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Beneficiation of Thermally Treated Brown Coal using Corona-Eletrostatic Separator

Andrei V. Moiseev, Vladimir G. Andrienko, Vladimir G. Piletskii, Valery A. Donchenko and Anatoly I. Urvantsev

CJSC COMPOMASH-TEK, 3-iy proezd Maryinoy Roshchi, 40, Moscow 127018, Russia.

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The article discusses development of new approaches to design of electric separators aiming at increase in their capacity upon beneficiation of thermally treated powdered brown coal. On the basis of the developed theoretical backgrounds and obtained results of applied researches into beneficiation of thermally treated powdered brown coal theoretical proposals have been prepared for enhancement of design of experimental apparatuses for electromagnetic pulse impact and electrostatic separation aiming at creation of innovative technology and equipment for efficient beneficiation of thermally treated powdered brown coal, Grades B1, B2, and B3. During fine grinding of thermally treated powdered brown coal the particles are coagulated (that is, agglomeration and coarsening of particles), which reduces the yield of extracted organic constituent of brown coal. In order to increase the pulse impact for neutralization of coagulation (agglomeration of coal particles) ZAO "Compomash-TEK" has developed and tested a KMShU 110.02.000 apparatus of electromagnetic pulse action. Investigation into the influence of corona discharge current and discharge electrode voltage in electric separator with vertical drum has promote arrangements of technical proposals for enhancement of design of developed corona electrostatic separator: •increase in diameter of discharge electrode leads to decrease in corona discharge current under the same voltage applied; • at low values of corona discharge current the more significant factor, influencing on engineering properties of the separator, is the voltage applied to discharge electrode;• at high values of corona discharge current, higher than 90 ìA, the corona discharge current exerts the major influence on the separator engineering properties. Herewith, the higher is the corona discharge current, the better are the engineering properties: the extraction efficiency of brown coal mineral constituent into tailings increase from 14.8 % at corona current of 10 ìA to 78.6 % at corona current of 320 ìA;• while determining the influence of the distance between discharge electrode and collecting electrode on engineering properties of separation of thermally treated powdered brown coal in corona electrostatic laboratory separator with vertical drum it has been demonstrated that with increase in inter-electrode distance the engineering properties increase even at equal values of corona discharge current. Simultaneously with the yield of non-conductive fraction the extraction of mineral constituent increases. Investigations under laboratory conditions of operation modes of corona electrostatic separator with vertical collecting electrode (drum) and engineering results of separation of thermally treated powdered brown coal confirm high forecasted performances during beneficiation with capability to increase capacity by 5-10 times in comparison with conventional horizontal position of collecting electrode. The technical proposals for enhancement of the experimental designs are aimed at increase in beneficiation capacity in order to produce competitive carbonaceous products of improved quality: high purity coal concentrated products, environmentally safe ash-free fuel briquettes for industrial demands including power engineering and housing and utility sector.

Key words: Thermally treated coal, Beneficiation, Neutralization of coagulation, Electric separator, Vertical collecting electrode, Capacity increase, Experimental specimens.

* To whom all correspondence should be addressed.
E-mail: info@compomash-tek.ru

The performed theoretical study into the beneficiation efficiency and preliminary laboratory experiments with finely powdered thermally treated brown coal demonstrated that before the coal feeding its particles were significantly coarsened which deteriorated the beneficiation effect both in triboelectrostatic and in corona electrostatic separators. In the obtained concentrated product the content of mineral constituent in organics reached up to 5 %. The reason of the coarsening was coagulation and agglomeration of fine particles. Electrostatic component of resistance of powdered coal decreases capacity of electrostatic separator. In order to prevent agglomeration and coarsening of brown coal particles prior to separator, according to the recommendation by TRANSMINAR S.A., Argentina, the occurring electrostatics can be eliminated by means of electromagnetic pulse apparatus. ZAO COMPOMASH-TEK developed a KMShU 110.02.000 apparatus for neutralization of electrostatic charges and tested in on laboratory scale.

On the basis of the analysis of beneficiation efficiency and selection of equipment it was established that for beneficiation of thermally treated powdered brown coal the most efficient methods of separation of semiconducting (its organic constituent) and dielectric materials (its mineral constituent) are the methods of electric separation, including corona electrostatic drum, electrostatic plate, drum triboelectrostatic and drum triboadhesive methods. The performed laboratory experiments on determination of the optimum coarseness of thermally treated powdered brown coal fed to separator and on selection of the most efficient procedure of beneficiation demonstrated that:

- The technologies with electrostatic plate separator and triboadhesive separator were rejected at once as inefficient for separation of thermally treated powdered brown coal;
- The performed comparative tests of triboelectrostatic and corona electrostatic separators revealed that the corona electrostatic drum separator is the most efficient apparatus.

