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ENERGY EFFICIENCY OF MINE DRAINAGE SYSTEMS

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Abstract

Mine drainage systems represent an important and most energy-consuming engineering process of mining operations; it ensures safety and efficiency of all mine working. At many drowned mines with water-inflow coefficient equal to more than one, the amount of pumped mine water exceeds the amount of excavated mineral product. One of the reasons behind high energy consumption of mine drainage is pollution of mine water with mechanical impurities, coal and rock dirt, the content of which reaches 10-20% of the pumped volume of liquid. Increase in energy efficiency of mine drainage systems is directly related to the necessity to use hydro-mechanized devices for removing solid constituent from mine water on production horizons and sites. Such technology of mine drainage helps to decrease the amount of the required pumping units' head, contributes to improvement of operation reliability of equipment and pipelines and their endurance. The existing methods of mine water clarification in the main mine drainage systems do not permit to reach the necessary quality of mine water. Water sumps and sedimentation tanks installed in the main mine drainage systems clarify mine water from the largest particles requiring herewith a periodical cleanout of silt. The methods used for calculation of mine drainage systems mainly disregard the presence of mechanical particles in mine water. Due to this, mine pumps operate at increased pressure.

Keywords: mine water; solid particle concentration; clarification; head loss; laminar thickener.

1. Introduction

The analysis of water drainage condition at underground mines and pits showed that the heads of mine pumps are excessive. This has received considerable attention in many research works of the mine drainage originators [1-3]. The reason is a significant content of solid particles in the pumped mine water. Devices for solid particles settling (mainly, sedimentation tanks) are used, as a rule, in the main mine drainage systems, while the main sources of mine water contamination are the section mine drainage systems, for which no clarification equipment is provided. Energy efficiency [kWh/(t·m)] of mine drainage systems can be determined by the value of volume energy [1] using the following formula:

$$E = \frac{N_{\Sigma}}{G_{\ddot{i}.\grave{e}} \acute{I}_{\tilde{a}}} = \frac{Q_{ø.\hat{a}} Đ}{G_{\ddot{i}.\grave{e}} \acute{I}_{\tilde{a}}} = K_{\hat{a}} \rho_{ø.\hat{a}} g \frac{\acute{I}_{\acute{i}}}{\acute{I}_{\tilde{a}}} = K_{\hat{a}} \rho_{ø.\hat{a}} g i_h \frac{L_{np}}{\acute{I}_{\tilde{a}}} \qquad (1)$$

where E is the volume energy; $G_{\ddot{i}.\grave{e}}$ is the mine (section) rock capacity, t/h; $H_г$ is the depth of the mine horizon, m; P is the pressure of pumping units, Pa; $Q_{ш.в}$ is the mine water flow, m^3/h; $K_в$ is the water inflow coefficient, m^3/t; $\rho_{ø.\hat{a}}$ is the density of mine water, kg/m^3; i_h is the specific loss of head in the pipeline, m/mwc; L_{np} is the effective length of pipelines, m.

It follows from formula 1 that an efficient means for reduction of volume energy of mine drainage systems is a decrease in specific losses of head i_h during pipeline transportation of mine water containing a significant amount of solid particles. The existing calculation methods do not account for the presence of solid particles in the pumped mine water, and the parameter of relative density (1.02) is introduced into the calculation formulae, which leads to the increase in head losses only by 2% in comparison with pumping clean fluid [4-6]. But actual head losses considerably exceed the calculated values. Figure 1 represents the calculated and actual values of pump and pipeline head-flow characteristics.

