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PHYSICAL MODEL OF DEHYDRATION PROCESS OF COAL SLUDGE UNFLOTATION SIZE SUSPENSIONS ON THE HIGH-FREQUENCY SIFTER WITH DIFFERENT SLOPED SITES OF THE WORKING SURFACE

A physical model of the process of dehydration of coal slurry suspension on the high-frequency rumble with areas of the working surface of a different angle, in which the dewatering process is accomplished in three stages: translation in the suspension of high concentration, in viscoplastic material, elasticplastic body.

In coal preparation technology processes for sludge dehydration on vibrating screens are widely used. The quality of dehydration products is largely determined by the parameters of the working surface of the vibration screen. However, now there are no adequate physical models of the suspension dehydration process on a vibrating sieve surface allowing selection of the optimal regime parameters.

In this article we attempt to develop a physical model of the dehydration process with the moving slurry flow on a vibration sieve with a monotonic decrease of the liquid phase concentration.

It is known [1] that the suspension dehydration process on vibrating screen can be divided into three stages.

In the first stage, which is characterized by a considerable content of liquid phase, a preliminary dehydration occurs mainly due to the hydrostatic pressure of the slurry layer; in the second stage the dehydration process is caused by the inertia oscillatory component, which provides separation of free moisture from interpore material spaces layer; in the third stage the dehydration process occurs due to the layer vibro compacting of material, which is accompanied by the release of free moisture from the pore space of the layer.

In the first step the initial slurry, loading to the sifter, has a rather low concentration of the liquid phase and can be considered as a homogeneous liquid with an effective viscosity, even greater than the viscosity of the liquid phase. For low concentration of suspended regular shaped particles the effective viscosity of the suspension is calculated using simple formulas [2]. Vibrating effect increases the suspension viscosity, because oscillation amplitude of the solid particles is less than the amplitude of the liquid particle oscillation. Therefore, in the case of low concentration of solid particles the liquid phase allocation through the sieve apertures is more efficient for fixed screening surface. If the suspension flow speed over the screen is not very high, the liquid outflow through the sieve is determined by the suspension flow depth.

During the first stage a coal suspension conversion into a highly concentrated one takes place due to discharge of free water.

At the second stage the transfer of highly concentrated suspension into the viscous-plastic material by removal of external moisture is executed.

The beginning of the third stage corresponds to the water-bearing system of the solid particles, wherein the particles have regular contact with each other. At this stage the dehydration process is determined by the process of solid particles vibro compaction and removal of interparticle space vacated liquid through a sieve.

It is known that during vibration of the structured suspension its flow properties change. Experimentally established [3] that the deformation of the mixture (or its speed) with an unchanged voltage increases into $\left[1+\alpha\left(A\omega^2/g\right)\right]\psi\left(Ti\right)$ times, compared with a static medium, where A и ω – accordingly, the amplitude and frequency of oscillation; $\psi\left(Ti\right)$ – the function of specific thixotropy, depending on granule composition and becoming equal to unity in the absence of vibration; g – acceleration of gravity; α – constant.

The solving of the problem concerning establishing connection between the vibration modes and the viscosity of highly concentrated suspensions has been studied by many authors [3]. As a result the semi-empirical formulas were derived, involving various criteria vibration intensity. The intensity criterion $u = A\omega^2/g$ is considered as the most reliable and the dependence of viscosity on the vibration mode is $\eta = \eta_o + \alpha/u$, where η_o – the viscosity of completely destroyed structure. Thus, the dehydration quality at this stage depends essentially on the parameters of the dehydration vibration surface.

It was established [4] that the dispersion medium compacting is determined by the acceleration of applied vibrations. Moreover, the optimal value of the acceleration depends on the physics-mechanical properties of the medium. Medium compacting is due to the reduction of friction forces between the particles because of the action of inertia and gravity forces.

It has been established experimentally [4] that under vibration with optimum acceleration for compacting medium particles with a high density and large size can rise to the layer surface. This phenomenon is explained by the difference values of optimal acceleration for the particles of different size and density during the vibrocompaction.

It is also known that at higher frequencies maximum compaction is achieved at lower amplitudes. However, with the increasing of frequency the maximum compaction degree is reduced. The increase of the amplitude vibrations to a certain limit promotes the density rising. Each amplitude value corresponds to the most efficient determined oscillation frequency, contributing to the achievement of maximum contraction.

The study results of the influence of vibrocompaction process time on the compaction degree [4] showed that the compaction process is irregular with decreasing rate: it is more intense at the initial moment, and then the densification rate decreases. Such irregularity is explained by the fact that with the medium compaction a contact surface area between the particles increases thereby the vibration efficiency decreases.

At the third stage the dehydration suspension occurs in two stages [5]: replacing of solid phase particles and their convergence.

At the stage of replacing, which is caused by vibration, destruction and restructuring of unstable random particles occurs. These particles tend to occupy the most favorable energy position due to gravity force.

Destruction cause of the dispersed particle structured system is relative inertial displacement of solid phase particles, which have different density and size.

The magnitude of this displacement is the larger, the greater mass of the particle, higher vibration acceleration, greater difference of densities between particle and the medium, the smaller the system viscosity. At the end of replacing the system obtains a stable structure.

