

Effect of electroosmosis to reduce the adhesion of lake sapropel to the metal surfaces of the machine for lake sapropel dewatering

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Abstract. Recently, there has been an increase in consumer demand for organic products, which implies the use of natural fertilizers in agriculture and food additives in animal husbandry. The moisture content of products obtained from sapropel for use in animal husbandry and agriculture should vary between 60 and 65%. But the reason for the low profitability of production for the extraction of sapropel is due to its high humidity, which can reach 92-96 %, and the complexity of removing moisture. Currently, a significant problem in the dewatering of sapropel is its sticking to metal surfaces of knives-inverters and plane-parallel plates-separators on machines for its dewatering. To solve this problem, it is proposed to use the effect of electroosmosis. In this paper, the rational parameters of the operation necessary to create the effect of electroosmosis in the intermediate attachment of processing of sapropel of the machine for sapropel dewatering are determined.

1 Introduction

There are about 50 thousand deposits of sapropel in Russia [1]. Sapropel extraction, which can be used in agriculture, medicine, construction, fuel and chemical industries, not only provides us with environmentally friendly raw material, but also facilitates natural water cleaning. Sapropel extraction produces no waste and does not require capital construction of buildings and structures in contrast to the production of chemical or peat-based fertilizers, which require the construction of mines and are associated with the formation of waste rock dumps or the drainage of large land plots [2].

Sapropel is mostly used in agriculture. Sapropel-based fertilizers have advantages over other fertilizers. For example, waste water sludge incineration ash is used as a fertilizer, but it contains heavy metals. But fertilizers based on sapropel improve the chemical properties of the soil: increases the amount of useful micro- and macronutrients necessary for plants, decreases the acidity and also increases land productivity. Sapropel fertilizers are the only kind of soil-forming fertilizers [3,4,5].

Activated sapropel (dried to 110 °C and then subjected to mechanical activation) can be used as an additive to asphalt concrete mix in the construction of highways and airfields. It is known that the use of sapropel as an additive in the asphalt concrete mixture can increase the strength of asphalt concrete 1.5-3 times, compared to other asphalt concrete mixtures [3].

In addition, activated sapropel can be used as a binder for the production of fuel briquettes. The briquetting process without adding binding components

only occurs at higher pressures, and cementitious properties of the briquetted substances are required. Therefore, the method of producing fuel briquettes using binders is more flexible, since it can be used for briquetting almost any raw material [3]. The addition of activated sapropel is improving technical characteristics of coal fuel briquettes [7].

The cheapest method of extraction of lake sapropel is hydro-mechanized, in which the extraction is carried out using a dredger [8,9,10]. Low profitability of sapropel production using this method is due to its high humidity, reaching 92-96 %, and the difficulties connected with moisture removing.

At present time, the most common methods of sapropel processing are dewatering in geotextile containers [11,12,13] and drying, but these methods have a number of disadvantages. Dewatering in geotextile containers allows one to process large volumes of sapropel, but the process takes a long time and this method requires large areas. When drying sapropel in the field, it is contaminated with plant seeds, which reduces the quality of the final product. In addition, large area and time resources are required for drying.

The basis for the creation of equipment for sapropel dewatering was machines and complexes for sapropel dewatering, described in articles [14,15,16,17] due to the use of hygroscopic effect of a porous material. However, the disadvantages of these devices are the pore size of the open capillary structure material used as a coating for dewatering drums, since the size of the colloidal structure sapropel particles ($\approx 10^{-6}$ m) is significantly smaller than the pore size of the material ($\approx 10^{-3}$ m), and

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these designs imply a constant thickness of the sapropel layer.

The designed sapropel dewatering machine is shown in Figure 1. To cover the dewatering drums, it is proposed to use microfiber, since the pore size of the material is comparable to the size of the sapropel particles. For agitating sapropel, it is proposed to install an intermediate attachment of processing of sapropel (Fig. 2), which is installed after each dewatering drum, except for the last one, and consists of flipping knives

made of metal and a roller-contact made of metal (the first version of the intermediate attachment of processing of sapropel). The second option includes flipping knives and, instead of a roller-contact, flat-parallel metal plates.

However, when the machine is running, the sapropel will stick to the metal parts of the intermediate attachment of processing of sapropel. To solve this problem, it is proposed to use the effect of electroosmosis.