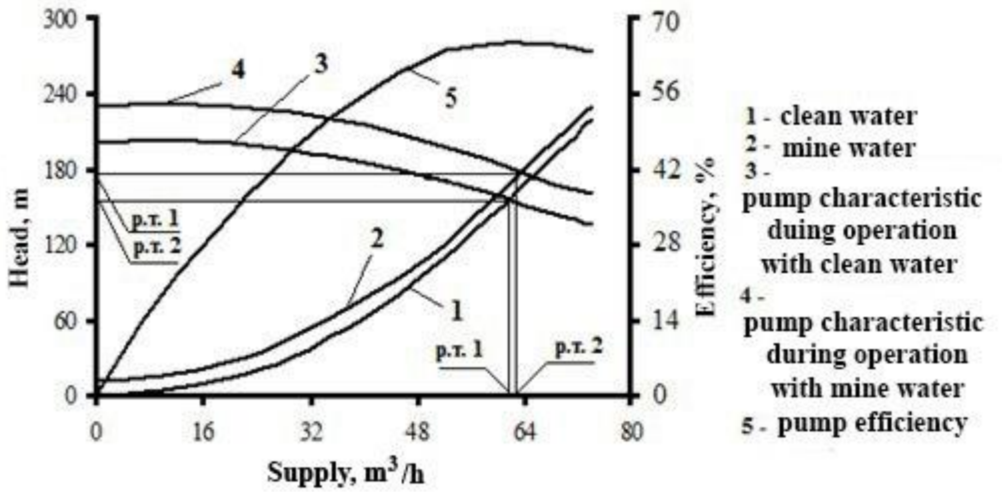

Figure 1. Head-flow characteristics of a pump operating with mine water and clean water

Suspended in mine water, solid particles change the water structure and, depending on the concentration, there are rheological properties of various degrees determined by the initial shearing stress, effective viscosity, shearing rate and other rheological parameters. To decrease the influence of rheological parameters on the specific head losses value, it is necessary to clarify mine water directly in the section mine drainage systems.

The energy characteristics of mine centrifugal pumps are determined by the kinematics of the flow in the impeller passes [7-8]. The presence of a solid phase in the pumped liquid influences the value of the theoretical pump head and leads to an increase in energy input in compliance with formulae 2 and 3

$$Í_{ò.øâ} = Í_{0ò}\left[1-ñ_{ð}\left(1-\frac{u_{òâ_2}}{u_{0_2}}\right)\right] \quad (2)$$

$$N_{ш.в} = H_{шв}\rho_{шв}gQ_{шв} \quad (3)$$

where $Í_{ò.øâ}, N_{øâ}$ are the theoretical head and capacity of the pump during operation with mine water; H_{0m} is the theoretical head during operation with clean water; c_p is mass concentration of solid particles in mine water; $u_{тв_2}$, u_{0_2} are the tangential components of speed of mine water delivery from the impeller blades; $\rho_{шв}, Q_{шв}$ are density and flow rate of mine water; g is intensity of gravity.The pump capacity and developed head are spent to overcome the resistance to mine water movement in the delivery line. Total stored energy is determined by accounting equation 4

$$E_э = D + T \quad (4)$$

where $E_э$ is the total stored energy of the mine water flow; D is the part of energy spent in some point of the volume; T is the part of energy spent for suspension of solid particles in oscillatory flow.

The theoretical analysis of formula 4 leads to a generalized formula of head losses during mine water flow

$$i_{шв} = i_0 + \Delta i \tag{5}$$

$i_{шв}$, i_0 are specific head losses during movement along the pipeline of mine and clean water, respectively; $\Delta i = \delta D - i_{шв} \frac{\rho_{шв}}{\rho_{тв}} c_p$ are additional head losses spent on suspension of solid particles in the mine water flow [9-10].

Figure 2 demonstrates a diagram of components of equation 5, from which it follows that energy losses consist of two components: used for movement of clean liquid and movement of solid phase of the flow.