At the convergence stage significant change in the particle structure doesn't occur. The mixture compaction is effected by particle convergence, their extendable and relative shifts, due not only to a vibration, but also the redistribution in the liquid phase volume. The second stage is much longer than the first. At this stage the liquid phase "pressing" from the mixture pores takes place with the relative particle displacement.

At the final dehydration stage, it is possible the formation of a thixotropic structured system, formed after coagulation interactions. As a result of the vibrating structure hardening effect, the formation of new reinforced contacts is possible, that leads to the dispersion structure formation similar to solid one.

Based on the previous ideas about the dehydration process a simplified dynamic model of the suspension layer on a work surface of vibrating screen can be interpreted as a viscous plastic flow body with an attached mass of a unit section rod, the height of which is equal to the height of the watering material layer, and density is equal to the density of the suspension. As a result of vibration yield material limit is $\sigma_o \to 0$, and the tension in the plastic element is proportional to the deformation: $\sigma_n = k_{ï} \varepsilon_{ï}$, where $k_{ï}$ – is plastic coefficient, and $\varepsilon_{ï}$ – plastic element deformation. Furthermore, we assume that the height of the layer of material dehydration is h_m, and then the tension in the plastic element during the layer compacting is proportional to $(h_1 - h)/(h_1 - h_m)$, because plastic deformation resistance varies from zero to $k_{ï}$.

We suppose that the height of the dehydration material layer $h = h(t)$ is a slowly changing parameter that remains unchanged during one period of working surface oscillation. Then the equation of motion of the dehydration material layer on the sieve screen under the influence of pulsating load $F_o \sin \omega t$, corresponding i - period of the oscillations will be:

$$\rho h(t)\,\ddot{y} + K\dot{y} + \frac{h(t)}{h(t) - h_m} k_{ï}\, y = F_o \sin \omega t. \quad , \qquad (1)$$

where ρ – dehydration material density; K – viscous strength coefficient; F_o and ω – accordingly, disturbing force amplitude and forced oscillations frequency of the screening working surface.

As layer plastic deformations are irreversible and develop only in the decrease direction of $h(t)$, during the half-wave oscillations, layer moves as a solid with mass ρh_i, and during the second half cycle it moves like a viscous plastic bingamovo inertial body in accordance with equation (1).

The solution of equation (1) is in the form

$$y = A_i \sin \omega t + B_i \cos \omega t . \qquad (2)$$

After substituting the expression (2) into equation (1) and equating to zero the coefficients sum of the functions $\sin \omega t$ and $\cos \omega t$ we define the values of the constants A_i and B_i.

Equation (2) can be written as:

$$A_i = F_o \frac{\frac{h_1 - h_i}{h_1 - h_m} k_ï - \rho h_i \omega^2}{\left(\frac{h_1 - h_i}{h_1 - h_m} k_ï - \rho h_i \omega^2 \right)^2 + K^2 \omega^2}, \qquad (3)$$

$$B_i = \frac{F_o K \omega}{\left(\frac{h_1 - h_i}{h_1 - h_m} k_ï - \rho h_i \omega^2 \right)^2 + K^2 \omega^2}.$$

$$y = a_i \sin(\omega t + \varphi_i), \qquad (4)$$

where

$$a_i = \sqrt{A_i^2 + B_i^2} = F_o \left[\left(\frac{h_1 - h_i}{h_1 - h_m} k_ï - \rho h_i \omega^2 \right)^2 + K^2 \omega^2 \right]^{-\frac{1}{2}},$$

$$\varphi_i = arctq(B/A) = arctq \frac{K \omega}{\rho h_i \omega^2 - \frac{h_1 - h_i}{h_1 - h_m}}.$$

Thus, fluctuations of the dehydration material layer surface occur with a frequency of forced oscillations and phase shift in the i - period of oscillation is equal to φ_i and depends on the layer height.

At the compacting beginning the dehydration material layer height is equal to $h = h_1$. In this case the plastic deformation is equal to zero and the movement of material is characterized by inertia and viscous strength. With the layer height decrease the plastic resistance appears and then increase. The computing algorithm for the changing layer height is following.

We assume $h = h_1$ and by formulas (3) calculate the coefficients A_i and B_i. And then according to the formula (4) we define a_1 – oscillation amplitude in the direction of decreasing h for the first oscillation period of the compacting process.

Then, for the first period of oscillation the height change material layer is $\Delta h_1 = F_o / \left(\rho h_1 \omega^2 \right) - a_1$. During the beginning of the second oscillation period $\left(i = 2 \right)$ $h_2 = h_1 - \Delta h_1$. Repeating the calculations by formulas (3) and (4) we define $\Delta h_2 = a_1 - a_2$, $h_3 = h_2 - \Delta h_2$ and so on. The iterative process continues until the time $t = i / 2\pi\omega$, equal to the time while dehydration material discharges from the sieve screen. For example, at rotation frequency of the screen unbalanced shaft 150 rad / s, average material transport speed during dehydration of 0.1 m / s and the screen portion length, which ensures the vibro compaction process, is equal to 2 m, the number of iterations is 3000.

Thus, based on the representation of the suspension dehydration process on vibrating screen, as a process of inertial deformation pulsating of the viscoplastic body, it is proposed a dynamic model, corresponding to equation (1), in which the viscosity coefficient K is equal to a function of vibration exposure intensity $A\omega^2 / g$.

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