It is known from the performed theoretical studies that the drum corona electrostatic separators can provide good engineering performances during separation of mineral mixtures, the components of which differ in their electric conductance. The main drawback of such separators is their low unit and specific capacity. The performed analysis of engineering properties of all known domestic and foreign separators of such type demonstrated that the existing separator design does not permit to increase significantly this engineering property. It was demonstrated thath the main drawback, preventing increase in the separator capacity, is a known limitation in diameter of settling drum and availability of one operation area. The known approaches to increase in capacity of separators of such type (increase in surface area of operation section; length of collecting electrode; material layer thickness, linear velocity of collecting electrode) have been implemented to the full extent in conventional designs of corona electrostatic separators with conventional horizontal drum. Nevertheless, such important characteristics as capacity per unit weight and volume of separator remain low and amount to 0.4 - 0.72 t/h/y. Increase in capacity of drum corona electrostatic separator at relatively small increase in its weight is related with elimination of the main limitation of design parameters of separator, namely, increase in diameter of collecting electrode (drum), which becomes possible after alteration of vector direction of forces acting on particles of powdered brown coal on the drum surface. This statement is implemented by alteration of horizontal orientation of collecting electrode to vertical one.

EXPERIMENTAL

If we orient settling drum vertically and increase its diameter, then the number of similar areas around this drum also increases. While decreasing angular rotational velocity of vertical drum it is possible to achieve the same value of linear velocity on the drum surface as with horizontal drum, hence, to create the same conditions of efficient separation of mineral particles as in separators of conventional design. As a consequence, an innovative design of corona electrostatic separator was proposed, its general view is illustrated in Fig. 1. It is known that the linear velocity of drum surface is a function of its diameter. Thus, the equation of capacity of separator with vertical drum is as follows (Plaksin and Olifinsky, 1965; Urvantsev et al.,1995):

$$Q_{\text{в}} = l_{\text{в}} \cdot V_{\text{в}} \cdot \sigma_{\text{в}} \cdot K_{\text{в}} = \sigma_{\text{в}} \cdot l_{\text{в}} \cdot 2\pi R_{\text{в}} \cdot n_{\text{в}} \frac{2\pi R_{\text{в}}}{S_{3\text{св}}} \quad ...(1)$$

where $V_{â} = 2pR_{â} \times n_{â}$; $\hat{E}_{â} = 2pR_{â}/S_{3ñâ}$ are the linear velocity and the number of separation areas for separators with vertical drum, respectively; $R_{â}$, $R_{ã}$ are the drum radii of vertical and horizontal separators, m; $n_{â}$, $n_{ã}$ are the rotation frequencies of vertical and horizontal drums, respectively, 1/s; $S_{3ñã}$, $S_{3ñâ}$ are the lengths of separation areas for vertical and horizontal separators, m, respectively.

It follows from Eq. (1) that the expected capacity of a separator with vertical drum, as with horizontal one, is proportional to the density of material on the drum and the band width of initial material in separation area and, besides, is proportional to squared drum radius and its rotation frequency and inversely proportional to the length of separation area. On the basis of the condition of similarity of vertical separator to horizontal one (Urvantsev et al., 1995; Mesenyashin, 1975). The first condition: upon conversion from separator with horizontal drum to separator with vertical drum of higher diameter the value of centrifugal force will not change, that is, $F_{ö.á.ã} = F_{ö.á.â}$. This condition results in two consequences:

$$V_{\text{в}} = V_{\text{г}} \sqrt{\frac{R_{\text{в}}}{R_{\text{г}}}}\,; \quad n_{\text{в}} = n_{\text{г}} \sqrt{\frac{R_{\text{г}}}{R_{\text{в}}}}\,, \quad ...(2)$$

that is, the linear velocity of vertical drum is higher than that of horizontal drum by the value equaling to square root of the ratio of radii of vertical to horizontal drum. At the same time the required rotation frequency of vertical drum decrease by the value inverse to the aforementioned one. In particular, upon conversion from horizontal separator with drum diameter of 150 mm to vertical one with drum diameter of 1000 mm the linear velocity of drum increases from 1.18 to 3.04 m/s, and rotation number decreases from 150 to 58.2 rpm (Urvantsev et al.,1995; Shikhov & Urvantsev, 2001).

The second condition: the material density on the drum will be obviously the same for horizontal and vertical separators.

The third condition: the length of separation area is expected to be the same for both separators. From this condition it follows that upon conversion from horizontal separator to vertical separator with higher drum diameter it is possible to increase the number of separation areas.