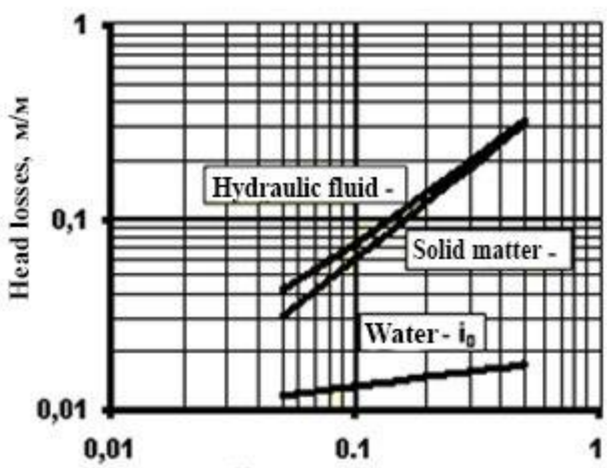

Figure 2. Diagrams of head losses changes for hydraulic fluid, solid material and clean water with a change in speed and concentration of solid particles

Description of a flow of mine water with fine particles was based on the model of visco-plastic fluid flow, Shvedov-Bingham model, establishing the dependence of shearing stresses on the shearing rate

$$\tau = \tau_0 + \eta_{эф} \frac{dV}{dr} \tag{6}$$

where τ, τ_0 are the shearing stress on the pipeline wall and the initial (static) stress, Pa; $\eta_{эф}$ is the coefficient of effective (dynamic) viscosity of mine water, Pa·s; *dV/dr* is the velocity gradient (shearing rate) across the section of the pipeline with diameter *D=2 r*.

Head losses depend on the concentration of solid particles and on their size. Fine particles of solid material are freely suspended in the flow of mine water, and additional head losses $\Delta i \to 0$. In this case, mine water can be considered as a homogeneous liquid with a density a little higher than that of clean water.

Solution of equation 6 in relation to specific head losses in mine water flow leads to equation 7

$$i_{шв} = \frac{64}{(1-\sigma)Re} \frac{v_{cp}^2}{2gD} \tag{7}$$

where $\sigma = \frac{\tau_0}{\tau}$ is relative stress ; $Re = \frac{v_{cp} D \rho_{шв}}{\eta_{эф}}$ is Reynolds number; v_{cp} is the average velocity of mine water in the pipeline with diameter *D*.

Value $\frac{64}{(1-\sigma)Re} = \lambda_\sigma$ is the coefficient of hydraulic resistances. The obtained formula 7 differs from the classical Darcy-Weisbach formula of head loss by the presence of parameter σ, accountting for the rheological properties of mine water. Formula 7 is obtained from the condition of laminar flow regime.

The peculiarity of the obtained calculation formulae is the fact that all the main parameters are the function of solid particle concentration and, consequently, the head losses in mine water flow are determined by function $i_{шв} = f(c_{об})$, where $c_{об}$ is the volume concentration of solid particles in mine water. Experimental researches were conducted for determination of the type of functions.

The mathematical model comes to the following main equations:

- head losses:

$$i_{\text{øâ}} = \frac{\pi \operatorname{Re}\left[\mu_o \exp(9.9333 c_{\text{îá}})\right]^4 c_{\text{îá}}^2 \rho_{\text{òâ}}}{0.27 g \left[c_{\text{îá}}(\rho_{\text{òâ}} - \rho_0) + \rho_0\right]^3} \times \\ \times \left\{ c_{\text{îá}}^{2.57} \cdot \exp 4.89 + \frac{\pi^3 \operatorname{Re}^4 \left[\mu_o \exp(9.933 c_{\text{îá}})\right]^4 c_{\text{îá}} \rho_{\text{òâ}}}{2 Q_{\text{øâ}} \left[c_{\text{îá}}(\rho_{\text{òâ}} - \rho_w) + \rho_0\right]^3} \right\} \tag{8}$$

- relative stress

$$\sigma = \frac{c_{\text{îá}}^{2.57} \exp 4.89}{c_{\text{îá}}^{2.57} \exp 4.89 + \frac{0.5 \pi \operatorname{Re}^3 \left[\mu_o \exp(9.933 c_{\text{îá}})\right]^4}{Q_{\text{øâ}}^2 \left[c_{\text{îá}}^2 (\rho_{\text{òâ}} - \rho_0) + \rho_0\right]^3}} \tag{9}$$