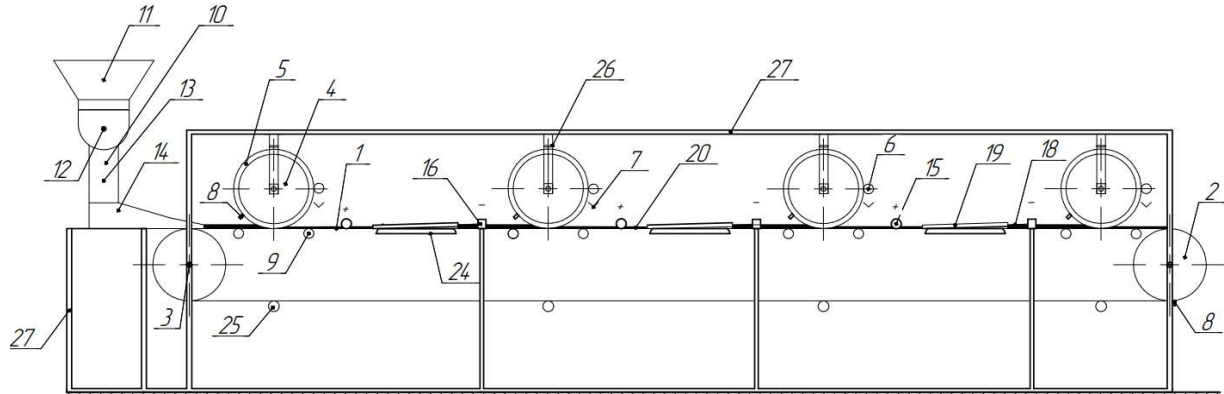


Fig. 1 Machine for sapropel dewatering

1 – flexible belt with sides; 2 – drive drum; 3 – tension drum; 4 – dewatering drums; 5 – layer of dewatering material; 6 – squeeze roller; 7 – chute; 8 – scraper; 9 – rollers; 10 – loading device; 11 – measuring hopper; 12 – screw; 13 – nozzle; 14 – mouthpiece; 15 – roller-contact; 16 – frame; 17 – rotary conductive supporting bracket; 18 – holding tool; 19 – flipping knives; 20 – a layer of sapropel; 21 – compression unit; 22 – elastic member; 23 – damping device; 24 – a retaining plate; 25 – roller carriage; 26 – guide frames; 27 – supporting frame.

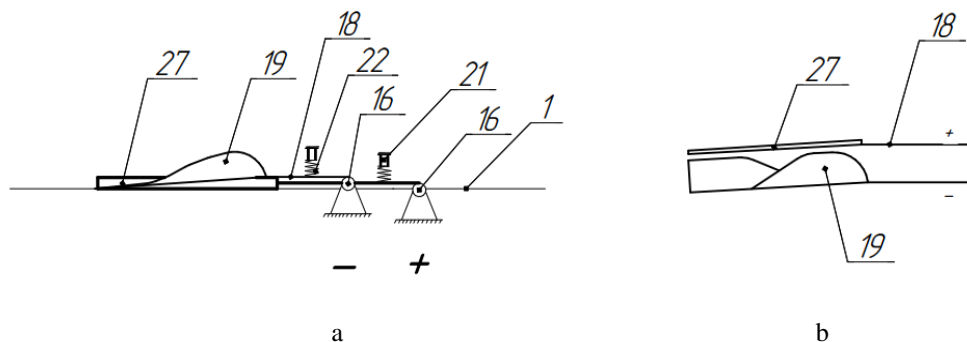


Fig. 2 Intermediate attachment of processing of sapropel (a – side view, b – plan view)

4 – dewatering drums; 6 – squeeze roller; 17 – rotary conductive supporting bracket; 18 – holding tool; 19 – flipping knives; 21, 22 – compression unit; 27 – supporting frame.

2 Materials and methods

Electroosmosis is the process of liquid transfer under the influence of an external potential difference applied to a colloidal solution relative to a solid wall [18]. The electroosmotic motion of the liquid can be directed to the positive or negative electrode, depending on the type of porous medium. In clay soils, usually the soil particles are positively charged, so they move to the negative electrode.

Currently, electroosmosis is used for transportation of liquids and to induce the movement of micro and nanostructures in various media [19,20,21,22], to improve the bearing capacity of soils by reducing their dispersion [23]. But since the beginning of the XX century, attempts have been made to use the phenomenon of electroosmosis to reduce the adhesion of soil to the metal surfaces of the operating tools of tillage and road construction machines [24, 25, 26, 27]. As a result of electroosmosis, the soil near the positive electrode is dried, and a thin water film is created near

the negative electrode, acting as a lubricant, which prevents sticking [28].

