Investigation of properties of coal-water slurries produced by electric discharge methods

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Abstract. The purpose of research is to obtain high quality coal-water slurry with minimum energy consumption. The paper presents the characteristics of coal-water slurries produced by electric discharge methods. The raw material is coal from different mines (Tugnuisky, Aduun-Chulunsky, etc.). Micrographs of the surface of the coal particles in the slurry and its chemical composition are obtained by scanning electron microscopy. Micrographs showed that the electric discharge treatment resulted in a significant dispersion of the coal particles. Elemental analysis showed a significant reduction of oxides of sulfur and nitrogen. Viscosity of slurries was determined by Brookfield rotational viscometer and corresponds to the standard of GB / T18856.4.

1. Introduction
Environmental problems associated with the use of coal fuel require the development of new effective coal technologies from economic and ecological points of views. So it is getting topical to use coal as a coal-water slurry fuel (CWSF). CWSF is a composite dispersion system and it consists of coal and a liquid phase – water [1].

Coal-water slurry (CWS) has technological properties of liquid fuels (transportation in road, rail tanks through pipelines, tankers and bulk vessels, storage in closed containers) and must retain its properties during prolonged storage and transportation, i.e. it must have sedimentation stability[2].

2. Experiment setup and methods
The solution is based on the use of plasma and electrolytic methods for the preparation of coal-water slurries without the use of plasticizers. The methods of the experiment and earlier received micrographs, and elemental analysis of coal before and after treatment were considered in this article in detail [3]. Determination of the viscosity using the rotary viscometer Brookfield was made. As a result the viscosity of the slurries corresponds to GB / T18856.4 (China). Coal from different mines (Tugnuisky, Aduun-Chulunsky etc.) was used as raw material.

This article shows the results of coal particles radius of CWS from Okinoklyuchevsky mine with sedimentation method and the speed of sedimentation.
Sedimentation method is the determination of grain size composition based on the difference in the speed of sedimentation of particles in a viscous medium, depending on its size. Measuring the sedimentation speed, the radius of the settling particles by the Stokes' law can be determined [4]:

\[ r = \sqrt{\frac{9 \cdot \eta \cdot U}{2(\rho_y - \rho_h)g}}, \]  

(1)

where, \( r \) - particle radius, \( U \) - settling speed of particles in liquid medium, \( \rho_y \) - density of the coal powder, \( \rho_h \) - density of the liquid medium, \( g \) - acceleration of gravity, \( \eta \) - the viscosity of the liquid medium.

The sedimentation speed was measured on a special device for sediment analysis.

The liquid medium is water with a known value of viscosity. Coal powder is dispersed yielding 0.5% solution (by volume) of the suspension. After mixing, the suspension remains for sedimentation periodically weighing sediments fell on the weight pan. As a result of continuous determinations of the sediments’ mass a sedimentation curve was plotted (Fig. 1).

![Figure 1. The sedimentation curve](image)

Then sedimentation curve is graphically treated (by plotting tangents at the points of the curve, corresponding to different values of \( \tau \)) and receive data to plot integral and differential distribution curves (Fig. 2, 3).

![Figure 2. The integral distribution curve](image)
The shape of the differential distribution curve shows the uniformity of coal particles size. However, when using a graphical method of calculating the distribution curves there may be errors related to insufficient accuracy in plotting the tangent to the curve. These disadvantages can be avoided with the analytical method of the construction of the distribution curves suggested by Tsyurupa N. (Fig. 4).

In the analytical method, the process of sedimentation is described by equation:

$$Q = Q_m = \frac{\tau}{\tau + \tau_0}$$  \hspace{1cm} (2)

Where $Q$ – fraction weight, $\tau$ – time, $Q_m$ and $\tau_0$ - constants, and $Q_m$ depends on the polydispersity and it is called the coefficient of polydispersity.