- pipeline diameter

$$D = \frac{4 Q_{\text{øâ}} \left[c_{\text{îá}}(\rho_{\text{òâ}} - \rho_0) + \rho_0\right]}{\pi \operatorname{Re} \mu_o \exp(9.933 c_{\text{îá}})} \tag{10}$$

- average velocity of mine water flow in pipeline

$$v_{\text{ñð}} = \frac{\pi \operatorname{Re}^2 \left[\exp(9.933 c_{\text{îá}})\right]^2}{4 Q_{\text{øâ}} \left[c_{\text{îá}}(\rho_{\text{òâ}} - \rho_0) + \rho_0\right]^2} \tag{11}$$

where ρ_0 is the density of clean water; $\mu_0 = 1.017 \cdot 10^{-3}$ is the dynamic coefficient of clean water viscosity at a temperature of 17°C, Pa·s.

Let us check the obtained calculation formulae by the example of section water drainage. Let us calculate the specific head losses on the basis of the following data:

- volume throughput of the mine drainage system $Q_{шв} = 200$ m³/h.
- content of solid particles in mine water volume $c_{об} = 5\% = 0.05$.

Let us determine specific head losses, i.e. the losses of energy per unit of the pipeline length.

2. Calculation

1. Let us determine the effective viscosity of pumped mine water at specified volume concentration $c_{об} = 0.05$:

$\eta_{эф} = \mu_0 e^{9.933 \cdot c_{об}} = 1.017 \cdot 10^{-3} \cdot 2.72^{9.933 \cdot 0,05} = 0.00167$ Pa·s

2. Mine water density

$\rho_h = c_{об}(\rho_{тв} - \rho_0) + \rho_0 = 0.05(2400 - 1000) + 1000 = 1070$ kg/m³

where $\rho_{тв} = 2400$ kg/m³ is the density of solid particles in mine water; $\rho_0 = 1000$ kg/m³ is the density of clean water.

3. Initial shearing stress

$\tau_0 = c_{об}^{2.57} \cdot e^{4.89 \cdot} = 2.72^{4.89} \cdot 0.05^{2.57} = 0.0604$ Pa.

4. Let us work out the pipeline diameter, or Reynolds number. The flow takes place, as a rule, in a transient mode – from laminar to turbulent one, since, as a rule, the volume concentration is insignificant and, correspondingly, viscosity and structural properties of the mixture are also manifested insignificantly. The transient friction area is rather extensive (from 10000 to 500000). Let us work out the average Reynolds number in this transient area, for example, equal to $Re = 250000$.
5. Let us calculate the velocity gradient (shearing rate) at the given Reynolds number:
$$\dot{\gamma} = \frac{dV}{dr} = \frac{1}{2}\left(\frac{\eta_{эф}\,\mathrm{Re}}{\rho_h}\right)^3\left(\frac{\pi}{Q_{шв}}\right)^2 \Rightarrow \dot{\gamma} = 0.5\left(\frac{0.0017\cdot 250000}{1070}\right)^3\left(\frac{3.14}{0.056}\right)^2 = 98.5 \text{ s}^{-1}.$$
6. Let us calculate the average velocity of mine water flow:
$$v_{cp} = \sqrt{\frac{\mathrm{Re}\,\eta_{эф}\dot{\gamma}}{8\rho_h}} = \sqrt{\frac{250000\cdot 0.0017\cdot 98.5}{8\cdot 1070}} = 2.2 \text{ m/s}.$$
7. Let us calculate the pipeline diameter:
$$D = \sqrt{\frac{8\,\mathrm{Re}\,\eta_{эф}}{\dot{\gamma}\rho_h}} = \sqrt{\frac{8\cdot 250000\cdot 0.0017}{98.5\cdot 1070}} = 0.179 \text{ m}.$$
8. Let us calculate the relative shearing stress σ:
$$\sigma = \frac{\tau_o D}{\tau_o D + 8\eta_{ef} v_m} = \frac{0.0604\cdot 0.179}{0.0108\cdot 0.179 + 8\cdot 0.0017\cdot 2{,}2} = \frac{0.0108}{0.04} = 0.265$$
or by the following formula:
$$\frac{1}{\sigma} - 1 = \frac{\eta_{ýô}}{\tau_0}\dot{\gamma} \Rightarrow \frac{1}{\sigma} = \frac{\eta_{ýô}}{\tau_0}\dot{\gamma} + 1 = \frac{0.0017}{0.0604}\cdot 98.5 + 1 = 1.051 \Rightarrow \sigma = 1.051^{-1} = 0.265,$$
i.e. the results coincide, consequently, $\sigma = \frac{\tau_0}{\tau}$ has been calculated correctly.

