when the liquid in pores moves in the same direction as the gradient of the operating force, which often occurs during filtration and, in particular, in vacuum belt filters (Fig.1).

When studying this process the following assumptions have been made: 1) the suspension has the concentration of granular solids when there is no vertical settling; 2) moisture removal process is considered as the movement of water in a porous body under the influence of the gradient pressure on different edges of a pore; 3) temperature is constant during the whole process; 4) porous medium is incompressible and its permeability is constant; 5) the filter belt speed is constant.

That is why pore dewatering by means of air can be seen as the process similar to dewatering by a piston.

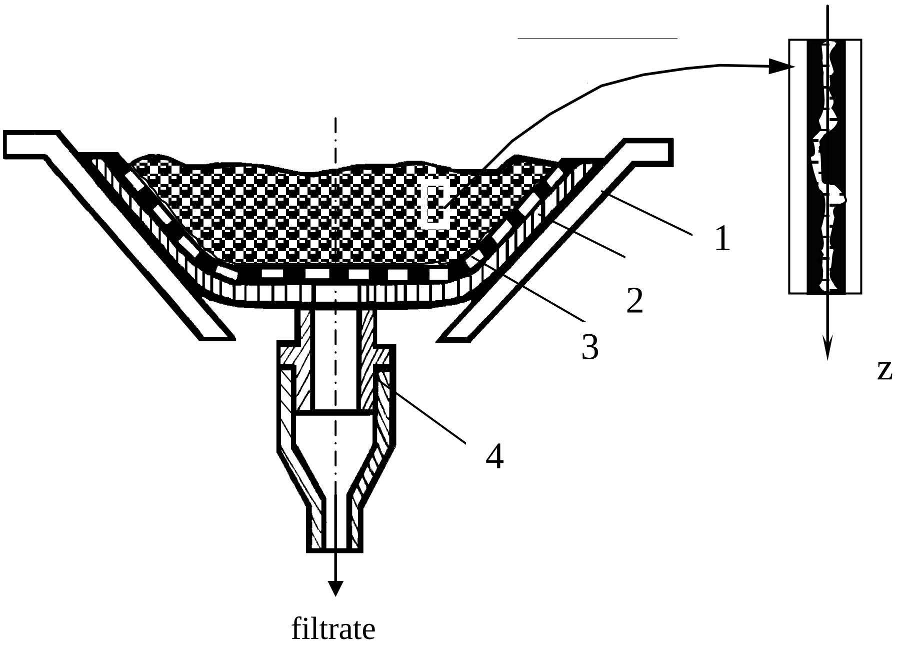


Fig. 1. Cross-section of a belt filter
(a pore in the sludge volume is shown on the right):
1 – supporting chute, 2 – rubberized belt with meshes along the axis, 3 – filtration fabric, 4 – discharge of filtrate

The piston moves along the vertical axis z, as shown in Fig. 2, and the task of the analytical research can be considered as one-dimensional.

It is necessary to define the change of the position of the phase boundary between water and air in time $h_i = h(\tau)$.

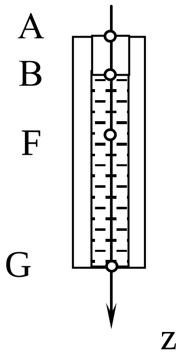


Fig. 2. Porous body dewatering using a piston

The reference time corresponds to the position of the point A, when time τ = 0, the horizontal coordinate x = 0 when the belt and the filtration fabric move with the constant speed. At this moment PA = P0 = 0,1MPa (1atm). The fact that there is the pressure gradient between the points A and G, where PG < 0,1 MPa, results in dewatering with air. The process takes place in the steady-state conditions. At the moment corresponding to the position of the point B the pressure is PB = P0 and the height of the liquid in a pore is h0 = h(τ). The current parameters hi = h(τ), PF = Pi, are in the point F, and at the end of the process, consequently, hG and PG = P1< 0,1 MPa in the point G.

Generally speaking, mass transfer in a porous medium is described by an equation of the following form:

$$\mathrm{div}\,[\delta\, C / \mu\, (\Delta P + \delta \Delta H)] = \partial\, m\, \delta / \partial\, \tau, \qquad (1)$$

where δ –density of a substance;

C – permeability of the sludge porous medium ;

μ – viscosity of water;

m – porosity of medium;

ΔP – pressure gradient;

ΔH – enthalpy change;

τ – time.

The following assumptions are made when rearranging, simplifying and solving this equation:

1) the process is isothermal ($\Delta H = 0$),

2) the porous medium and liquid are incompressible ($m = const$),

3) the permeability is constant,

4) the correlation $P / P_0 = (\delta / \delta_0)^\eta$ is taken into account for an isothermal process,

5) boundary and initial conditions: $0 \le z \le h_0$, $\tau > 0$, at $\tau = 0$; $P = P_0$, $\partial P/\partial\tau = 0$, at $z = 0$: $P = P_0$; at $z = h$: $P = P_1$

On rearrangement, the following is received at the phase boundary between gas and liquid :

$$P(z,\tau) = P_B + K\frac{dh_B}{d\tau}(h_B - z) + \frac{1}{2} f(\tau)(h_B - z)^2. \tag{2}$$

Here, $K = m\mu_{B\text{-x}} / C$.