It is known that the effect of electroosmotic wetting of the friction surface of a ski is used when an aircraft takes off on a ski landing gear from wet ground. The research conducted by G. S. Gurov showed that the use of the effect of electroosmosis for skis helps to reduce the adhesion of the soil to the surface of the ski and also transfers the friction processes from the ground to the interface "soil – solid" surface. The efficiency of electroosmosis depends on the shape and location of electrodes, current strength, and soil moisture. The use of electroosmosis is effective at a speed range up to 1 m/s at a humidity range of 18-35 % (for loams), and the optimal humidity is 21 %. The specific energy consumption for creating the electroosmosis effect was approximately 7 W/cm² [29].

D. L. Larson and H. E. Clyma studied the possibility of applying the phenomenon of electroosmosis to reduce the tractive effort during soil tillage. The following parameters were investigated: the value of the applied

voltage and the number of anodes (1 or 2), the anode is the working body of the machine. The experiment was conducted on clay and loamy soils. The use of electroosmosis reduced the traction force by 39 % in loamy soils and by 11% in clay. The traction force decreased linearly with increasing stress in all soils [30].

In the studies of Lofitsky and Reltov, the diagrams of the arrangement of the longitudinal electrodes, the dependence of the width of the wetted strip on the width of the anode and on the voltage at different widths of the gap between electrodes, the dependence of the duration of the ground shift and the current strength on the voltage and the duration of the discharge from the inclined soil tray at different humidity levels are given. In this case, electrodes are the parallelly oriented plane [24].

Using the graph shown in Figure 3, the optimal width of the cathode can be determined, but the studies have shown that, depending on the type of soil, the optimal dimensions may differ [29].

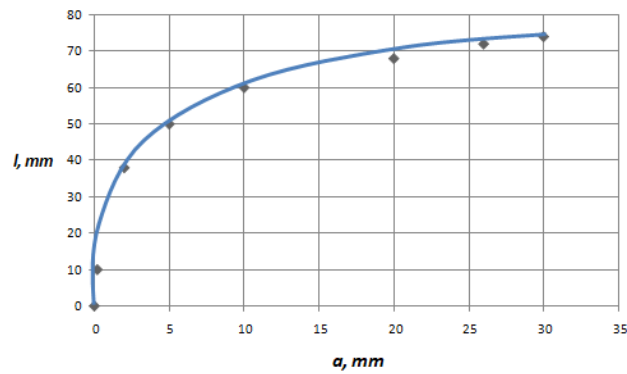


Fig. 3. Dependence of the width of the wetted area l on the width of the anode a [24]

The dependence of the width of the wetted area on the width of the anode is shown in the graph (Fig. 4). The graph shows that the effect of the gap dimensions between electrodes on the electroosmotic effect is insignificant. As the gap decreases, the energy

consumption increases. The use of a voltage below 80 Volts is impractical, and the use of a voltage above 80 Volts, on the contrary, contributes to the rapid release of the water film and, as a result, an increase in the rate of discharge of the adhering soil [24].

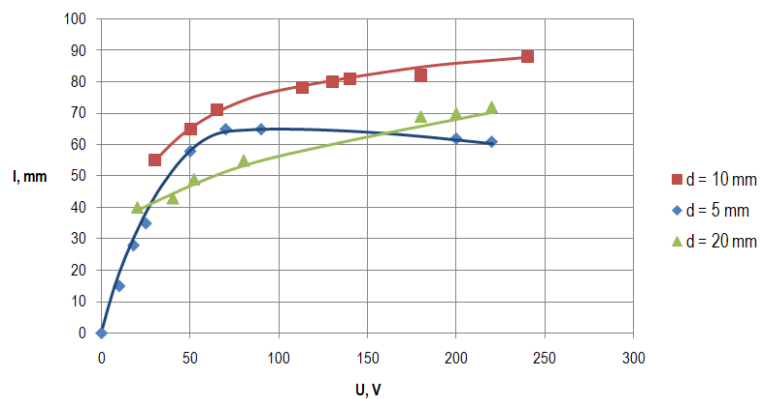


Fig. 4. - Dependence of the width of the wetted area on the voltage with different widths of the gap between the electrodes [24]

The graph shown in Figure 5 shows results of experiment on the discharge of wet clay soil from an inclined shield (slope 45°), which is equipped with longitudinal electrodes. The t curve shows a reduction in the reset time with an increase in voltage. The second

curve J shows the dependence of the current in the circuit on the voltage. To increase the rate of soil discharge, it is necessary to increase the power of the DC source.