9. Let us calculate specific head losses: $i_{шв} = \lambda_\sigma \frac{v_{cp}^2}{2gDp}$.

Here $\lambda_\sigma = \frac{64}{(1-\sigma)\mathrm{Re}\,p}$; this formula is true for laminar mode of mine water movement. The accepted mode is transient ($Re = 250000$), and for this reason we introduced a correction for plasticity of mine water and deviation of actual flow mode from the laminar one. This correction within the range of Reynolds numbers from (2-5)·10^6 is calculated by formula 12
$$p = p_0 + k\cdot(\mathrm{Re} - \mathrm{Re}_0) = 4 + 5.6\cdot\left(\mathrm{Re}\cdot 10^{-6} - 0.21\right) \quad (12)$$
where $k = 5.6\cdot 10^{-6}$ is the slope ratio, $\mathrm{Re}_0 = 210000$ is the limit value of Reynolds number in the transient friction zone, Re is the Reynolds number of the mixture flow.

The mentioned formula is true within the range of Reynolds numbers from $Re = 210000$ to $Re = 500000$.

For the considered case, allowance for deviation of the flow mode from the laminar one will be equal to $p = 4 + 5.6\cdot(0.25 - 0.21) = 4.23$
$$\lambda_\sigma = \frac{64}{(1-\sigma)\mathrm{Re}\cdot p} = \frac{64}{(1-0{,}265)\cdot 2000\cdot 4.23} = 0.018.$$

Let us compare the values of λ, calculated by other formulae, for example, by the Blasius formula ("smooth pipe" flow mode): $\lambda = \frac{0.3164}{\mathrm{Re}^{0.25}} = 0.014$.

Using Shevelev empirical formula, most widely used in calculation of mine drainage due to its simplicity, we shall obtain $\lambda = \frac{0.021}{d_p^{0.3}} = \frac{0.021}{0.179^{0.3}} = 0.035$.

It is evident that this formula leads to an increased value of resistance factor.

Let us accept the value of $\lambda_\sigma = 0.018$.

Specific head losses for the calculated case will be equal to:

$$i_{øâ} = \lambda_\sigma \frac{v_{cp}^2}{2gD} = 0.018\frac{2.2^2}{2g \cdot 0.179} = 0.025 \text{ mwc/m.}$$

The required head of the system is: $H_{сист} = H_г + i_{шв}L_{пр}$ m.

Further, it is possible to compare the calculations made on the basis of the existing method, and calculations, made on the basis of the method developed and proposed by the authors. At that, let us take into consideration the fact, that the content of solid particles in the given calculation is accepted as a minimum one. This presupposes that in the system of section mine drainage there will be used a thickener-clarifier which will enable to decrease the concentration of solid particles from 15-20% to the 5% accepted in the calculation.