The capacity of drum corona electrostatic separator with vertical collecting electrode can be determined on the basis of capacity of electric separator with horizontal electrode as follows (Bogdanov, 1983; Plaksin & Olofinsky, 1964):

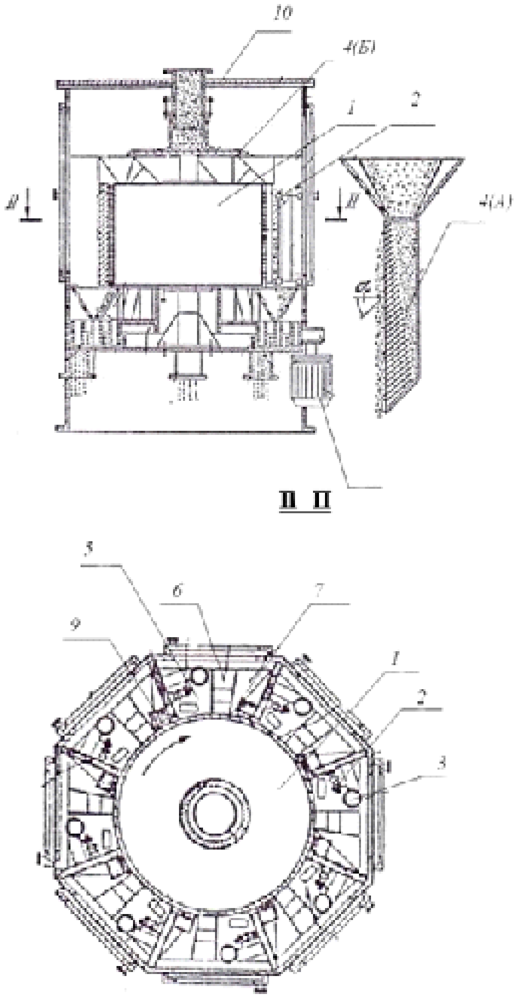
$$Q_{Â.Ñ} = \hat{E}_{Â} \cdot Q_{Ã.Ñ} \cdot \sqrt{\frac{R_{\text{В}}}{R_{\text{Г}}} \cdot \frac{L_{\text{Г}}}{L_{\text{Г}}}} \cdot N \quad ...(3)$$

where $\hat{E}_{â}$ is the coefficient of surface filling of vertical collecting electrode, which is determined by the ratio of length of feeder outlet ($L_{â.ï}$) to the length of generatrix of collecting electrode ($L_{â}$), expressed in the form of unit fractions ($\hat{E}_{Â} = \frac{L_{\text{В}.\text{П}}}{L_{\text{В}}}$); $Q_{ã.ñ}$ is the capacity of electric separator with horizontal collecting electrode, determined by calculations or experimentally, t/h; $L_{â}$ and $L_{ã}$ is the length of generatrix of collecting electrode, vertical and horizontal, respectively, m; N is the number of autonomous sections (number of feeders) of electric separator with vertical collecting electrode.

In this equation the square root of the ratio of radii of collecting electrodes $\sqrt{\frac{R_{\text{В}}}{R_{\text{Г}}}}$ is the coefficient of the ratio of linear velocities of drums, at which centrifugal force acting on a particle is the same for separation both in horizontal and vertical separators. The ratio of generatrix lengths of collecting electrode (Lâ/Lã) is the conformity coefficient of packing density of particles on the surface of collecting electrode upon conversion from horizontal to vertical drum. Equation (3) is illustrated in Fig. 2 by the values of unit capacity of drum electric separators with horizontal and vertical collecting electrode for quartz sand with bulk density ($ñ_{i}$) of 1.86 t/m^3 as a function of drum linear velocity (Levitov, 1966).

From the given data it follows:

with increase in the drum linear velocity at constant intensity of electric field the capacity of separators decreases. This is related with increase in centrifugal force, acting on the particles on the surface of collecting electrode. Herewith, the coarseness of non-conducting particles, retained on collecting electrode due to electric pressing forces, decreases, that is, the material layer thickness on the drum decreases, as well as the volume of transporting material, and, as a consequence, the capacity of separators decreases. For instance, when the linear velocity of horizontal drum with the diameter of 240 mm increases from 1 to 2 m/s the centrifugal force increase by four times and the capacity decreases only by 1.2 time: from 2.71 to 2.24 t/h; at increase in the linear velocity to 3 m/s the centrifugal force increases by 9 times and the capacity decreases by 1.6 times: from 2.71 to 1.68 t/h (Urvantsev et al.,1995; Mesenyashin, 1975).



1 – collecting electrode; 2 – discharge electrode; 3 – electrostatic electrode; 4 – feeder (4A – vertical; 4Á – rotary table); 5, 6, 7 – collectors of separation products; 8 – electric motor of drum drive; 9 – skimmers of non-conducting fraction; 10 – separator shell; 11 - electric motor

Fig. 1. General view of corona electrostatic separator with vertical collecting electrode.