The function $f(\tau)$, the type of which is unknown, can be defined on the basis of the initial conditions, when $z = 0$, $P = P_A$:

$$f(\tau) = \frac{2}{h_B^2}(P_A - P_B - K\frac{dh_B}{d\tau}h_B). \tag{3}$$

The resultant expression to define the required pressure is:

$$P(z,\tau) = P_B + K\frac{dh_B}{d\tau}(1 - \frac{z}{h_B})z + (P_A - P_B)(1 - \frac{z}{h_B})^2. \tag{4}$$

Having rearranged equation (4), the differential equitation of second order for the phase boundary between air and water is received:

$$\frac{K h_B^2}{6}\frac{d^2 h_B}{d\tau^2} + [(P_A - P_B)\frac{1}{3} + 2K_2 K]\frac{dh_B}{d\tau} + \frac{K h_B}{3}(\frac{dh_B}{d\tau})^2 + \\ + \frac{2}{3}h_B\frac{dP_B}{d\tau} = \frac{2K_2}{h_B}(P_A - P_B). \tag{5}$$

In the region of incompressible liquid flow the liquid filtration equation and the boundary conditions have the following form:

$$\partial P/\partial z = 0,$$

$$at\ z = h \quad P = P_G; \quad at\ z = h_B \quad P_B^+ = P_B^-, \quad \frac{\partial P^-}{\partial z}\Big|_{z=h_B} = -K_3 \frac{dh_B}{d\tau}, \tag{6}$$

where $K_3 = m\mu_{\text{water}} / C$.

This task has the following function as its solution:

$$P = P_G + K_3 \frac{dh_B}{d\tau}(h - z). \tag{7}$$

At $z = h_{\text{B}}$ the following dependence is received:

$$P_B = P_G + K_3 \frac{dh_B}{d\tau} \quad (h - h_B). \tag{8}$$

Upon rearranging, simplifying and taking into account the initial and boundary conditions the simultaneous solution of equations (5) and (8) gives the possibility to define the position of the phase boundary between gas and liquid and the pressure in it. The formula to calculate the position of the phase boundary between gas and liquid is the following:

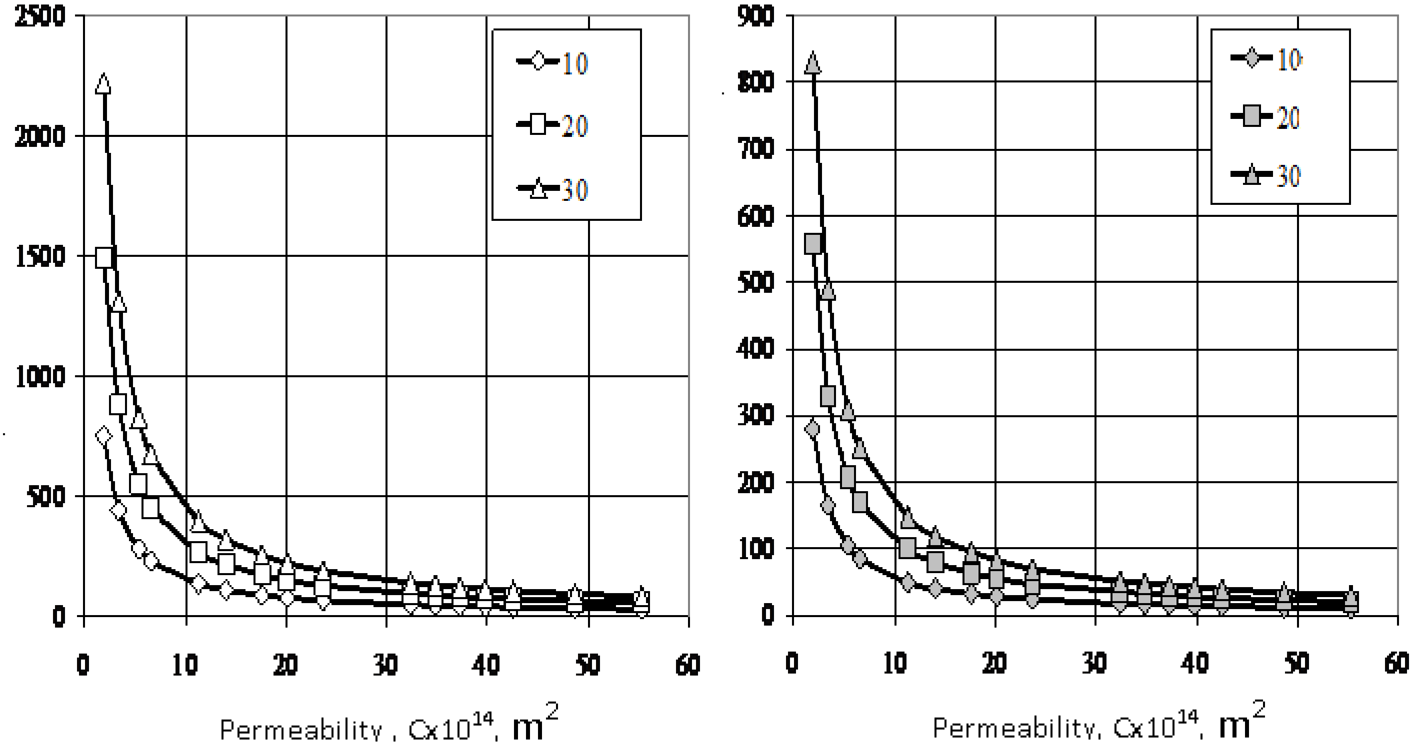
$$h_B = \frac{-6\,K_2K_3h}{\Delta P + 6K_2(K - K_3)} + \sqrt{[\frac{6K_2K_3h}{\Delta P + 6K_2(K - K_3)}]^2 + \frac{12K_2\Delta P\tau}{\Delta P + 6K_2(K - K_3)}}\,. \tag{2.26}$$