This presupposes that in the system of section mine drainage a thickener-clarifier is used and, for this reason, the content of solid particles is reduced from, for example, 15% to the accepted 5%. These 15% of solid matter in mine water influence its density, which, in this case, will be equal to

$\rho_h = 0.15(2400 - 1000) + 1000 = 1210$ kg/m^3.

Specific head losses will be equal (using the existing and applied methods) to:

$$i_{øâ}^{ñóù} = \lambda \frac{v_{cp}^2}{2gD}\frac{\rho_h}{\rho_w} = 0.035\frac{2,2^2}{2g \cdot 0.179}\frac{1.21}{1.0} = 0.058 \text{ mwc/m,}$$

i.e. specific head losses are reduced by 0.033 mwc/m, which constitutes 56%,

$$\Delta i_{øâ} = \frac{i_{øâ}^{ñóù} - i_{øâ}}{i_{øâ}^{ñóù}} \cdot 100\% = \frac{0.058 - 0.025}{0.058} \cdot 100\% = 56\%.$$

These reduced specific head losses determine the technical and economical effect of the developed propositions.

Let us pay attention to the fact that in the developed method the pipeline velocity and diameter were determined from the rheological equation, and not selected by experience, as it is done in the existing methods.

Here, in the above mentioned preliminary calculation, the task of selecting the pumping equipment and determining its efficiency was not set, which will be shown below. In the total balance of energy consumption for mine drainage, the main energy is spent on overcoming linear resistance along the pipeline length. The remaining components of head losses are common both in the existing methods, and in the developed ones.

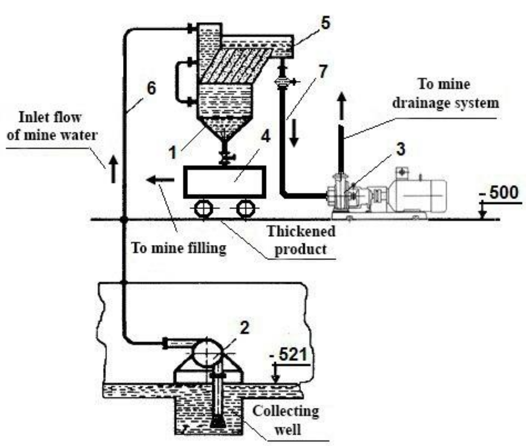

Figure 3. Hydro-mechanized complex of section mine drainage:
1- laminar thickener-clarifier; 2 - peristaltic (hose-type) pump; 3- mine pump of CPS-type; 4 - mine car for thickened product collection; 5 - collecting tray for clarified mine water; 6 - filling line (hose); 7 - suction line

To reduce the influence of solid particles content in the mine water and to bring the concentration to the minimum value (3-5%), it is necessary to use preliminary clarification of mine water from suspended mechanical impurities. In this work, it is proposed to use a laminar type thickener which is put on the production level of the mine, Figure 3.Let us quote the numerical calculation of the thickener using the following initial data:

- hourly inflow of water $Q_{вп} = 200$ m^3/h=0.055 m^3/s;
- volume content of solid particles in hourly inflow of water $c_{об} = 15\% = 0.15$;
- density of initial mine water $\rho_{hи} = c_{об}(\rho_{тв} - \rho_0) + \rho_0 =$ 0.15(2400-1000)+1000=1210 kg/m^3

where $\rho_{тв} = 2400$ kg/m^3 is the actual density of solid particles; $\rho_0 = 1000$ kg/m^3 is the density of clean water.

Let us work out the density of the thickened mixture in underflow of thickener-clarifier $c_{об.р} = 0.6$, i.e. let us assume, that 60% of the volume of mixture in the thickened product consists of solid particles, and 40% are represented by clean water.

According to the initial data, the thickener-clarifier arrives from the collecting well (Figure 3) with mine water:

-solid matter $q_{тв.об} = Q_{вп}c_{об} = 200 \cdot 0.15 = 30$ m^3/h;

- clean water $q_{чв} = Q_{вп}(1 - c_{об}) = 200(1 - 0.15) = 170$ m^3/h.