Contrary to the force diagram in the separator with horizontal drum, the projection of gravity force, acting on a particle in the separator with vertical drum, onto the axis of interaction of electric pressing forces and centrifugal pulling force will be zero. Taking into account that upon separation of brown coal particles with size of more than 0.01 mm in air the forces of medium resistance, adhesion, ascending force, ponderomotive constituent can be neglected, the main equation of force balance for the separator with vertical drum will be as follows (Bogdanov, 1983):

$$\sum \overline{F} = \overline{F}_{К} + \overline{F}_{З.О.} + \overline{F}_{ц.б}, \quad ...(4)$$

where $\overline{F}_{Ê}$ is the Coulomb force of electric field impact onto a charged particle:

$$\overline{F}_{К} = 4\pi\varepsilon_0 \cdot \left(1 + 2\frac{\varepsilon_1 - 1}{\varepsilon_1 + 2}\right) \cdot r^2 \cdot E_К^2 \cdot f(R) \quad ...(5)$$

where e_1 is the dielectric permeability of particle material; e_0 is the dielectric permeability of vacuum equaling to 8.85´10^{-12} F/m; $Å_ê$ is the field intensity in the place of particle location, W/m; r is the particle radius, m; $\overline{F}_{ö.á.}$ is the centrifugal force

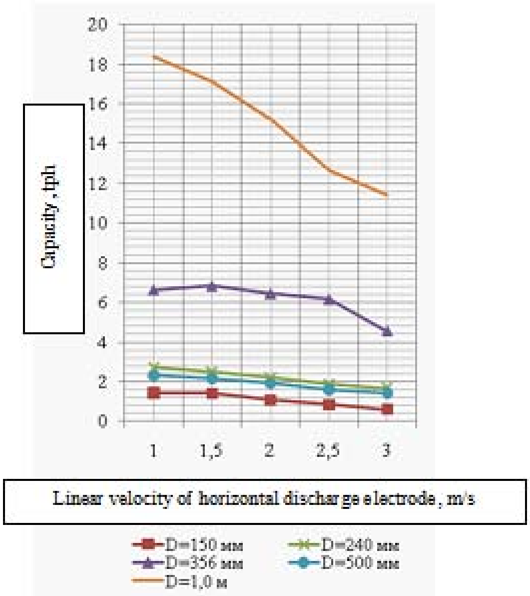


Fig. 2. Specific capacity of electric separators with horizontal (Ø150, 240, 356 mm) and vertical (Ø 0.5 and 1.0 m) discharge electrodes as a function of drum linear velocity .

acting on a particle on the surface of collecting electrode (drum) and stipulated by its rotation:

$$\overline{F}_{ц.б.} = \frac{\pi^3 \cdot r^3 \cdot \gamma_ч \cdot R_1 \cdot n^2}{675}, \qquad ...(6)$$

where R_1 is the radius of collecting electrode , m; n - is the number of drum rotation per a minute; $\overline{F}_{Ç.Î.}$ is the force of mirror charge occurring as a consequence of interaction between resultant particle charge and induced electrical charge on collecting electrode equaling to the value of resultant charge but with opposite sign.

Taking into consideration particle discharging, the equation of the force of mirror charge upon particle exit from ionization area will be rewritten as follows (Komlev, Urvantsev, Rublev, Shikhov, Zhuravsky, Mushketov, 1986; Komlev, Urvantsev, Rublev, Shikhov, Naidenov and Khalda, 1986):

$$\overline{F}_{З.О.} = \frac{\left(Qp \cdot e^{-\frac{t}{R\cdot c}}\right)^2}{16 \cdot \pi \cdot \varepsilon_0 \cdot r^2} = \pi \cdot \varepsilon_0 \cdot \left(1 + 2\frac{\varepsilon_1 - 1}{\varepsilon_1 + 2}\right)^2 \cdot r^2 \cdot E_к^2 \cdot f^2(R) \cdot e^{-\frac{2t}{R\cdot c}}, \qquad ...(7)$$

where $Q_ð$ is the equilibrium particle charge acquired in the corona field, C; R is the contact resistance between the particle and collecting electrode, Ù; $\tilde{N}$ is the capacitance between the particle and electrode.

In practice the term - $\frac{2t}{Rc}$ in Eq. (3.7) is neglected due to its tending to unity.

In order to study into the influence of design and engineering parameters of separation area on separation performances in corona electrostatic separator with vertically positioned collecting electrode the laboratory facility was developed and assembled, it is a model of commercial scale corona electrostatic separator with vertical drum (Urvantsev et al.,1995; Shikhov & Urvantsev, 2001).

Figure 3 illustrates kinematic and electric layouts of the laboratory facility. The experimental