This equation is better to use in the linear form (Fig. 4):

$$\frac{\tau}{Q} = \frac{t_0}{Q_m} + \frac{\tau}{Q_m},$$  \hspace{1cm} (3)

After getting a line $\frac{\tau}{Q} = f(\tau)$, $Q_m$ is calculated according to the values of cotangent angle to the x-axis:

$$Q_m = ctg \alpha = \frac{1}{tga} = \frac{1}{\frac{0.2671}{0.86}} = 4.6 \%,$$  \hspace{1cm} (4)

$\frac{t_0}{Q_m}$ – over the interval on the ordinate and $\tau_0 = \frac{\tau}{Q}Q_m$
Using the equation \( r_0 = \frac{K \cdot h}{Q_m} \), \( K \) is calculated:

\[
K = \frac{9 \cdot \eta \cdot h}{2 \cdot (\rho_y - \rho_w) \cdot g} = \frac{9 \cdot 0.897 \cdot 10^{-3} \cdot 16.5 \cdot 10^{-2}}{2(1.66 - 0.9971) \cdot 10^{3} \cdot 9.8} = 10.2521 \cdot 10^{-8}
\]

From the kinetic equation of sedimentation the following integral sedimentation distribution law can be derived [4]:

\[
Q_0 = Q_m \left( \frac{r_0^2}{r^2 + r_0^2} \right)^2
\]

where \( Q_0 \) - the proportion of fractions with a radius \( \leq r; r_0 \) – index depending on the dispersion. The differential form of this equation is the following:

\[
F = \frac{dQ_0}{dr} = 4Q_m \cdot r_0^4 \frac{r}{(r^2 + r_0^2)^3}
\]

Next, three major radius are determined characterizing the particles distribution curve.

3. Results

The minimum size of the particles:

\[
r_{\text{min}} = r_0 \cdot \sqrt{0.1 \cdot \left( \sqrt{Q_m - 1} \right) = 9.22 \cdot 10^{-5} \cdot \sqrt{0.1 \cdot (\sqrt{4.6} - 1)} = 3.11 \cdot 10^{-5} \text{ (m)}}
\]

The most probable particles size:

\[
r_{\text{m.p.}} = \frac{r_0}{2.24} = 4.12 \cdot 10^{-5} \text{ (m)}
\]

The maximum size of the particles:

\[
r_{\text{max}} = 3 \cdot r_0 = 3 \cdot 9.22 \cdot 10^{-5} = 27.66 \cdot 10^{-5} \text{ (m)}.
\]

The system is polydisperse, the sedimentation speed of the particles is the following:

\[
U_{\text{ed}} = \frac{2gr^2(\rho - \rho_0)}{9\eta}
\]

Where \( U \) - sedimentation speed, \( r \) – the radius of the particles of coal, \( g \) - acceleration of gravity.

The minimum size of the particles: \( r_{\text{min}} = 3.11 \cdot 10^{-5} \text{ (m)}, \quad U_{\text{set.}} = 15.58 \cdot 10^{-4} \text{ m/s} \)

The most probable particle size: \( r_{\text{m.p.}} = 4.12 \cdot 10^{-5} \text{ (m)}, \quad U_{\text{set.}} = 27.35 \cdot 10^{-4} \text{ m/s} \)

The maximum size of the particles: \( r_{\text{max}} = 27.66 \cdot 10^{-5} \text{ (m)}, \quad U_{\text{set.}} = 1232.59 \cdot 10^{-4} \text{ m/s} \)
4. Conclusions

Measuring the sedimentation speed the radius of the settling particles was determined by the Stokes' law. Basically predominate particle with a radius \( r_{m.p.} = 4.12 \cdot 10^{-5} (m) \), the minimum radius of the particles \( r_{min} = 3.11 \cdot 10^{-5} (m) \) and the maximum radius \( r_{max} = 27.66 \cdot 10^{-5} (m) \).

All real disperse systems are polydisperse and therefore sedimentation speed is different: the large particles settle faster, the small ones more slowly.

References

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