Let us work out the coefficient of solid matter extraction into the thickened product: k_u=0.8. Then, the following amount will arrive into the thickened product:

-solid matter $q_{тв.сг} = q_{тв..об} \cdot k_и = 30 \cdot 0.8 = 24$ m^3/h.

The total volume of solid matter (solid particles) arriving to the inlet of the thickener-clarifier from the collecting well is equal to

$$Q_{сг} = \frac{q_{тв.сг}}{c_{об.р}} = \frac{24}{0.6} = 40 \text{ m}^3/\text{h}.$$

Output of solid particles with clarified mine water (in the overflow from the collecting tray)

$$q_{тв.ос.} = q_{тв.об} - q_{тв.сг} = 30 - 24 = 6 \text{ m}^3/\text{h}.$$

Productiveness of the thickener-clarifier in clean mine water (volume of clarified mine water in the overflow) $Q_{шв.ос} = Q_{вп} - Q_{сг} = 200 - 40 = 160$ m^3/h.

Volume content of solid particles in the clarified mine water $c_{об.ос} = \frac{q_{тв.ос}}{Q_{шв.ос}} = \frac{6}{160} = 0.0375 \approx 0.04$.

Thickener-clarifier geometric dimensions. The average flow velocity in the channels between the laminae is calculated by formula

$$v_c = \sqrt[3]{\frac{1}{4} g\nu Fr \, \text{Re}} = \sqrt[3]{\frac{1}{4} g \cdot 1.017 \cdot 10^{-6} \cdot 5 \cdot 10^{-4} \cdot 400} = 0.008 \text{ m/s}$$

- total area of inclined channels' passage section $S = nS_c = nH_p b = \frac{Q_{шв.ос}}{v_c} = \frac{0.044}{0.008} = 5.5$ m^2;
- number of channels $n = \frac{S}{H_p b} = \frac{5.5}{0.05 \cdot 2.0} = 55$;
- hydraulic size of solid particles (for $d_0 = 0.038$ mm)

$$\omega = \frac{2g \cdot (s-1) \cdot r^2}{9 \cdot \nu} = \frac{2g \cdot \left(\frac{\rho_s}{\rho_w} - 1\right) \cdot \left(0.019 \cdot 10^{-3}\right)^2 \cdot}{9 \cdot 1.017 \cdot 10^{-6}} = 7.74 \cdot 10^{-4} \cdot (2.4 - 1) = 1.08 \cdot 10^{-4} \text{ m/s}.$$

Let us accept the following geometric dimensions:

- the length of the channel part with laminar flow L_p = 0.369 m;
- total length of channels in compliance with formula $L = 2.2 \cdot L_p = 2.2 \cdot \frac{0.517}{\rho_s - 1} = \frac{1.137}{2.4 - 1} = 0.812$ m;

- tilt angle of lamina $\alpha = 62^\circ$;
- the area of thickener drain surface by formula $S_f = \frac{125 \cdot Q_{шв.ос}}{\sin 62} = 141.6 \cdot Q_{шв.ос} = 141.6 \cdot 0.044 = 6.2$ m^2;
- height of lamina unit (tilt module) by formula $H_{sm} = \frac{1.137 \cdot \sin 62}{\rho_{ТВ} - 1} = \frac{1.04}{2.4 - 1} = 0.742$ m;
- volume of storage hopper at k_u = 0.8; t_e = 8 *min* and volume concentration $c_{об} = 0.15$

$$W_t = \frac{Q_{шв} \cdot c_{об}}{c_{об.р}} \cdot k_и \cdot t_e = \frac{0.055 \cdot 0.15}{0.6} \cdot 0.8 \cdot 480 = 5.3 \text{ m}^3;$$

- height of storage hopper $h_t = 9.66 \frac{c_{об}}{c_{об.о}} = 9.66 \frac{0.15}{0.6} = 2.4$ m;
- total thickener height $H_{th} = \left(3.01 \cdot \frac{\rho_0}{\rho_{ТВ} - \rho_0} + 9.66 \frac{c_{об}}{c_{об.р}}\right) = 2.1 + 2.4 = 4.5$ m.