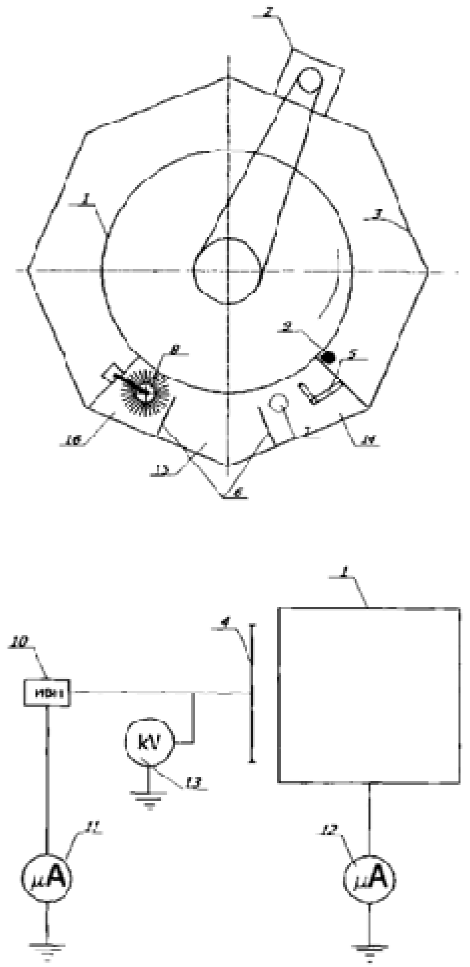
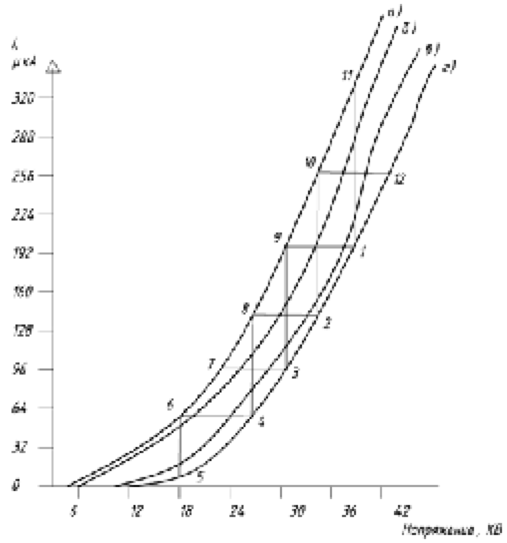


Fig. 3. Kinematic and electric flowcharts of laboratory facility.



à – 0.1 mm; á – 0.18 mm; â – 0.45 mm; ã – 0.65 mm

Fig. 4. Voltage—current characteristics of corona discharge for various diameters of discharge electrode.

facility is comprised of the collecting electrode 1 with the diameter of 1 m and the length of 0.7 m, rotating around the vertical axis by means of V-belt transmission from the direct current motor 2, which enables smooth adjustment of the drum rotation velocity. The collecting electrode is located in the octagonal frame-type body 3, the size of each side corresponds to the sizes of separation area of commercial separator. Contrary to the commercial embodiment, the laboratory facility is equipped with one separation section 4, its sizes correspond to two separation areas of commercial unit (Komlev, Urvantsev, Rublev, Shikhov, Zhuravsky, Mushketov, 1986; Komlev, Urvantsev, Rublev, Shikhov, Naidenov and Khalda, 1986).

The following items are assembled in the separation section of the laboratory facility: the discharge electrode 5, the moveable splitters 6, the electrostatic deflecting electrode 7, the mechanical brush 8 for removal of non-conducting fraction from the surface of collecting electrode. Feeding of the material for separation is aided by the installed holders for mounting of both upper (end) and lateral feeder 10. The corona discharge field is generated between the collecting electrode 1 and the discharge electrode 5 upon applying of rectified high voltage in the range from 0 to 40000 V from the high voltage supply 11 to the discharge electrode. The current intensity of corona discharge was measured by the microammeter 12 or the double-beam storage oscilloscope connected to grounding circuit of the collecting electrode. High voltage, applied to the discharge electrode, was controlled by means of the S-30 kilovoltmeter 13. The separation products were directed to three collecting hoppers: for semiconducting fraction 14, for middlings 15, and for non-conducting fraction 16.

The experiments on determination of the influence of engineering and design parameters of the separation area (the size of extraction area of conducting fraction) consisted of complete factorial experiment and analysis of the obtained separation products. The following process variables were selected:

1. The discharge electrode voltage in the range from 20 to 32 kV with the reference level of 26 kV and the variability interval of 6 kV;
2. The inter-electrode distance in electric separator with vertical collecting electrode;
3. The rotation frequency of collecting electrode in the range from 30 rpm to 60 rpm with the reference level of 45 rpm and the variability interval of 15 rpm;
4. The length of extraction area of conducting fraction (position of the splitter of conducting fraction and middlings, mm) in the range from 150 mm to 280 mm with the reference level of 215 mm and the variability interval of 65 mm.
5. The number of discharge electrodes (pieces).

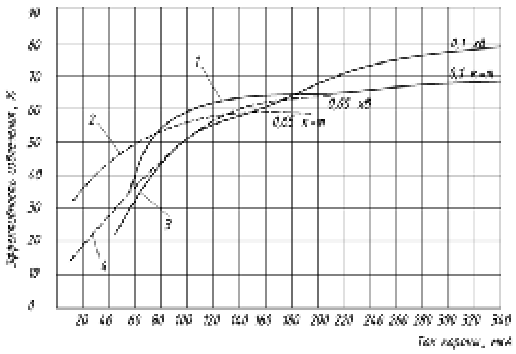


Fig. 5. Extraction efficiency of brown coal organic constituent into concentrated product (1, 2) and brown coal mineral constituent into tailings (3, 4) as a function of corona current.