The maximum time of the sludge layer dewatering τ_{max} can be defined by calculating the parameter h_B. This moment occurs when h_B reaches the value of h_G. To carry out the calculations it is necessary to know the values of permeability and porosity of the sludge under study. These parameters can be defined during the hydrodynamic investigation of the sludge pore medium; they are specified by the arrangement of particles in the sludge and by grain-size composition of the material the sludge consists of.

The equation analysis enables to obtain the time of dewatering for sludge of different thickness and permeability at various pressure difference.

The initial parameters for calculations are the sludge porosity and permeability; their values are determined by the grain-size composition of the raw material, by the parameters of the pore medium and they can be easily calculated.

The results of the calculations based on formula (8) are given in the form of curves to define the maximum time required for dewatering sludge of different thickness and permeability depending on the applied pressure difference.



30 кPa 80 кPa

Fig.3 Time of phase boundary movement at pressure difference.

Three sections can be distinguished in each curve. In the sludge with high permeability (32,4-55,3)x10^{-14}m^2 τ_{max} has practically linear dependence on permeability, and the maximum dewatering time is within the range 80-30s. Coarse - grain coal slurry in the underscreen water of the classification with water or of the gravity separation, thickened products of hydrocyclones belong to the sludge with such properties.

For the sludge with medium permeability (14-23,7)x10^{-14} m^2 it is typical that τ_{max} increases and reaches the value 400-150 s. Medium permeability is characteristic for sludge with low content of fine particles (with fineness less than 100µm)

For the sludge with low permeability (1,99-11,3)x10^{-14}m^2 the time to reach the pore edge is the longest and it changes in the range from 2220 to 830s when increasing the applied pressure difference. The sludge with high content of fine or clay particles (more than 30%), for instance, floatation tailings, has low permeability. Sudden change of the time of moving the boundary between water and air in the sludge pore medium when its permeability changes is typical for such materials.

In such a way it is possible to achieve the increase in sludge permeability by regulating the sludge structure and subsequently, it is possible to improve the dewatering values without the significant increase in the pressure difference.

Conclusions and directions for future research. The analysis of the mass-transfer equation for the porous medium of finely dispersed sludge has enabled to receive the dependence to define the position of the phase boundary in a sludge pore which has the following form:

$$h_B = \frac{-6\,K_2K_3h}{\Delta P + 6K_2(K-K_3)} + \sqrt{[\frac{6K_2K_3h}{\Delta P + 6K_2(K-K_3)}]^2 + \frac{12K_2\Delta P\tau}{\Delta P + 6K_2(K-K_3)}}\ .$$

While analyzing this equation the maximum time required for dewatering of finely dispersed sludge with different permeability has been defined.

It has been proved that for the sludge with high permeability the time required for the phase boundary to reach the pore edge is not too long and practically there is a linear dependence between the time and the applied pressure difference. It is especially obvious for shallow thickness sludge.

It has been established that for the coal sludge with low and medium permeability there is a typical linear dependence between the sludge humidity and the time required for the phase boundary between water and air to reach the pore edge, and this time is considered to be the maximum dewatering time.

High-ash sludge has low permeability.

So, determination of the maximum time required for filtering of coal bearing sludge enables to define the optimal parameters for a dewatering unit (the speed of the belt of a vacuum belt filter) depending on the properties of the feedstock.

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