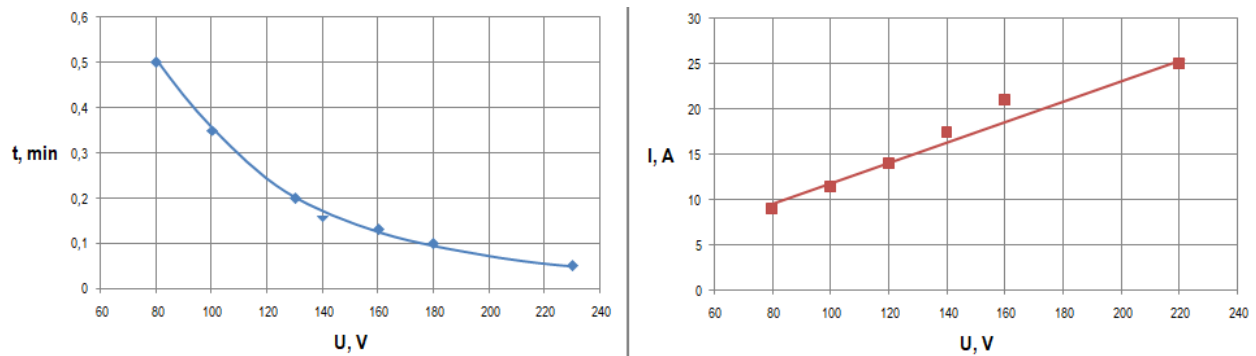


Fig. 5. Dependence of the period of soil shear and strength of current on the voltage [24]

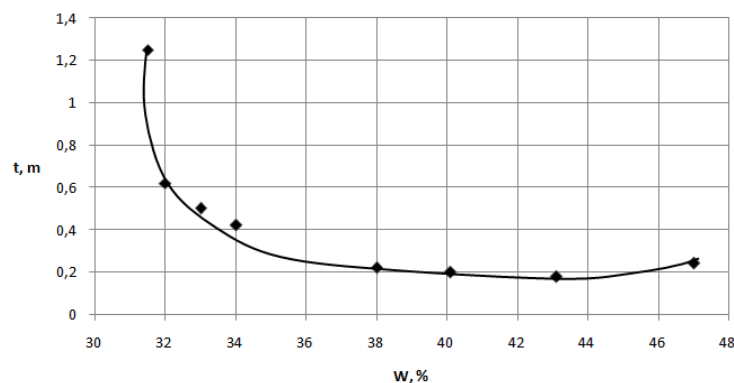


Fig. 6. The period of soil shear at its different humidity [24]

Laboratory performed tests, shown in the graph (Fig.6), showed that with an increase in soil moisture (within the plastic state), the rate of discharge of wet soil from the metal surface increases; with higher humidity values, the rate of discharge of wet soil increases slightly [24].

Further studies were carried out in conditions close to production, using a large model of the dump truck body.

In the steel body of the dump truck, in which a wooden shield is installed, equipped with electrodes in the form of alternating longitudinal wide and narrow strips of roofing iron, clay soil was loaded, the humidity of which was 35 %. With the help of a winch, the body could be tilted at an angle of 40° . The specific energy consumption at a voltage of 120 V was about 0.015-0.020 kW*h per 1 m². At the same time, the entire volume of clay soil was 0.2-0.8 m³ and was discharged within 15-25 s [24].

3 Conclusions

Based on the data obtained by Lofitsky and Reltov, the following conclusions can be drawn:

- To create the effect of electroosmosis in the intermediate attachment of processing of sapropel, it

is necessary to connect the flipping knives to the negative pole of the DC source, and the plane-parallel metal plates to the positive one.

- The supply voltage must be at least 80 V, since the use of a voltage below 80 V is not advisable.

- The current value must be in the range of 10 A – 25 A.

- To increase the discharge rate of the stuck sapropel, it is necessary to increase the voltage and current.

- The width of the cathode should be greater than the width of the anode with the same length 5-7 times, but since the flipping knives that perform the function of the cathode have a curved shape, the width of the plates that perform the function of the anode can be greater.

As a result of the electroosmosis effect, the dehydrated sapropel layer near the positively charged contact roller or plane-parallel plates is dried, and near the negatively charged flipping knives it is waterlogged. This ensures the necessary humidity gradient with the orientation of the wetter sapropel layer towards the contact with the dewatering drums.

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