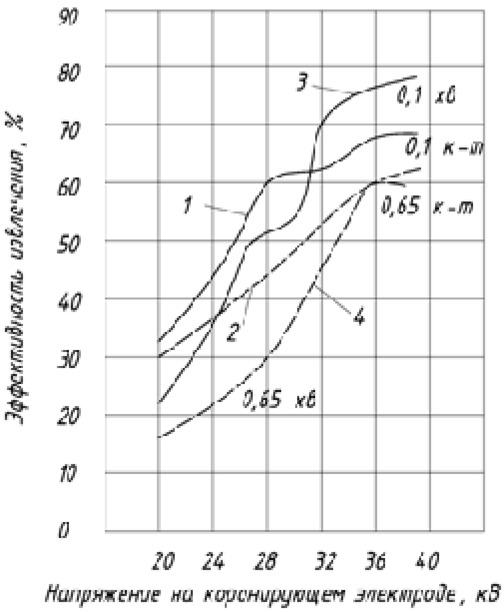


Fig. 6. Extraction efficiency of brown coal organic constituent into concentrated product (1, 2) and brown coal mineral constituent into tailings (3, 4) as a function of corona voltage.

RESULTS AND DISCUSSION

In corona and corona electrostatic separators the separation of powdered coal depends first of all on the behavior of particles of brown coal organic constituent, characterized with low conductivity. The influence of corona discharge current and discharge electrode voltage in electric separator with vertical drum was studied on organo-mineral mixtures (Mesenyashin, 1975; Zhebrovsky, Olofinsky, Rybkin & Balabanov, 1940; Olofinsky, 1947).

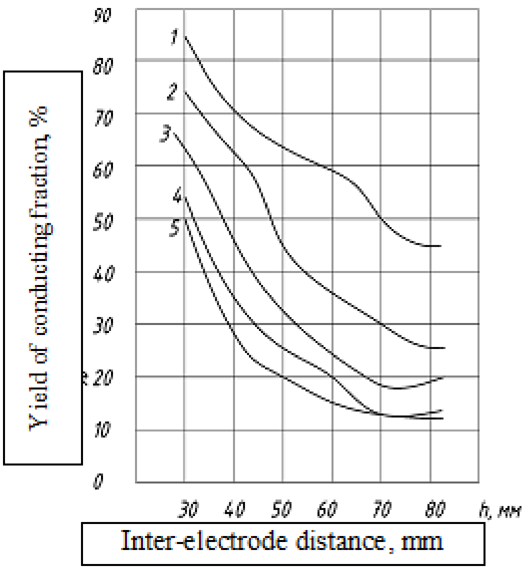
In the experiments current-voltage characteristics of corona discharge were detected at the same distance between the discharge electrode and the drum, similar design parameters of the corona discharge area, but with different diameters of discharge electrode. On the basis of the current-voltage characteristics the values of corona discharge current were recorded at identical voltages. Such voltages were used for the engineering experiments on separation of thermally treated powdered brown coal (Urvantsev et al., 1995; Shikhov & Urvantsev, 2001).

Figure 4 illustrates the current-voltage characteristics of the corona discharge for electrode system in the electric separator with vertical drum at the distance between the electrode and the drum $h_{ê}$ = 80 mm and diameter of discharge wires of 0.1 mm; 0.18 mm; 0.45 mm; and 0.65 mm. As seen in the plots, an increase in the diameter of discharge electrode leads to decrease in corona discharge current at the identical voltage applied. At the same time an increase in the voltage applied to discharge electrode leads to increase in corona discharge current (Plaksin and Olifinsky, 1965; Levitov, 1966).

The experimental results of separation of thermally treated powdered brown coal at fixed voltages and currents of corona discharge for various diameters of discharge electrode are illustrated in Figs. 5 and 6.

It can be seen in Fig. 6, which illustrates the yield of semiconducting fraction as a function of inter-electrode distance, that the higher is the distance between the discharge electrode and the collecting electrode, the lower us is the yield of electric conducting fraction.

While analyzing the experimental results on the influence of corona discharge current and discharge electrode voltage on engineering performances of separation of thermally treated



1 – $Å_{ñð}$ = 2 kV/cm; 2 – $Å_{ñð}$ = 3 kV/cm; 3 – $Å_{ñð}$ = 4 kV/cm; 4 – $Å_{ñð}$ = 5 kV/cm; 5 – $Å_{ñð}$ = 6 kV/cm;

Fig. 7. Yield of semiconductor fraction as a function of inter-electrode distance.