For supply of mine water from the collecting tank to the inlet of thickener-clarifier, it is proposed to use in the system a peristaltic hose-type pump with the output (for the given example) of 200 m^3/h. Peristaltic hose-type pumps are self-priming and are manufactured by the native industry in a wide assortment. The design model of laminar thickener is given in Figure 4.

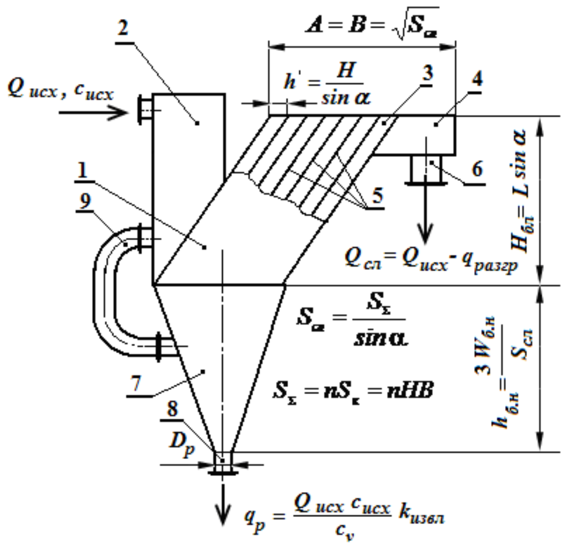

Figure 4. Geometric parameters of laminar thickener:
1 – inclined lamina unit, 2 – inlet standpipe, 3 – sedimentation channel, 4 – overflow launder, 5 – inclined lamina,6 – drain tube, 7 – storage hopper, 8 – discharge tube,9 – filling line

3. Conclusions

1. The analysis of the status of the problem devoted to reduction of mine water drainage device energy consumption has shown that there exists a significant reserve for saving electrical energy by preliminary clarification of mine water from mechanical impurities directly at production units and levels.
2. The existing and used for calculation of mine drainage systems methods mainly disregard the presence of mechanical particles in mine water. Due to this, mine pumps operate at increased head. Various measures aimed at optimization of mine drainage systems operation do not lead to a considerable improvement of head-flow characteristics and operational reliability of mine drainage systems. The main source of mine water pollution is represented by section water drainage devices, whose process operations on mine water clarification are not provided for.

3. The total mine water energy reserve realized by mine pumping units in drainage systems includes two components – the energy spent on transportation of clean fluid, and the energy spent on suspension of solid particles, which is reflected in the increase of total mine pumps' head and consumed power, and also reduces the total efficiency of the system.
4. To separate solid particles from the mine water flow, the most reasonable method is the use of the developed in this work hydro-mechanized complex for mine water clarification from mechanical impurities installed in section water drainage systems. The improvement of clarification effect is ensured by the increase in sedimentation area of solid phase formed by inclined lamina.
5. Mine water containing suspended solids with mass concentration from 5 to 15% is a rheological fluid with apparent viscoplastic properties; the flow of this fluid along the mine drainage system pipelines is described by Shvedov-Bingham rheological equation, the parameters of which are the functions of solid matter concentration. Specific head losses in mine water flow are determined by Darcy-Weisbach equation, while the coefficient of hydraulic resistances depends on Reynolds number of the flow and relative shearing stress.
6. The developed method of energy efficiency improvement can be used in pumping equipment for mine water drainage; it consists in division of mine water phases in gravitational thickeners-clarifiers of a thin-layer type. It is recommended that the main functional connections between the solid phase concentration and the rheological properties of the flow should be introduced into the documents regulating the process of mine water drainage at coal mines and pits.

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