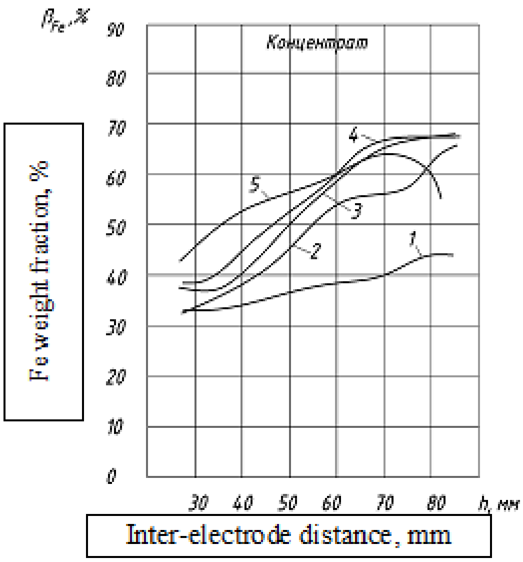


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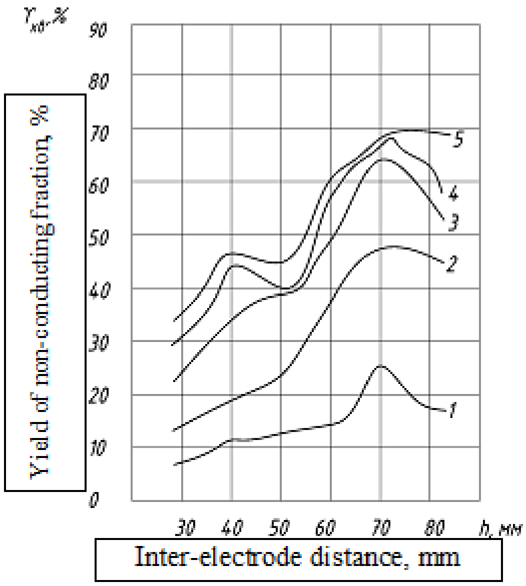
Fig. 8. Organic constituent content as a function of inter-electrode distance at various field intensities of corona discharge.

powdered brown coal in corona electrostatic separator with vertical position of collecting electrode, the following conclusions can be reached:

- At low corona discharge currents significant influence on the performances of separation of thermally treated powdered brown coal is exerted by the discharge electrode voltage;
- during separation of thermally treated powdered brown coal with corona discharge current of 90 ìA and higher the main influence on the separation performances is exerted by the corona discharge current ;
- The higher is the corona discharge current, the higher are the engineering performances. Thus, in the presented experimental series the efficiency of extraction of mineral constituent into tailings increased from 14.8 % at corona current of 10 ìA to 78.6 % at corona current of 320 ìA (Urvantsev et al.,1995).

The experiments on the study of the influence of inter-electrode distance in electric separator with vertical collecting electrode were as follows. The discharge electrode made of nichrome wire with the diameter of 0.3 mm was set subsequently at the distance of 30 mm, 40 mm, 50 mm, 60mm, 70 mm, 80 mm from the grounded drum.



1 – $Å_{ñð}$ = 2 kV/cm; 2 – $Å_{ñð}$ = 3 kV/cm; 3 – $Å_{ñð}$ = 4 kV/cm; 4 – $Å_{ñð}$ = 5 kV/cm; 5 – $Å_{ñð}$ = 6 kV/cm;

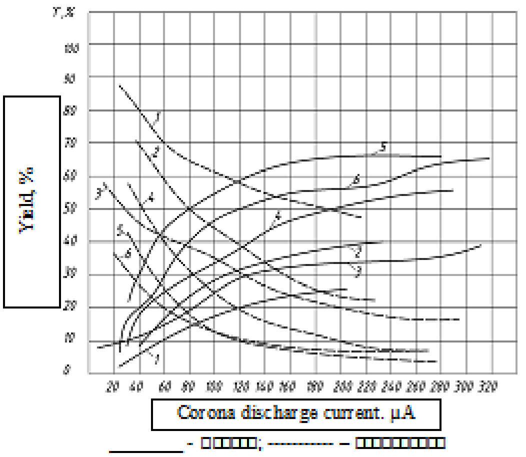
Fig. 9. Yield of non-conducting fraction as a function of inter-electrode distance

It can be seen in Fig. 7, which illustrates the yield of semiconducting fraction as a function of inter-electrode distance, that the higher is the distance between the discharge electrode and the collecting electrode, the lower us is the yield of electric conducting fraction.

In addition, it should be mentioned that even at one and the same inter-electrode distance but increasing $Å_{ñð}$, the yield of semiconducting fraction decrease due to transfer of the particles to other collectors, that is, the fan of separation products is expanded. At the same time, with decrease in the yield of particles to the collector of semiconducting fraction the content of organic constituent particles in this fraction increases, as illustrated in Fig. 8.

On the other hand, as illustrated in Fig. 9, with increase in the inter-electrode distance the yield of mineral particles to the collector of non-conducting fraction increases (Komlev, Urvantsev, Rublev, Shikhov, Zhuravsky, Mushketov, 1986; Komlev, Urvantsev, Rublev, Shikhov, Naidenov è Khalda, 1986; Urvantsev et al.,1995).

Figure 10 illustrates the yields of semiconducting and non-conducting fractions as a function of corona discharge current at various values of inter-electrode distance. With increase in the inter-electrode distance the engineering parameters of separation increase even at identical values of corona discharge current. For instance,



1 – 30 ìì; 2 – 40 ìì; 3 – 50 ìì; 4 – 60 ìì; 5 – 70 ìì; 6 – 80 ìì

Fig. 10. Yield of concentrated product and tailings as a function of corona current *I* at various distance *h.*

the yield of non-conducting fraction at corona discharge current of 150 ìA and *h* = 30 mm equals to 23.46 %; at *h* = 40 mm to 36.78 %; at *h* = 60 mm to 45.88 %; at *h* = 70 mm to 62.15 %; and at *h* = 80 mm to 55%. Simultaneously with the yield of non-conducting fraction the extraction of mineral constituent into this product also increases.

CONCLUSIONS

The performed theoretical studies of efficient beneficiation of thermally treated powdered brown coal have determined the following engineering proposals for enhancement of experimental design of apparatuses of electromagnetic pulse impact and electrostatic separation:

1. During fine grinding of thermally treated powdered brown coal the particles are coagulated (aggregated and coarsened), which decreases the yield of extracted organic constituent of brown coal.
2. Aiming at increase in acting pulse neutralizing coagulation (aggregation of coal particles) ZAO Compomash-TEK developed and tested a KMShU 110.02.000 apparatus for electromagnetic pulse impact.
3. The performed laboratory experiments with thermally treated powdered brown coal aimed at determination of its optimum coarseness upon beneficiation have demonstrated that the maximum beneficiation efficiency can be achieved at the powdered coal particle size of 0.5+0.0 mm.
4. Among previously considered electric separators (triboelectrostatic, triboadhesive, electrostatic plate, corona electrostatic) the technologies with electrostatic plate and triboadhesive separators have been rejected as inefficient for separation of thermally treated powdered brown coal at the rate of 10 t/h.
5. The performed analysis of comparative tests of triboelectrostatic and corona electrostatic separators revealed that the most efficient for this certain task can be corona electrostatic separator, and for further enhancement of this separator design additional study was carried out.
6. Using experimental laboratory facility the dependences of separation performances of thermally treated powdered brown coal have been obtained with the optimum yield of: semiconducting fraction (organic constituent of brown coal), middlings, non-conducting fraction (mineral constituent of brown coal), content and extraction of organic constituent.
7. The yield and quality of semiconducting fraction are strongly influenced by the voltage on discharge electrode: at maximum size of extraction area of semiconducting fraction and maximum voltage applied to discharge electrode, the increase in drum rotation frequency by two times (increase in centrifugal force by four times) leads to increase in the yield of concentrated product only by 8.6 % with minor decrease in the quality of concentrated product; the voltage decrease on discharge electrode by 37.5 % (from 32 kV to 20 kV) at maximum values of drum rotation frequency and extraction area of semiconducting fraction (in the considered range) leads to significant (by 1.92 times) increase in the yield of semiconducting fraction with simultaneous quality deterioration of concentrated product by 14.25 %;
8. The highest influence on the yield of non-conducting fraction is exerted by the voltage applied to discharge electrode, the increase in voltage on discharge electrode from 20 kV to 32 kV at maximum rotation frequency leads to increase in the yield of non-conducting fraction by 2.69 times;
9. The quality of extracted non-conducting fraction is strongly influenced by the drum rotation frequency, the decrease of drum rotation frequency by two times (from 60 to 30 rpm), with stabilization of other factors at maximum level, leads to increase in the yield of non-conducting fraction by 10.8 % and decrease in the quality of semiconducting fraction by 2.9 times.
10. The study of the influence of corona discharge current and discharge electrode voltage in electric separator with vertical drum demonstrated the following values required for design enhancement of the considered corona electrostatic separator :

- Increase in the diameter of discharge electrode leads to decrease in corona discharge current at the same applied voltage;
- At low values of corona discharge current the stronger factor influencing on engineering performances of separator are the voltage applied to discharge electrode;
- At high values of corona discharge current (above 90 ìA, with regard to the considered experiments) the main influence on the engineering performances of the separator is exerted by corona discharge current. Herewith, the higher is the

corona discharge current, the higher are the engineering performances: the efficiency of extraction of brown coal mineral constituent into tailings increased from 14.8 % at corona current of 10 ìA to 78.6 % at corona current of 320 ìA;

• While determining the influence of the distance between discharge electrode and collecting electrode on engineering performances of separation of thermally treated powdered brown coal in corona electrostatic laboratory separator with vertical drum it has been demonstrated that with increase in the inter-electrode distance (in the considered range) the engineering performances of separation also increase even at the same values of corona discharge current. Simultaneously with the yield of non-conducting fraction the extraction rate of mineral constituent also increases.

11. The determined operation modes of corona electrostatic separator with vertical collecting electrode (drum) and engineering results of separation of thermally treated powdered brown coal are confirmed by high performances upon beneficiation with possibility to increase the capacity by 5-10 times in comparison with horizontal position of collecting electrode.

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